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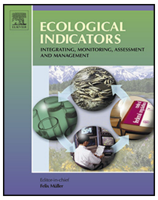

Application of indicators for identifying climate change vulnerable areas in semi-arid regions of India

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ABSTRACT

This paper aims at assess district-wise vulnerability index of the state of Karnataka State, which is predominantly is rainfed and is highly susceptible to climatic variability. Secondary data on relevant indicators were collected to prepare indices *viz.*, crop production losses, exposure, sensitivity and adaptive capacity. Following normalization and using appropriate weights for indicators, these four indices were used for constructing vulnerability index, which can be used a rapid assessment method for prioritizing districts that need measures to moderate the detrimental impact of climate change. It has been observed that Climatic variability caused higher production losses in cereals, pulses and oilseeds in Davangere, Gulbarga and Raichur districts, respectively. Districts like Koppal, Raichur, Bijapur Gulbarga, Gadag, Bagalkote and Bellary were placed under extreme degree of exposure. As per the sensitivity index scores, Kolar district is the most sensitive. Further, Bengaluru (Urban), Dakshin Kannada and Kodagu are ranked first, second and third in terms of adaptive capacity in the state. Overall, vulnerability index scores indicate that Gulbarga, Koppal, Raichur, Bellary, Bagalkote, Bijapur and Belgaum are extremely vulnerable districts in the state. It was also estimated that around 70% of the cultivated area, which supports 60% and 67% of livestock and rural population of the state, respectively are facing 'extreme to high' level of vulnerability. The ranking based prioritization of the vulnerable areas calls for a holistic approach for each district or a group of districts to reduce their sensitivity, minimize exposure to rainfall variability through implementation of site-specific and leverage adaptive capacity through better health and education facilities, expansion of employment opportunities in other sectors or reducing over dependence on agriculture.

1. Introduction

The agriculture sector in developing countries is most vulnerable to the adverse impacts of climate change (Kato et al., 2011). Failure of farmers in adapting to changing climate will have a negative effect on agricultural productivity and food security (Rosenzweig and Hillel, 1998). India is highly vulnerable to climate change (World Bank, 2003; Rao et al., 2011), being one of the most drought-prone countries in the world (Mishra and Singh, 2010; Shetty et al., 2013). Within India, rainfed area constituting about 55% of the net sown area and supporting 66 and 40% livestock and human population of the country, and is highly susceptible to the harmful impact of climate change (Rao et al., 2011). These areas receive around 80% of the annual rainfall during a short span of four months (June to September), inter and intra annual variations and its distribution have a profound impact on the agricultural sector (Bhate et al., 2012). Low rainfall can reduce irrigation water supplies leading to decline in irrigated area in the subsequent season (Kumar et al., 2014). Inter-annual monsoon rainfall variability leads to large-scale droughts and floods resulting in a major effect on food grain production (Parthasarathy et al., 1992; Selvaraju, 2003; Kumar et al., 2014) and on the economy as whole (Kumar and Parikh, 2001). A typical example of monsoon rainfall and food grain production relationship is the year 2002–03 during which a 19% decline in monsoon rainfall in 2002 resulted in a steep decline of 18% in foodgrain production compared to year. Forecasts for 2020 using crop simulation models incorporating future projections warned that climate change is likely to reduce the production of wheat and rice in the range of 6–18% and 4–6%, respectively (Shetty et al., 2013). Vulnerability to climate change has been

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defined as the extent to which a system or society is prone, or at risk to, and unable to deal with the negative effects of climate change and variability (IPCC, 2007a,b). Presently, vulnerability assessment has become a tool for policy response to climatic variability since it helps identifying vulnerable regions/sections of society. For vulnerability assessment, indicator approach is the most commonly adopted method for quantifying as it combines socio-economic and biophysical factors contributing to vulnerability to climate change (Hebb and Mortsch, 2007). Vulnerability index can facilitate decision making and can be useful for setting targets and priorities as it provides a single-value, easy to comprehend estimate, and facilitates easy and meaningful monitoring and evaluation of progress (Briguglio, 2003). Therefore, indicators are being increasingly recognized as useful tools for policy making and public communication in conveying information on performance in diverse fields such as environment, economy, society or technological development (KEI, 2005). However, vulnerability assessment through indicators are constrained by: (a) subjective selection of variables; (b) not able to reflect the real situation, being average of sub-indices; (c) not able to explain the intra-regional status of vulnerability (Briguglio, 2003; Barnett et al., 2008) and (d) as the indicators do not explain the processes which shape vulnerability (Eriksen and Kelly, 2007). Yet, vulnerability assessment with the help of indicators is vital as it facilitates the identification of climate susceptible regions and, can act as an entry point for understanding and addressing the processes that cause and exacerbate vulnerability (Yohe and Tol, 2002; Brooks et al., 2005). Against this background, by combing socio-economic, climatic and production losses indicators, an attempt has been made to develop a composite index for assessing the district-wise vulnerability status of Karnataka, which is one of the most drought prone states in India.

2. Material and methods

2.1. Study area

Karnataka state is situated in southern western part of India and has the second highest area under arid land after Rajasthan and, agriculture is highly dependent on vagaries of the southwest and north east monsoon (Biradar and Sridhar, 2009). Of the net cultivated area (9.94 mha), 66% is rainfed (GoK, 2013) and therefore it is considered as highly vulnerable to climate change (BCCI-K, 2011). The south-west monsoon is the major rainy season during which the state receives about 80% of its rainfall. Hot and dry weather occurs from March to May with probability of mean maximum temperature exceeding 40 °C during the latter months. The temperature ranges from 20 to 32 °C and, 34–42 °C during winter and pre-monsoon season, respectively. Karnataka is projected to experience a warming of 1.8 and 2.2 °C by 2030, in minimum and maximum temperatures, respectively. The quantum of rainfall received is projected to decrease, especially South-West monsoon. The northern districts of the state are projected to experience increased incidence of drought by 10–80% in the *kharif* season and most of the Eastern districts will experience an increase in the frequency of droughts in the *rabi* season (BCCI-K, 2011).

2.2. Data

This study used district-wise time series data on area and yield (2000–01 to 2009–10) collected from the Directorate of Economics and Statistics, Karnataka and Ministry of agriculture, Government of India. Data pertaining to 29 districts of the state were collected under three major crop group viz., cereals (wheat, rice, sorghum, pearl millet, maize and minor millets), pulses (chick pea, horse gram, red gram, black gram, green gram, and some other minor pulses grown in the summer (*Kharif)* and *winter (Rabi)*) season and oilseeds (groundnut, sunflower, safflower, niger, rapeseed & mustard, castor, soy bean, linseed and sesame). The data for other indicators were collected from Central Ground Water Board (CGWB); Ministry of Water Resources, Government of India, Planning, Programme Monitoring and Statistics Department and Rural Development and Panchayathi Raj Department, Government of Karnataka.

2.3. De-trending of time-series data

According to Larson et al. (2004) and Antwi-Agyei et al. (2012), inter-annual fluctuations in sown area and yield of crops is due to long-term trend, which shows the impact of technological advancements (changes in management practices and use of new technologies) and short term factors (spatial and temporal variations of climatic parameters). Therefore, an important step for analyzing climate – yield relationships is to first remove long term or technological trends.

The trend effect in area and yield of a crop was captured with the help of a linear regression given in Eq. (1)

$$Z_t = \alpha + \beta t + \varepsilon_t \tag{1}$$

Where Z_t is the dependent variable (area or yield), α is intercept, β is parameter to be estimated, t is years and ε_t is residual with mean zero and variance σ^2.

To obtain the de-trended area or yield, the residuals were centered on mean area or yield ($\overline{z_t}$). De-trended data for the yield or area can be obtained by using Eq. (2).

$$Z_{dt} = \varepsilon_t + \overline{z_t} \tag{2}$$

Z_{dt} is de-trended area or yield. The de-trended production was computed by multiplying the de-trended area by the de-trended yield, and which has all the variations that can be attributed to climatic variability.

2.4. Normalization

Drawing on literature (Gbetibouo and Ringler, 2009; Antwi-Agyei et al., 2012; Piya et al., 2012; Liu et al., 2013; Acheampong et al., 2014; Geng et al., 2014) appropriate indicators were chosen keeping in view of their relevance to the study area and availability of data. Since indicators are measured in different units, they therefore were subjected to normalization so as to bring their values within the comparable range between 0 and 1 (Vincent, 2004; Kumar et al., 2014).

Normalization is done based on the functional relationship of indicator with targeted index- sensitivity, exposure and adaptive capacity. If there is a positive relationship (increase in the target index with increase in the value of indicator) indicators are normalized following Eq. (3).

$$Y_{ij} = \frac{x_{ij} - Min\{x_{ij}\}}{Max\{x_{ij}\} - Min\{x_{ij}\}} \tag{3}$$

Where, Y_{ij} is the index for the ith indicator related to jth district, x_{ij} is the actual/observed value of ith indicator for jth district. $Max\{x_{ij}\}$ and $Min\{x_{ij}\}$ is the maximum and minimum value of ith indicator among all the L (J = 1,. . .., 29) districts, respectively. And if the variable has negative functional relationship, then use equation 4 was used.

$$Y_{ij} = \frac{Max\{x_{ij}\} - x_{ij}}{Max\{x_{ij}\} - Min\{x_{ij}\}} \tag{4}$$

Generally, there are different methods to assign weights to different indicators: (a) Assigning equal weights to indicators while computing an index (Vincent, 2004). However, it may be too