RAJPUTANA (THAR) DESERT BLOOMS WITH UNPRECEDENTED RAINS IN 2006: THE EFFECT OF A WARMING ENVIRONMENT?

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ABSTRACT

In 2006, Rajasthan recorded unusually heavy rainfall in the month of August that led to severe floods. Several stations registered very heavy rainfall of about 125 mm in 24 hours. A recent study showed that in the future similar extreme events tend to occur in central India which includes a part of Rajasthan. This event is studied in the context of a probable climate change over this region using satellite data. For this, the MODIS (MODerate resolution Imaging Spectroradiometer) vegetation indices (NDVI, Normalized Difference Vegetation Index and EVI, Enhanced Vegetation Index) and precipitation data from TRMM (Tropical Rainfall Measuring Mission) satellite for 7 years (2000 through 2006) were used. Both NDVI and EVI MODIS product (MOD13) revealed exuberant growth of vegetation in September 2006 over Rajputana desert. The analysis of both rainfall and EVI data for the seven years confirmed the growth of vegetation in 2006. Some earlier studies noted that the rainfall over West Rajasthan during the monsoon season shows a significant increasing tendency. Thus in the future, the growth of vegetation in Rajputana desert seems to be highly plausible.

Keywords: Climate change, Rajputana desert, Floods in 2006, EVI, MODIS

Introduction

One can argue endlessly whether the recent observed climate change is natural or anthropogenic. But, the mounting observational evidence seems to convince even the skeptics that man is inadvertently changing the Climate. In a very recent study (Goswami *et al*., 2006), it has been shown that the number of extreme rainfall events (>110 mm/day) over central India (74.5^{o} - 86.5^{o} E and 16.5^{o} – 26.0^{o} N) have increased during the 1951-2000 period. This seems to be the result of a warming environment associated with higher atmospheric moisture content that triggers the convective instability systems and causes extreme rainfall events (Goswami *et al*., 2006).

In 2006 monsoon season (June to September), Rajasthan desert region experienced unprecedented heavy rainfall events which led to severe floods and intense human suffering. Unconfirmed sources mentioned that 138 people lost their lives and the property damage up to the end of August was about 366 million dollars.

The objective this paper is to study this event using satellite data. For this, the MODIS (MODerate resolution Imaging Spectroradiometer) vegetation indices (NDVI, Normalized Difference Vegetation Index and EVI, Enhanced Vegetation Index) and precipitation data from TRMM (Tropical Rainfall Measuring Mission) satellite were used.

Material and Methods

The study area selected for this study is the Great Indian Desert, also called Thar Desert. This desert is located in two countries: Republics of India and Pakistan. Most of the area of this inhospitable desert is in the Rajasthan state of India, that is located in western India and the other part is located in the southeastern of Pakistan (Fig. 1).

This work utilized the land product MOD13 from MODIS sensor, obtained from National Aeronautic and Space Administration (NASA) in the site http://edcimswww.cr.usgs.gov/pub/imswelcome. This product was derived from data obtained by MODIS sensor on board the Earth Observing System (EOS) – Terra platform launched in December 1999.

The MOD13A3 is a vegetation index product with 1 km spatial resolution and is a composite of monthly observation. The composition of the mosaics is done by taking the highest vegetation index value which minimizes the effect of several factors (cloud cover, geometry of data acquisition, etc.). The product MOD13 includes two vegetation indices: Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) (Huete *et al*., 2002) and also the original bands that generated them.

Vegetation Indices (VI) are designed and produced routinely to study the global distribution of vegetation types and their spatial and temporal variations. The VI are successful as vegetation measures and are sufficiently stable to permit meaningful comparisons of seasonal and inter-annual changes in vegetation growth and activity. The EVI was found to perform well in a heavy aerosol conditions (Miura *et al*., 1998). Thus the EVI may be useful in a desert atmosphere. The VI images are produced globally over land at 1 km, 500 m and 250 m spatial resolutions and 16 day and monthly compositing periods.

The Enhanced Vegetation Index (EVI) was developed to optimize the vegetation signal with improved sensitivity and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences (Huete *et al*., 2002).

$$EVI = G \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L}$$

where G = 2.5, C1 = 6, C2 = 7.5 and L = 1.

On 21st and 22nd August 2006, Barmer (25º 45´ N, 71º 23´ E) situated in the meteorological subdivision of West Rajasthan (Parthasarathy *et al*., 1995) received rainfall of 120 and 160 mm respectively (Climate Diagnostics Bulletin of India, 2006). This rainfall is a record for the month of August since 1945. In this month West Rajasthan received a rainfall of more than twice, 202.9 mm of its normal (93.6 mm). East Rajasthan also received good amounts of rainfall, 319.5 mm. The departure from normal (232.9 mm) was 37% of its normal. The weekly (17th to 23rd August) rainfall anomaly over West Rajasthan was 367% above normal. The observed rainfall in this week was 99 mm which is almost 5 times the normal of 21 mm.

Table 1 shows very heavy rainfall events according to India Meteorological Department (> 125 mm in 24 hrs over Rajasthan). These rainfall episodes fall into the category of extreme events (Goswami *et al*., 2006) noted for Central India that includes part of Rajasthan state and thus seem to be due to a warming environment. In August 2006 several synoptic systems formed over Bay of Bengal and moved in a westerly and west-north-westerly direction. They had long tracks across Central India and moved up to West Rajasthan as remnants. These seem to have triggered the convective instability and provoked the intense rainfall events mentioned earlier over Rajasthan leading to floods.

Other source of precipitation is provided by TRMM (Tropical Rainfall Measuring Mission) satellite launched on November 27, 1997. TRMM is a joint of U.S. and Japan satellite mission to monitor tropical and subtropical precipitation from 40^o S to 40^o N. The TRMM 3B43 product contains the "TRMM and Other Data" best-estimate precipitation rate (Liu *et al*., 2002). These gridded estimates are on calendar month with 0.25 x 0.25 degree of spatial resolution.

Results

Figure 2 shows the evergreen vegetation, bare soil, and fresh vegetation land covers samples selected for helping this analysis. Evergreen vegetation corresponds to dense vegetation, soil corresponds to bare soil areas, and fresh vegetation corresponds to the areas of regenerating vegetation occurred due to precipitation increases.

Figure 3 shows the spectral responses for August and September of 2004, 2005, and 2006, for the corresponding land cover samples as marked in Fig. 2. In Fig. 3, it can be seen that evergreen vegetation and bare soil classes presented consistent spectral responses for all years, while fresh vegetation class presented spectral response like soil in 2004 and 2005 years and spectral response like vegetation in 2006. It means that vegetation has been generated during 2006 due to the increase of precipitation in the study area.

Figure 4 shows the rainfall for 7 years. It can be seen that in the months of July and August of years 2001 and 2003 the precipitation was higher than in years 2000, 2002 and 2004. Also the high precipitation in the month of August of 2006 can be seen. These data set used is from TRMM 3B43 product in the latitude 27.25^{o} N and longitude 70.75^{o} E, that correspond to the location of fresh vegetation land cover sample (Fig. 2).

The intense rainfall events and the associated flash floods increase the soil moisture over a relatively larger region and this increase of soil moisture helps the growth of vegetation. The intense rainfall in August 2006 might have generated a vegetation growth which was observed by the MODIS sensor.

Figure 5 shows the EVI over the Thar Desert (both India and Pakistan side) for the month of August and September for the years 2000, 2001, 2002, 2004, 2005, and 2006. The VI monthly product (MOD13A3) are not available for the year 2003. In September 2006 which is the month after following the heavy rainfall events of August, the EVI shows the exuberant vegetation coverage. The EVI like other vegetation indices is a measure of vegetation greenness. Thus, increased values of EVI indicate the vegetation cover density.

Figure 5 clearly shows the high EVI values for 2006 showing an exuberant vegetation coverage in the midst of the Rajputana Desert which is very unusual. In 2001 EVI image shows some vegetation coverage in the border of the Rajputana Desert and agrees with the precipitation graph (Fig. 4) that shows greater precipitation in this year and 2003 (not available). In the 2002 and 2004 EVI image no vegetation was seen while in the 2000 and 2005 EVI image only traces of vegetation were seen in this study region. Whether a similar growth of vegetation continues in the coming years is an interesting question. In an earlier study (Pant & Hingane, 1988) an increasing trend of 141.3 mm of rainfall per 100 years was observed over Northwest India including West Rajasthan during the summer monsoon season. The trend over West Rajasthan is significant at 99% level of ‘t’ test. A similar increasing trend of rainfall was also observed for Northwest India in another study (Rupa Kumar *et al*., 1992). This information put together with the recently found increase of heavy rainfall events (Goswami *et al*., 2006) suggests that in a continued warming environment the increase of vegetation over West Rajasthan is highly probable.

In the image of EVI of 2001 it shows some vegetation in the edge of the desert and agrees to the precipitation graph that shows to greater precipitation in this year and 2003 (not available).

Conclusions

The TRMM satellite data shows the increase of precipitation for the month of August of 2006 compared to August of previous years. The intense rainfall in August 2006 generated a vegetation growth which was observed by the EVI images derived from MODIS sensor. A careful analysis of vegetation index from MODIS sensor and TRMM rainfall data for seven years confirmed the vegetation growth.

The recently found increase of heavy rainfall events by Goswami *et al*.(2006) suggests that in a continued warming environment the increase of vegetation over West Rajasthan is highly probable.

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List of Figures

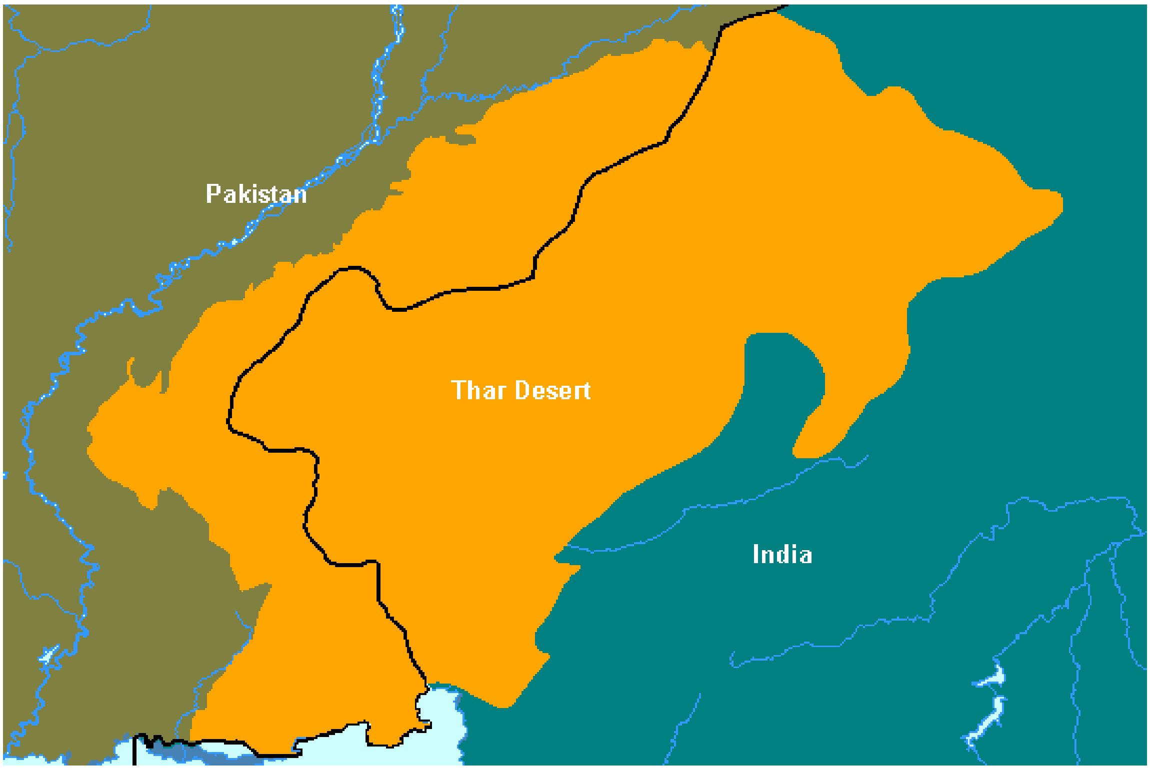


Fig. 1

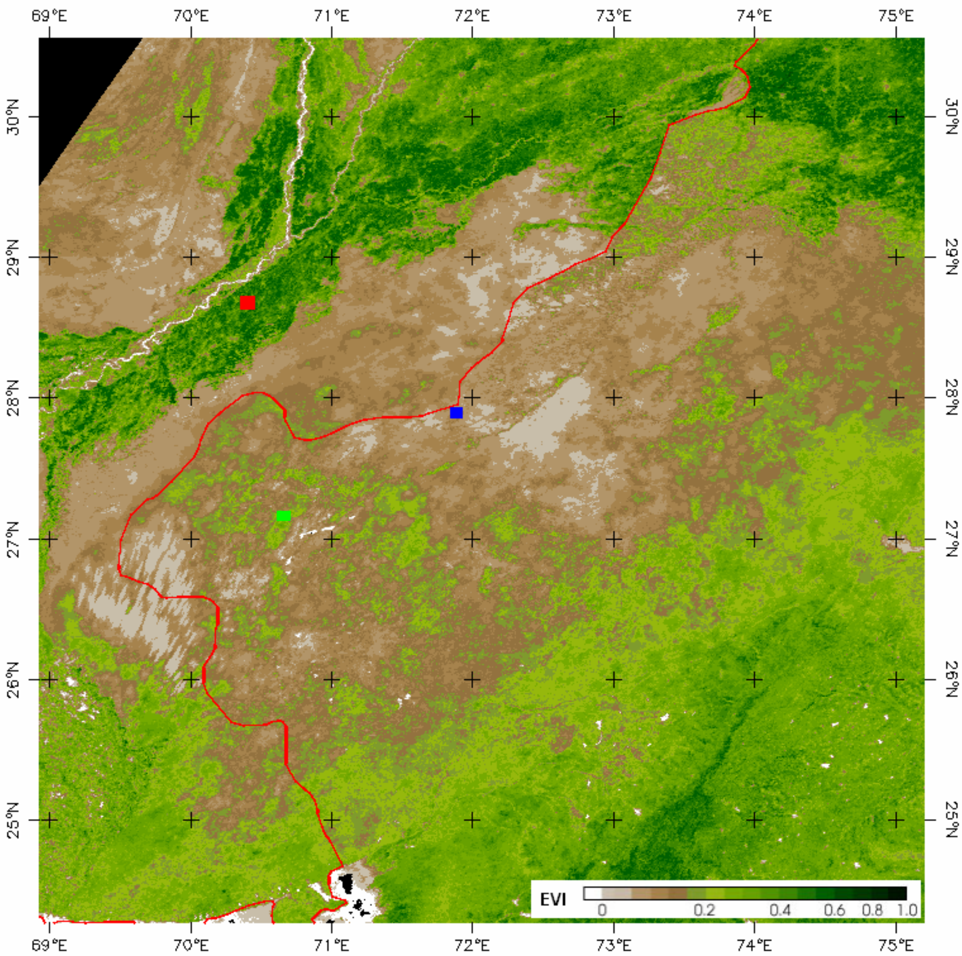

69°E
70°E
71°E
72°E
73°E
74°E
75°E
30°N
29°N
28°N
27°N
26°N
25°N
EVI
0
0.2
0.4
0.6
0.8
1.0

Fig. 2

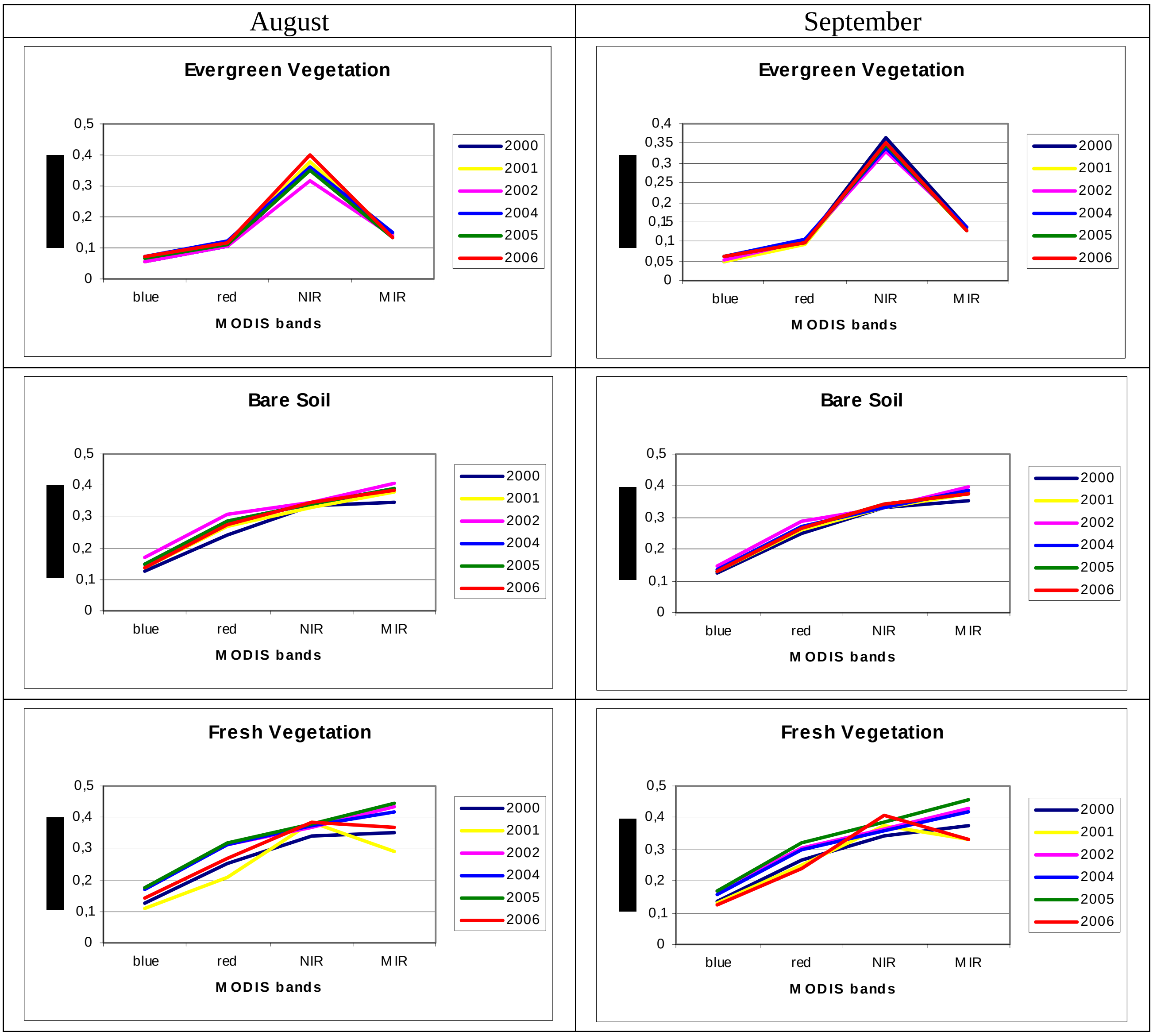

August
September
Evergreen Vegetation
Bare Soil
Fresh Vegetation
0
0,1
0,2
0,3
0,4
0,5
0,05
0,15
0,25
0,35
blue
red
NIR
MIR
MODIS bands
2000
2001
2002
2004
2005
2006

Fig. 3

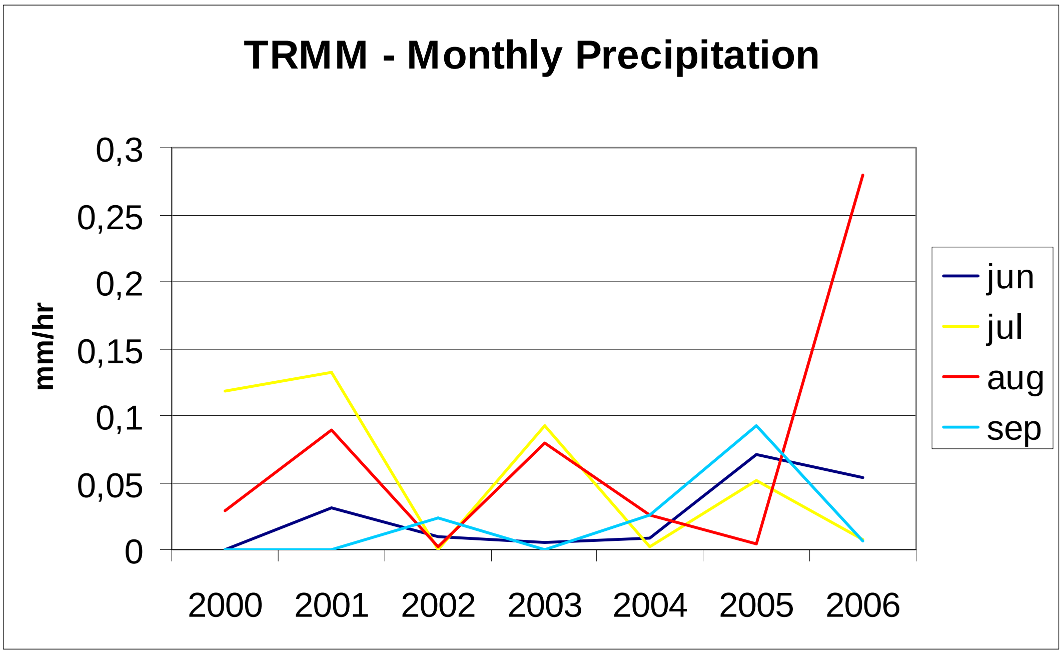
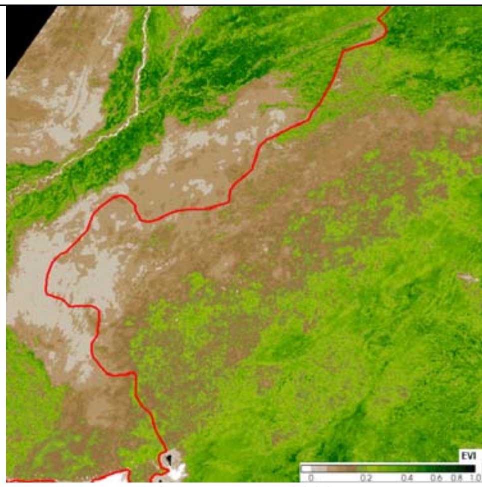

TRMM - Monthly Precipitation
mm/hr
0,3
0,25
0,2
0,15
0,1
0,05
0
2000
2001
2002
2003
2004
2005
2006
jun
jul
aug
sep

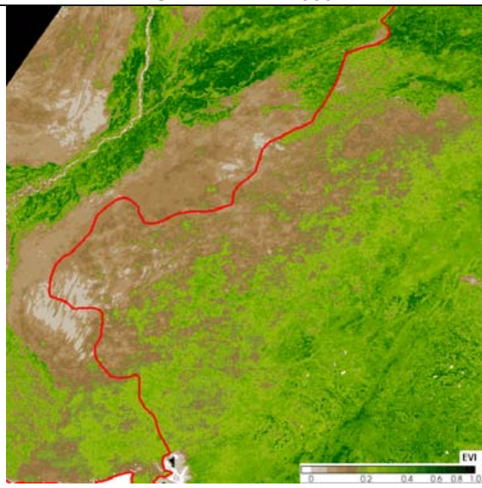
Fig. 4

AUGUST 2000



SEPTEMBER 2000

AUGUST 2001



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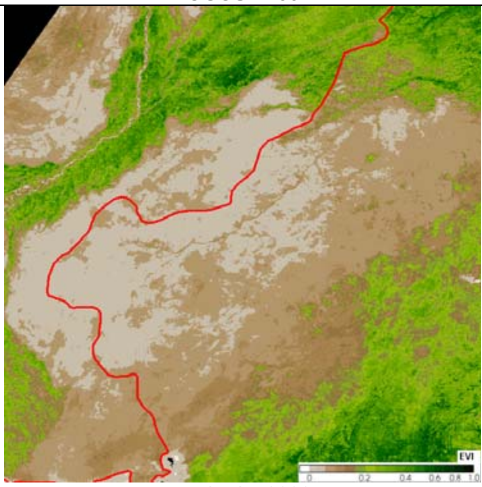

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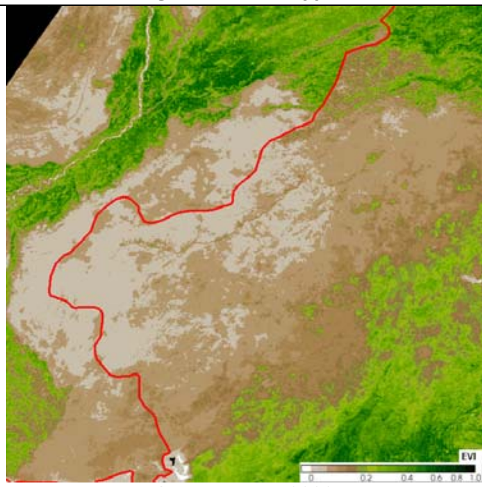

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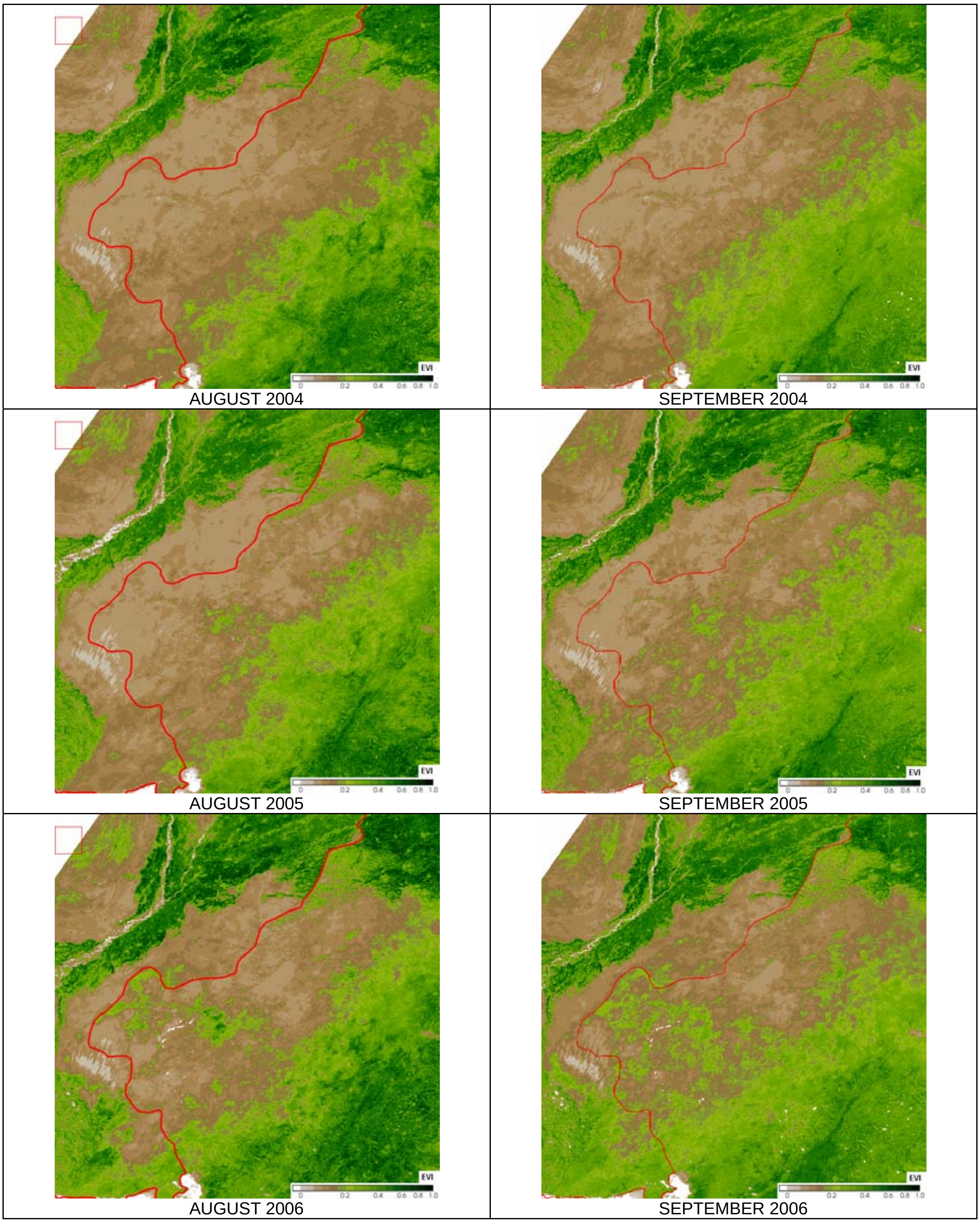

Fig. 5

List of Tables

Table 1: Daily rainfall over different stations in Rajasthan

Table 1

Station (Lat / Long)	Date	Rainfall in mm/day
Jaisalmer (26^{o}.54´ N / 70^{o}.55´E)	6-8-2006	130
Loharia (23^{o}.45´ N / 74^{o}.14´E)	12-8-2006	160
Danta (24^{o}.11´ N / 72^{o}.46´E)	20-8-2006	260
Jaisalmer (26^{o}.54´ N / 70^{o}.55´E)	21-8-2006	140
Barmer (25^{o}.45´ N / 71^{o}.23´E)	22-8-2006	160