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Original article

An evaluation of vegetation health and the socioeconomic dimension of the vulnerability of Jharkhand state of India in climate change scenarios and their likely impact: a geospatial approach

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ABSTRACT

Geospatial evaluation of various datasets is extremely important because it gives a better comprehension of the past, present and future and can therefore be significantly utilized in effective decision making strategies. This study examined the relationships, using geospatial tools, between various diversified datasets such as land use/land cover (LULC), long term Normalized Difference Vegetation Index (NDVI) based changes, long term forest fire points, poverty percentage, tribal percentage, forest fire hotspots, climate change vulnerability, agricultural vulnerability and future (2030) climate change anomalies (RCP-6) of Jharkhand state, India, for a better understanding and knowledge of its vegetation health, LULC, poverty, tribal population and future climate change impact. The long term NDVI (1982-2006) evaluation revealed negative change trends in seven northwest districts of Jharkhand state, these were: Hazaribag, Ramgarh, Palamu, Lohardaga, Chatra, Garhwa and Latehar. The forests as well as the agriculture of these districts have lost their greenness during this period. The forest fire frequency events were found to be more pronounced in the land use/land cover of "tropical lowland forests, broadleaved, evergreen, <1000 m" category, and were roughly twice the intensity of the "tropical mixed deciduous and dry deciduous forests" category. In the nine districts of Jharkhand it was found that 40 % of the population was living below the poverty line which is around twice the national average. The highest poverty districts, in percentage, were: Garwah (53.93), Palamu (49.24), Latehar (47.99) and Chatra (46.2). The southwest and south of Jharkhand state shows a tribal population density of more than 40%. The climate change vulnerability was found to be highest in the district of Saraikela followed by Pashchim Singhbhum, whereas agricultural vulnerability was found to be highest in the district of Pashchim Singhbhum followed by Saraikela, Garhwa, Simdega, Latehar, Palamu and Lohardaga. The temperature anomalies prediction for the year 2030 shows an increasing trend in temperature with values of 0.8°C to 1°C in the state of Jharkhand. The highest increases were observed in the districts of Pashchim Singhbhum, Simdega and Saraikela. Based on these evaluations we can conclude that a few of the districts of Jharkhand, such as Pashchim Singhbhum, Garhwa, Palamu and Latehar need to be prioritized for development on an urgent basis. The outcomes of this study would certainly guide the policymakers to prepare more robust plans when keeping in mind the future climate change impacts for the prioritization of various districts of Jharkhand which suffer from extreme poverty, diminished livelihood and insignificant agricultural productivity for the betterment of the people of Jharkhand based on their adaptive capacity.

KEY WORDS: LULC, NDVI, climate change vulnerability, agricultural vulnerability, climate change anomalies (RCP-6), Jharkhand

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1. Introduction

Geospatial technology plays an important role in land cover mapping and as a source of information relating to land resource conditions. Land Use Land Cover (LULC) of any area and its distribution pattern of various classes serve as a crucial parameter in current strategies and policies for natural resource management and monitoring (SINHA ET AL., 2015). Changes in LULC are due to natural or anthropogenic factors probably due to climate change (RAWAT & KUMAR, 2015). Normalized Difference Vegetation Index (NDVI) is one of the standard formulas for measuring and investigating the health of vegetation using remote sensing data (Guo et al., 2014). It reflects a significant relationship to climate change (Bing et al., 2014; Ning et al., 2014) because of spatial and temporal resolution and satisfactory accuracy. The study conducted by Anyamba & Tucker (2005) utilized the long term NDVI from NOAA-AVHRR data (1981-2003) and showed the trend of negative and positive changes of vegetation health at a regional scale. In one of the recent studies conducted by Chakraborty et al. (2018) they utilized the MODIS NDVI time series data (2001–2014) and revealed the negative trend of forest seasonal greenness over the various forest types of India. Furthermore, the results highlight the negative changes in the seasonal greenness which was found to be highest in tropical moist deciduous forest. Satellite based fire data is widely used in fire mapping (Ager et al., 2017; Ahmad & Goparaju, 2017a; Dwyer et al., 2000) and analysis of their relationship with land-use/land-cover change (Eva & Lambin, 2000). The identification of fire hotspots using long term forest fire frequency data by utilizing the GIS tool provides better comprehension of fire spatial distribution patterns (Ahmad et al., 2017; Ahmad et al., 2018). Climate plays a significant role in manoeuvering the fire regimes (Harrison et al., 2010) and dictates the vegetation patterns. It has a crucial role in the distribution, structure, composition and ecology of forests (Kirschbaum et al., 1996). Vulnerability to climate change is defined as the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change (Fussel & Klein, 2006). Agriculture is the most vulnerable to climate change; therefore scientific evaluation of agricultural vulnerability to climate change is of great significance for the formulation of an effective adaptation strategy (Tao et al., 2011). Agricultural vulnerability due to climate change impacts the crop yields which leads to food insecurity (Campbell et al., 2016) and poverty. Ethnic tribes are the most marginalized and vulnerable communities in India and Jharkhand is one of the states dominated by such communities (Agrawal & Agrawal, 2010). There is a need to critically examine the diverse climate change risks for indigenous peoples and their ability to adapt to future climate change (McNeeley et al., 2017). The climate (rainfall and temperature) spatial distribution pattern is an important factor for their economy and livelihoods (Bothale & Katpatal, 2014) whereas climate change controls the distributions of plant species and vegetation (Sykes, 2009). Extreme weather events such as droughts, forest fire, floods, heat waves and cyclones (Goswami et al., 2006) impact not only the natural vegetation but also causes a fall in the productivity of food grains, loss of livelihood and poverty (Birthal et al., 2014).

The aims of the present study are to create maps, examine the spatial patterns and relationships of diverse datasets such as land use/ land cover (LULC), long term NDVI, long term forest fire points, forest fire hotspots, poverty percentage, tribal percentage, climate change vulnerability, agricultural vulnerability and future (2030) climate change anomalies (RCP-6) for the state of Jharkhand, India.

2. Materials and methods

2.1. The study area

The study area (Fig. 1) is one of the states of India named Jharkhand with a total geographical area of 79,710 km^2 and lies between 21°58'02''N to 25°08'32"N latitude and 83°19'05''E to 87°55'03''E, longitude. It is, surrounded by the state of West Bengal on the eastern side, Chhattisgarh on the western side, Bihar on the northern side and Orissa on the southern side. Jharkhand state is the second highest poverty dominated state in India after Chhattisgarh state where 37% of the total state population is living below the poverty line (World Bank Report, 2016). Around one fourth of the total population of Jharkhand consists of ethnic tribes and 90% of the population lives in rural areas and is largely found in the vicinity of forest villages. Climate induced extreme weather events are common phenomena in this state which substantially affects agricultural production and degrades the forests. The forests of the state are dominated by deciduous trees which are vulnerable to fire due to extreme weather events (Ahmad et. al., 2017). These forests are the major source of the livelihood of the large tribal population.

2.2. Data acquisition and processing

We utilized land use /land cover (LULC) datasets (VEGA 2000 dataset) in this study for our analysis (Roy et al., 2003). These land use /land cover datasets were provided by FAO for the whole globe at the spatial resolution of 1 km. The legend of the land cover classes was designed by FAO Land Cover Classification System (LCCS) with the help of regional experts. It covers the data of the SPOT 4 satellite between the periods November 1999 to December 2000. The quality control was done systematically and validated with reference material (thematic maps, Landsat & SPOT images, aerial photographs and ancillary sources) by specialists (Bartholome et al., 2002). The land use/land cover data was extracted using Erdas imagine software for the Jharkhand state boundary of India (Fig. 2).

Normalized Difference Vegetation Index (NDVI) is one of the significant parameters which are widely used to analyze vegetation health. It is most commonly used as a vegetation index and is an indicator of plant "greenness" (RANI ET AL., 2015). The long term NDVI (1982-2006) map (GEOSPATIAL WORLD, 2012) based on NOAA-AVHRR data was utilized and brought into the GIS domain for this study and is shown in Fig. 3. This reflects the long term (1982-2006) vegetation health of Jharkhand. The negative change, positive change and no change indicate the loss, gain and static of its greenness, respectively.

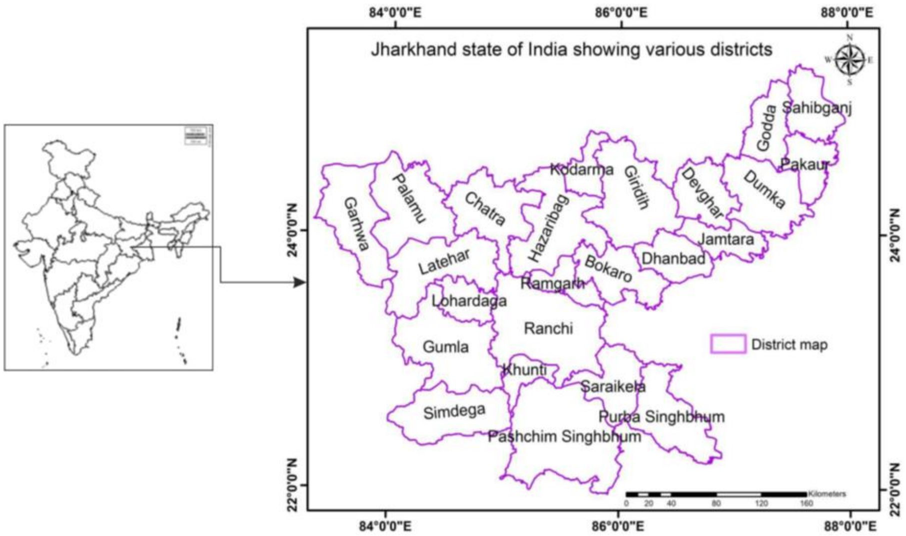

Fig. 1. Study area (Jharkhand state of India)

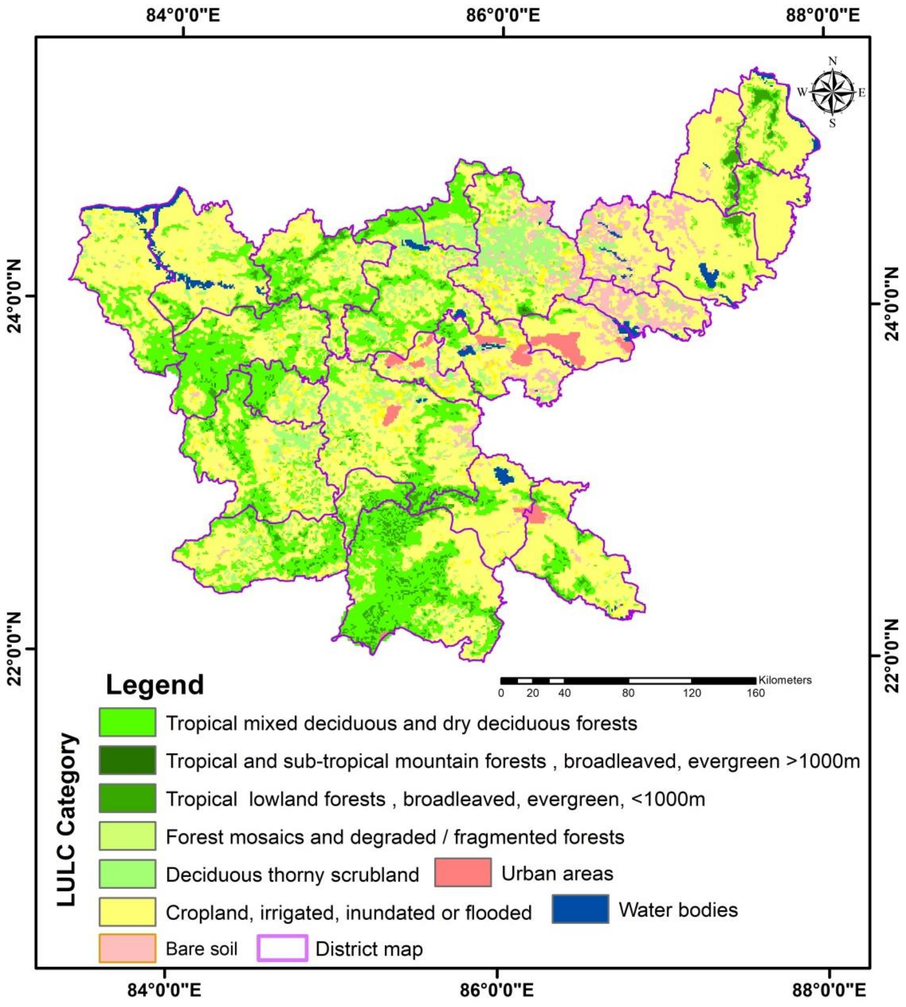

Fig. 2. Land use /land cover map

The long term forest fire data (2005 to 2016) was downloaded from the Forest Survey of India (FSI) website (http://fsi.nic.in/forest-fire.php). FSI has been evaluating the forest fire events regularly using MODIS satellite system from the year 2005 onwards (http://nidm.gov.in/pdf/pubs/forest%20fire.pdf). The forest fire point inputs are masked by FSI using the latest forest cover which eliminates non-forest fire points. A few categories of land use/land cover classes representing forests were merged to generate the forest map of Jharkhand. We have used the methodology of AHMAD ET AL. (2017) for generating forest fire hotspots and these were brought into GIS domain. Fig. 4 shows the forest with fire points showing the fire hotspot area and the NDVI based negative change polygon.

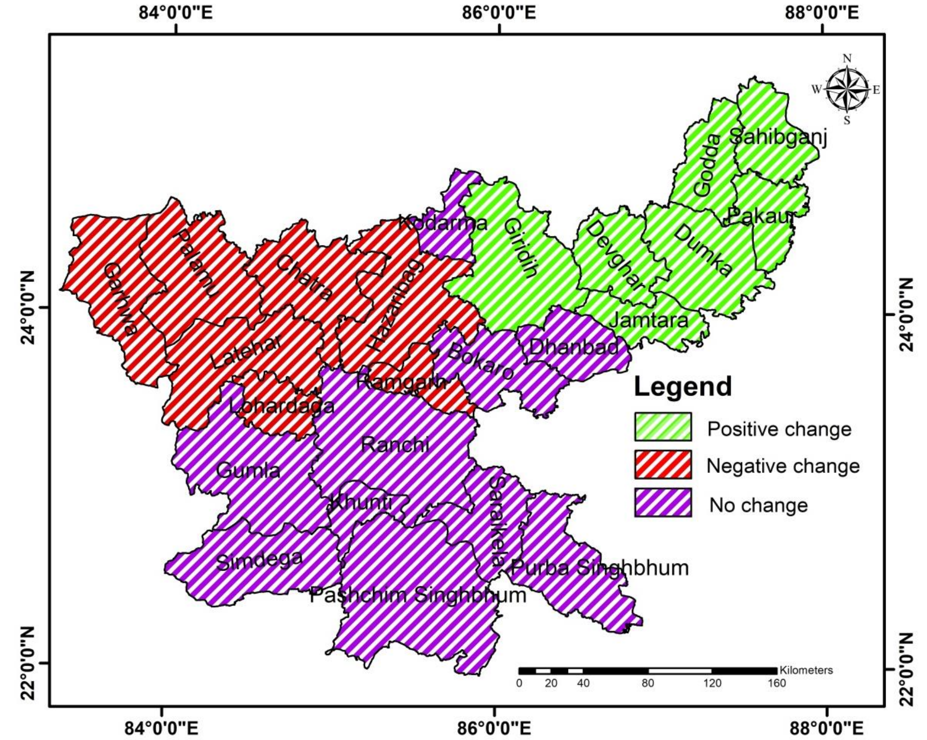

Fig. 3. Long term NDVI map showing changes in greenness

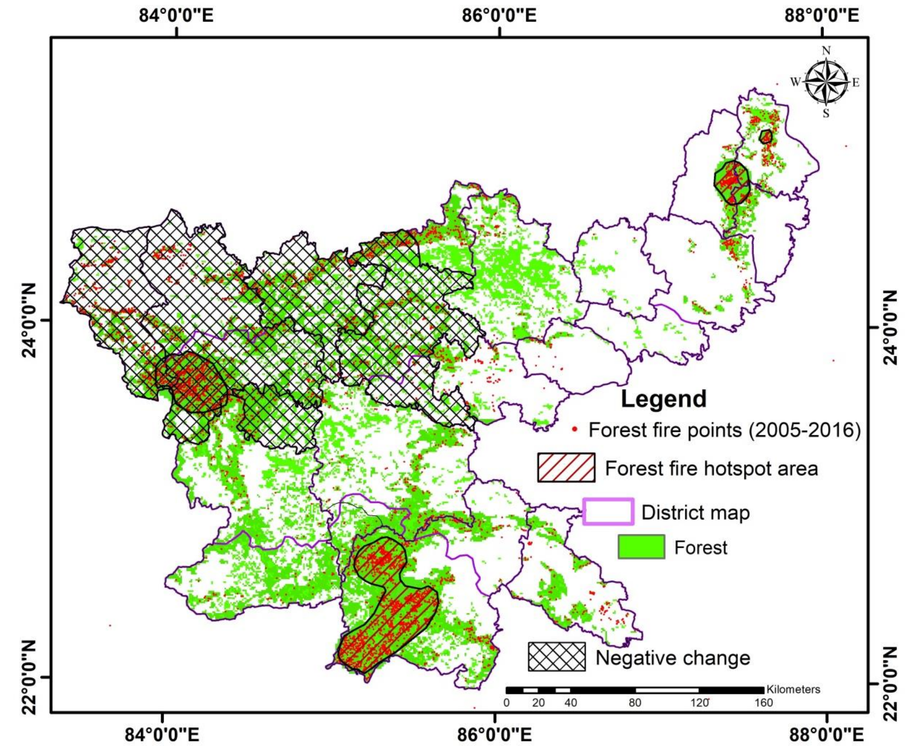

Fig. 4. Forests with fire points showing fire hotspot areas and the NDVI based negative change polygon

The climate change vulnerability (sensitivity) map and agricultural vulnerability map were utilized in this study. They were downloaded from the Jharkhand Action Plan on Climate Change data (JAPCC, 2014) which was in tabular form (district wise) and were brought into the GIS platform and surfaces were generated based on the kriging interpolation technique. The maps of climate change vulnerability and the agricultural vulnerability map with respect to climate change are given in Fig. 5 and Fig. 6 respectively.

Jharkhand district wise poverty percentage data (Bhandari & Chakraborty, 2014) was used and brought into the GIS environment for better understanding (Fig. 7). The latest 2011 census data (http://www.census2011.co.in/) were utilized and district wise tribal population percentages were calculated and brought into the GIS domain for creating the spatial pattern generated by the kriging interpolation technique (Fig. 8).

The temperature and precipitation anomalies (climate change greenhouse scenario RCP-6) data were downloaded for the year 2030 for Jharkhand (NCAR GIS Program, 2012). The data was in a Gaussian grid, where each grid point's longitude was equally spaced at 1.25°, while the latitudes vary in spacing slightly around 0.94° (https://gisclimatechange.ucar.edu/gis-data-ar5).

The temperature and precipitation surface were generated from the point vector file using the kriging interpolation technique and are given in Fig. 9 and Fig. 10 respectively.

We have significantly utilized various modules of Erdas Imagine (version 9.1) and ArcGIS (version 10.1) software to analyze and examine relationships to achieve these objectives.

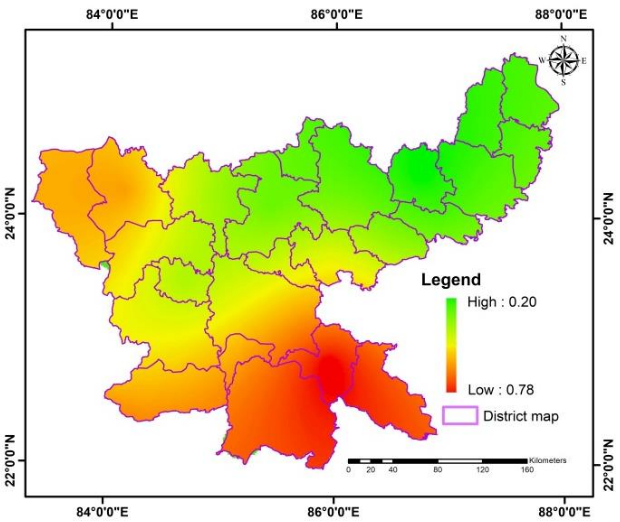

Fig. 5. Climate change vulnerability

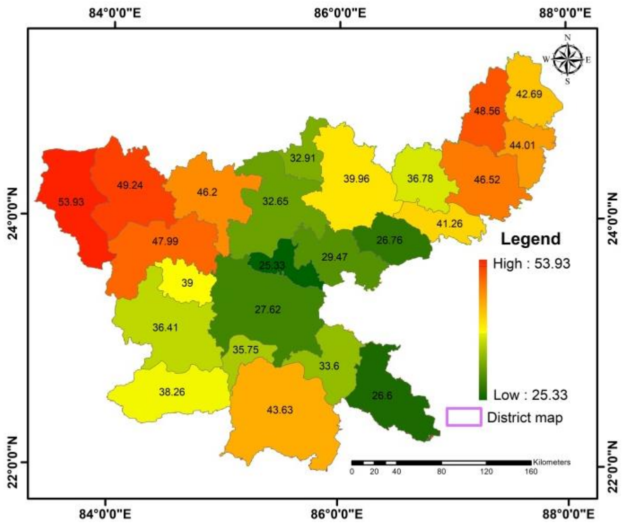

Fig. 7. District wise poverty percentage

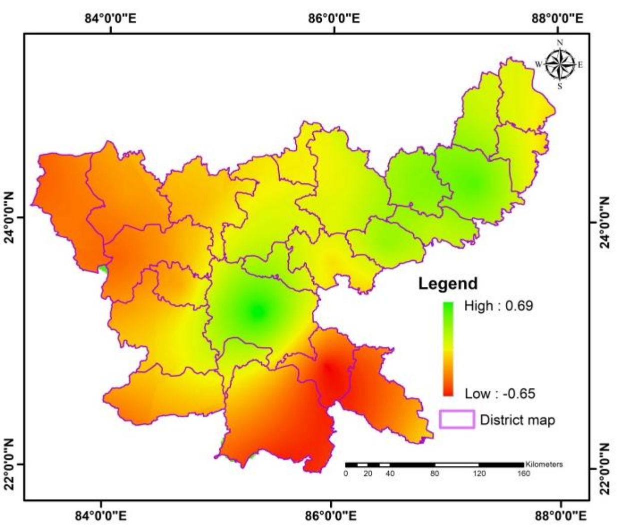

Fig. 6. Agricultural vulnerability

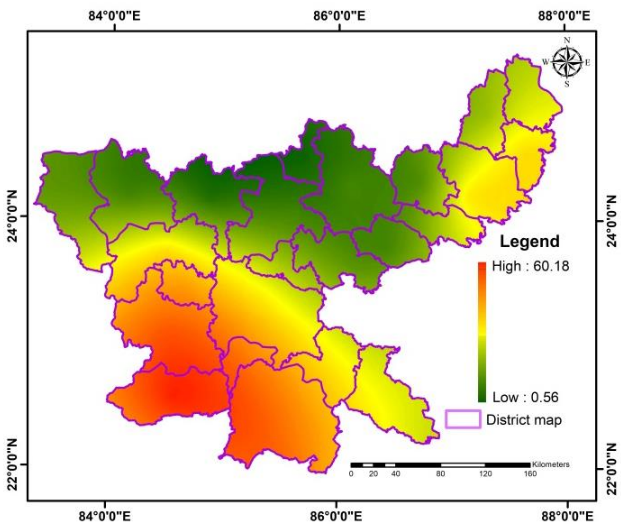

Fig. 8. Tribal population percentage

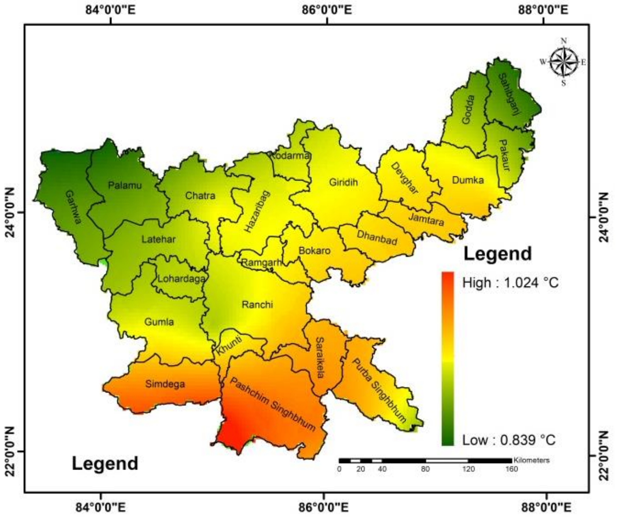

Fig. 9. Temperature anomaly

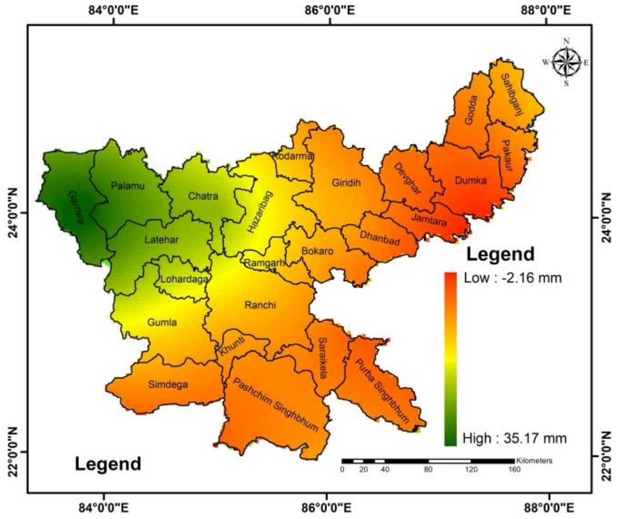

Fig. 10. Precipitation anomaly

3. Results and discussion

The land use/land cover area statistics are given below in Table 1. 94% of the total geographical area was covered by vegetation (agricultural crop and forest). 35% of the geographical area of Jharkhand in the year 2000 was found to be forest including scrubland. The actual crop and land agriculture area was 59%. A similar land use/land cover map was utilized for evaluation by AHMAD ET AL. (2018) in Arunachal Pradesh, India.

Our study reflects the vegetation health of Jharkhand between the periods 1982 to 2006. The long term NDVI (1982-2006) map shows the negative trend in seven northwest districts of Jharkhand state (Fig. 2). These are Hazaribag, Ramgarh, Palamu, Lohardaga, Chatra, Garhwa and Latehar. The forests, as well as the agriculture, of these districts lost their greenness during this time period (1982-2006). A similar identification of negative change assessment using long term NDVI was done by CHAKRABORTY ET AL. (2018). The average annual rainfall of the northwest districts of Jharkhand state is low when compared with the annual Jharkhand state average (http://www.indiawaterportal.org/met_data/). The poor socio-economic condition of the people, frequent drought and inadequate soil moisture in the off monsoon season are the major reasons for negative change in the agriculture sector. The forests of these areas have deteriorated a lot over the long term duration (AHMAD & GOPARAJU, 2017b).

The analysis of forest fire points when examined with land use/land cover categories shows an interesting trend. The "tropical lowland forests, broadleaved, evergreen, <1000 m" category occupied a total geographical area of Jharkhand, equivalent to 3.7%, whereas it retained 19% of the total Jharkhand fire events. Similarly the "tropical mixed deciduous and dry deciduous forests" category occupied the total geographical area of Jharkhand, equivalent to 23.4%, whereas it retained 66% of the total Jharkhand fire events. The forest fire frequency events are more significant in the category of "tropical lowland forests, broadleaved, evergreen, <1000 m" and are roughly twice the size of the category of "tropical mixed deciduous and dry deciduous forests" and is a serious concern. The study of CHAKRABORTY ET AL. (2018) found a similar observation. AHMAD ET AL. (2018) have also done a similar evaluation and identified the intensity of fire events in various LULC classes.

In this analysis we examined the forest fire hotspot map alongside existing literature and old *in situ* experiences. Three out of four forest fire hotspot polygons (AHMAD ET AL., 2017) which are overlaid in the map fall on biodiversity hotspot areas such as Palamu Tiger Reserve, Saranda Forest Hills and Rajmahal Forest Hills which significantly constitute high numbers of flora and fauna which is a serious challenge to the government as far as their conservation, protection and fire control strategies are concerned. Similar threats to forests from fire in Jharkhand have been reported by AHMAD & GOPARJAU (2017b).

Poverty is one of the biggest issues in India and it is more pronounced in Jharkhand. By evaluating the poverty percentage map it was found that nine districts of Jharkhand have greater than 40% of the population below the poverty line. In some of the districts the poverty percentages are higher than the sub-Saharan region of Africa. Most of these districts are non-industrial. The highest level was found in Garwah (53.93) followed by Palamu (49.24), Godda (48.56), Latehar (47.99), Dumka (46.52), Chatra (46.2), Pakaur (44.01), Pashchim

Singhbhum (43.63), Sahibganj (42.69) and Jamtara (41.26). Large pockets of poverty in the areas close to forests are dominated by tribal populations (BHANDARI & CHAKRABORTY, 2014). Similarly, based on evaluation of the tribal population percentage map it was found the southwest and southern Jharkhand state have a high tribal population percentage (Fig. 8). Furthermore, four districts of Jharkhand show the tribal population as more than 40%. These are Simdega with the highest percentage (60.18) followed by Gumla (54.06), Pashchim Singhbhum (53.68) and Lohardaga (43.97). Several people, including ethnic tribes, in rural areas of Jharkhand are suffering from acute poverty and their living conditions are miserable. The livelihood of the people in rural areas comes from agriculture, farming, cattle rearing and collection of minor forest produce from the surrounding forests which suffers badly due to frequent drought and weather severity due to climate change. Droughts increase the frequency of fire in forests (AHMAD ET AL., 2017) as well as badly affecting agricultural productivity. The study conducted by TIRKEY ET AL. (2018) about long term (1984-2014) climate extremes reveals that the north western state of Jharkhand shows an increase in seasonal maximum temperatures and a decrease in seasonal cumulative rainfall trends between the periods 1984 to 2014. The highest temperature increase was found to be in the range of 0.8°C to 1.5°C in the districts of Garhwa, Palamu and Latehar which are the highest poverty dominated districts (Fig. 7). In our study, it was found that the vegetation of these same areas is also suffering from long term negative change (Fig. 3).

Table 1. Land use/ land cover (LULC) area statistics of Jharkhand

LULC Classes	Area [km^2]	%
Tropical and sub-tropical mountain forests , broadleaved, evergreen >1000 m	28.69	0.04
Tropical lowland forests , broadleaved, evergreen, <1000 m	2944.05	3.69
Tropical mixed deciduous and dry deciduous forests	18675.56	23.43
Forest mosaics and degraded / fragmented forests	59.17	0.07
Deciduous thorny scrubland	6195.60	7.77
Cropland, irrigated, inundated or flooded	45570.09	57.17
Bare soil	3913.15	4.91
Urban areas	1064.13	1.33
Water bodies	1259.56	1.58

By examining the map of climate change vulnerability which reflects some interesting statistics. It was found that eight districts of Jharkhand have a higher climate change vulnerability than 0.5 values. The highest was found in Saraikela (0.78) followed by Pashchim Singhbhum (0.7), Purbi Singhbhum (0.68), Simdega (0.66), Palamu (0.6), Garwah (0.57), Ranchi (0.52) and Latehar (0.52). Similar observations of climate change impacts and their socio-linkages was studied by MINJ (2013) in Jharkhand.

Similarly, we have analyzed the map of agricultural vulnerability which was developed scientifically utilizing parameters such as climatic conditions, demographic features and agricultural productivity (JAPCC, 2014). In this analysis the lowest value shows high agricultural vulnerability. The ten highest agricultural vulnerable districts are Pashchim Singhbhum (-0.65), Saraikela (-0.63), Garhwa (-0.56), Simdega (-0.46), Latehar (-0.43), Palamu (-0.27), Lohardaga (-0.23), Pakaur (-0.21), Chatra (-0.17) and Gumla (-0.1). Ranchi, Dumka, Deoghar and Dhanbad are the least vulnerable districts with values of 0.69, 0.5, 0.36 and 0.31 respectively. RAO (2018) also found related observations while analyzing agricultural vulnerability.

Evaluation of the map which shows the prediction scenario RCP-6 of climate anomalies in Jharkhand state shows some facts. The temperature anomalies map shows an increase in temperature in the year 2030 which will be in the range of 0.8°C to 1°C for the state of Jharkhand. The highest increases in temperature were observed for the districts of Pashchim Singhbhum, Simdega and Saraikela. Similarly, the predicted precipitation map for the year 2030 shows the variation in rainfall pattern in Jharkhand. JANA & MAJUMDER (2010) also analyzed climate change (A2 and B2) scenarios in Jharkhand and made similar observations.

Based on these evaluations we can conclude that a few districts of Jharkhand, such as Pashchim Singhbhum, Garhwa, Palamu and Latehar, need to be prioritized on an urgent basis. Furthermore, existing policies should be significantly manoeuvred for more robust planning considering the poor socio-economic conditions of people and their adaptive capacity to future climate change. The tribal people of Jharkhand are highly vulnerable to climate change (Minj 2013). A large section of poor people/ ethnic tribes in rural areas of Jharkhand state will suffer from diminished livelihoods and agricultural vulnerability due to high climate change. The insignificant agricultural productivity and the continuous degradation of local forests (qualitative and quantitative) are not able to support them which were once their major sources of income, nourishment and occupation.

4. Conclusion

In this research we have created a map and examined the interlinking relationships among the diversified field of data such as land use/land cover, long term NDVI, long term forest fire points, forest fire hotspots, poverty percentage, tribal percentage, climate change vulnerability and agricultural vulnerability of Jharkhand for a better perception and knowledge of vegetation (forest and agriculture) health, LULC, poverty, tribal population and future climate change impacts using high end Remote Sensing and GIS data.

The state of Jharkhand is a very important state which retains beautiful forests with a diverse flora and fauna and huge mineral reserves. Poverty is one of the biggest issues of this state as it has acute tribal dominated areas which have never been seriously tackled politically, socially and administratively. The agriculture and forests of this state which are the biggest contributors to the livelihoods of the rural people have been suffering due to a lack of clear cut policies on climate change. Forests which are threatened due to fires every year need policy intervention for fire prevention and control. The poverty eradication and tribal development plan in Jharkhand are ineffective because they do not give significant results due to poor implementation and execution. This was also proven by our study because long term NDVI based negative change trends in vegetation were found in most of the north western parts of Jharkhand which retains a very high poverty percentage. In some of the districts poverty percentages are higher than those of sub-Saharan regions of Africa.

The climate change vulnerability and agricultural vulnerability were found to be highest in the southern parts of Jharkhand state. Furthermore, the predicted map (2030) for future temperature anomalies also shows a high increase in temperature in the southern part of Jharkhand state. The southern part of the Jharkhand population also shows the highest dominance of tribes with a weak adaptive capacity to climate change and this is a serious challenge for future policymakers.

The outcomes of this study are of high importance because such a diverse evaluation and analysis of these relationships have never been examined before for the state of Jharkhand. Therefore these results must be incorporated into the prioritization of various districts of Jharkhand for poverty eradication, enhancing livelihoods, tribal upliftment, and climate change evaluation. The insignificant agricultural productivity and continuous degradation of forests (qualitative and quantitative) now a days which were the major source of income, nourishment and occupation of the majority of the people in the past are continuously threatened and must be adequately addressed in conservation and climate change mitigation programmes.

Geospatial technology is one of the most important tools for examining large and diversified spatial data sets and for analyzing spatial relationships which are highly beneficial in policy decision making.

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