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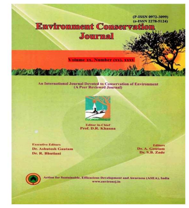

Drought in Indian perspective, its impact on major crops and livestock and remedial measures

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ABSTRACT

Drought is one of the important natural disasters which lead to maximum severity to human among all others. The vulnerability increases with the resource poor nature of developing and under developing nations. Considering the extent of rainfed area in India, the vulnerability to drought is higher compared to other peer nations. It has implications on agriculture, livestock, fisheries, rural employment, human nutrition and health. However, the impact initiates with crop production and encompasses livestock in medium term which has severe economic implications for farmer. Therefore, it is desirable to present an extensive study on the impact of drought on major crops and livestock in India. Further, we have also emphasized on the remedial measures to be followed for crop production and livestock.

Introduction

Drought is one of the several atmospheric phenomena which has catastrophic implication for life and livelihoods of the particular country. It is defined in various contexts from shortage of rainfall compared to the long period average, reduction in soil moisture and levels of water resources to the shortfall in ET demands of the crops. Increased incidence of disasters is the new normal, and drought incidence (along with other weather and climate related disasters) frequency has quadrupled from average 40 per decade in 1970s to 150 in 2010s (FAO, 2021). Drought is among the other extreme meteorological events such as heat waves, storms etc which can worsen other high impact events such as flooding, landslides, wildfires and avalanches (WMO, 2020). Drought causes short and medium term water shortage and reduces yield of crop and livestock under extreme heat stress (FAO, 2021). Drought is an extreme climatic event whose intensity and duration increases slowly and can have hydrological and socio-economic impacts including wild-fires, loss of crops and livestock, water scarcity, migration, increase in food prices and health effects (Mukherjee *et al.,* 2018). The severity of drought can be gauged from the fact that it is dependent on twin atmospheric conditions *i.e.* prevailing precipitation and the temperature. While the former supplements the water, later put a demand on it and thus balance of two determine the drought conditions. Historically, precipitation is considered as the major cause of drought, however, with global warming scenario, rising evaporative demand is considered as major cause of drought events (Zhao and Dai, 2015). Drought is classified as meteorological, hydrological, agricultural and socio-economic, depending on the extent and severity of its impact. At individual plant level, it can bring physiological and biochemical stress which is manifested in the form of reduced growth and yield and at crop level, it impacts the gross harvesting of solar radiation and consequent yields which ultimately disrupts the food security and economy of the nation(s). Drought has impacted parts of interior South America in 2020 with an

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estimation of loss of $ 3 billion in agriculture in Brazil alone whereas in parts of South Africa, it is continued to persist (WMO, 2020); however, prolonged drought along with conflict has resulted in the famine in Somalia between October, 2010 to April, 2012 (FAO, 2017) .Globally agriculture supports livelihood of 2.5 million peoples and on account of its direct interaction with the environment, reliance on natural resources for production and importance in socio-economic development of nation, urgent actions are needed to build resilient agricultural systems (FAO, 2021).If only impact of drought is considered agriculture share rose to 84% whereas it is upto 25% with climate related disasters (FAO, 2017).There are evidences of the shift in climatic regimes which has increased the vulnerability towards the drought. It is evident from the recent impact of climatic extremes that ecosystems and human lives are vulnerable to heat waves, drought, floods, cyclones and wildfires (IPCC, 2014).It is important to have a comprehensive strategy for the drought management as it starts as small event of precipitation deficit and affects the soil moisture, hydrology and agriculture of the particular place (Rajasivaranjan, 2015). To mitigate impacts of drought along with other extreme events, it is suggested to integrate crop production with livestock, horticulture, apiculture, fisheries and agro-forestry (MoEFCC, 2021).

Drought in Indian perspective

The importance of drought situation to the country as whole can be gauged from the trailing facts. Agriculture contributes around 16 % of gross value addition and supports 48 % of the employment. 68 % of the total agriculture is rainfed. Around 74 % of the total rainfall is obtained during the south west monsoon. Overall drought risk to agriculture is higher in India due to the deviated monsoon, depleted ground water and food demand of population of 1.252 billion (Zhang *et al.,* 2017). The monsoon in India is characterized by its erratic behavior in terms of its spatial and temporal distribution.. The monsoon has the impact of various atmospheric phenomena such as Rossby waves/ jet streams and El-Nino which are strong in reducing rainfall over Indian sub-continent. Most of the drought conditions of the Indian summer monsoon rainfall are associated with El Niño (13 of the 18 years) indicating that about 72% of the drought years are associated with the influence of Pacific Ocean (Varikoden *et al.,* 2015). Though every El Nino year is not associated with drought, however, there is strong inverse relationship between strength of El Nino and monsoon occurrence which negatively impacts the Indian agriculture (Pandey *et al.,* 2019). Dry areas constitute 94 mha where one-third of Indian population resides and 50 % of the region is hit by drought once in four years (Sonawane *et al.,*2016).Around 28 % of total agriculture area in India is susceptible to critical water shortage (Gautam and Bana, 2014). Rainfed area in India extends over more than 100 mha (Kumar *et al.,*2014) and according to Badatya, (2005) out of total rainfed area of 104 mha, 32 % fall under the high rainfall (>1125 mm) and rest 68 % under the low and medium rainfall with states of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Karnataka having most of the low rainfall regions. There are several criteria for assessing the severity of drought. In India, the meteorological rainfall variability of ±19 % is considered to be the normal, and deficit between 20 to 59 % is moderate drought and more than 60 % is categorized as severe drought (Samra, 2004; Badatya, 2005). In recent past, India has experienced 22 droughts, of which 5 were severe(Samra, 2004; Gautam and Bana, 2014) and there had been 12 major droughts in past five decades with successive droughts in 1965-66 and 1966-67 and the recent one in 2002-03 (Badatya, 2005). Drought is characterized by non-uniformity of its occurrence and impact. Drought has hardest impact on the Southern and Western regions, however, these states have better adaptations whereas it has significant impact on North and Central regions, but the adaptation level is lower (Amarsinghe *et al.,* 2020). It is considered that frequency of drought is once in 15 years in North Eastern India, however, it has been reported by Parida and Oinam (2015) that in the period 2000-15, eight years has experienced meteorological drought in this region. In a prediction study of 48 years (2050-2099). Ojha *et al.* (2013) predicted increase in drought incidence in west central, peninsular, and central northeast regions of India. In a study on drought characterization in India over projected climatic scenario in different time frames i.e. near-future (2010–2039), mid-future (2040–2069), and far-future (2070–2099) in comparison with reference period (1976–2005), increasing trend in drought severity, duration, occurrences, and the average length of drought under warming climate scenarios was concluded (Bisht *et al.,* 2018). Drought studies in India are important not only in context of her own food security but also for nations which are dependent on imports of food grain from India (Udmale *et al.,* 2020).

Impact on crop production

Agriculture is mainstay of Indian economy and any prolonged drought condition can jeopardize food security and bring the famine conditions. Understanding the impact of drought on crop production is itself challenging as it is complex interaction of temperature, precipitation, vapour pressure and solar radiation (Leng and Hall, 2019).In the crop production, drought can have impact from preparation of field, sowing operations, weakening of standing crops, increased vulnerability to the pest incidence and final impact on the quantity and quality of yield obtained (Gautam and Bana, 2014). The reproductive stages of the crops are more sensitive to the drought stress than vegetative stages leading to reduced flowers, pods, fruit set and number of seeds and is more severe when accompanied with heat stress and these two will be more common in current and future climate change scenario (Sehgal *et al.,* 2018).The impact of drought on the crop production shows fluctuations. In the twelve drought years, the loss in crop production when compared to previous years varied from 2.8 % in the year 1982-83 to 19 % in 1965-66 and 13.2 % in 2002-03 (Badatya, 2005). Average crop loss of 86.1 % (for both Kharif and Rabi) was reported in 2012 in Southern Maharashtra, which varied from 67.8 % in maize to 98.2 % in cotton (Udmale *et al.,* 2015).

The impact of drought among major crops of India is presented below

Rice

In India around 42 percent of the total 44 mha area under rice cultivation is rainfed (Mention the area of which country or region) (Birthal *et al.,* 2015) and drought is major constraint of rainfed rice production (Kumar *et al.,* 2014; Sharma *et al.,* 2016). Drought has been reported to reduce relative leaf water content, inhibition of cell enlargement leading to reduced leaf size, reduced tillering and plant height and increase in the mean root length (Sharma *et al.,* 2016). Multi stage drought led to the 86% reduction in yield in rice along with reduction in yield attributes; and deterioration of physiological parameters including decrease in chlorophyll content, relative water content, photosynthesis, transpiration rate, starch content and increase in proline content and lipid peroxidation when compared to non-stress, however, differences exist among growth stages and genotypes (Kumar *et al.,* 2020). Similar findings were reported by Nahar *et al.* (2018) in rice.

Wheat

Out of 29 mha under wheat cultivation in India, 3-5 mha is susceptible to drought (Sheoran *et al.,* 2015). The vegetative stage of wheat is more sensitive to drought as the root growth is reduced consequently reducing the leaf area, leaf number per plant, leaf size and leaf longevity (Zhang *et al.,* 2018). Drought reduces chlorophyll content, membrane stability, relative water content, reduction in chlorophyll fluorescence and the yield and yield components, reduction in NPK uptake and increased the catalase, peroxidase and superoxide dismutase content (Abdullah *et al.,* 2011; Nawaz *et al.,* 2012; Sheoran *et al.,* 2015), however the effect was pronounced with late stage drought stress than early season (Nawaz *et al.,* 2012). 57-59 per cent reduction occurs in iron and zinc content per hectare with drought stress in wheat (Velu *et al.,* 2016).

Sugarcane

Drought stress significantly reduces the juice quality including decrease in sucrose percentage, purity coefficient, (=Sucrose%/ Brix), commercial cane sugar %{ = (1.022 × Sucrose %) – (0.292 × ^{0}Brix)}, total soluble solids or brix, marginal decrease in pH, increase in reducing sugar content (Hemprabha *et al.,* 2004; Mishra *et al.,* 2016). Increase in proline content, SOD and peroxidase enzyme activity and decrease in plant height, single cane weight, number of millable canes, cane yield, relative water content, chlorophyll and cartenoids content was recorded with drought stress (Pawar and Bhutkar, 2011; Jain *et al.,* 2015; Santeshwari, 2021).

Oil seeds

The morphological and physiological impacts of drought on oilseeds will be similar as described under rice and wheat. In oilseeds, drought can impact the fatty acid synthesis and can lead to increase in saturated fatty acid (palmitic and stearic acid) content and decrease in unsaturated fatty acids (linoleic and linolenic acid) (El Sabagh *et al.,* 2019). Drought stress reduces rate of flower production, peg elongation rate, seed growth rate and its weight; number of mature pods; pod yield; shelling percentage; harvest index and adequate pod zone soil moisture is important for development of pegs into pods; also leads to reduction in oleic: linoleic acid ratio which reduces the keeping quality and increases aflatoxin content which was independent of the drought tolerance of genotypes (Kenchanagoudar *et al.,* 2002; Reddy *et al.,* 2003; Hamidou *et al.,* 2014), however, Dwivedi *et al.*(1996) reported increase in oleic acid content with end season drought in groundnut. Oil content reduces under the end season drought, however, it was not affected by mid-season drought (Dwivedi *et al.,* 1996; Kenchanagoudar *et al.,* 2002). Drought stress reduces the growth parameters and isoflavone content in soybean (Akhita Devi and Giridhar, 2013). There had been varying impact of drought stress on the growth and physiological parameters, yield attributing characteristics and yield of mustard depending on the genotypes (Chauhan *et al.,* 2007; Singh *et al.,* 2009). Though sunflower is considered moderately drought tolerant, any incidence of drought at critical stages can reduced photosynthesis, water potential, xylem and phloem transport, nutrient uptake, reduced capitulum diameter, number of achene per capitulum, achene weight per capitulum and ultimately achene yield, reduced oil content depending on the intensity of drought and its fatty acid composition (Nezami *et al.,* 2008; Jaleel *et al.,* 2009; Hussain *et al.,* 2018). The bud initiation stage is more critical for drought stress than seed filling in sunflower (Jaleel *et al.,* 2009).

Pulses

Pulses are generally grown under the rainfed conditions in India, therefore, more susceptible to the drought conditions. Chickpea being grown under residual moisture conditions, therefore, susceptible to terminal drought or moisture stress situations causing 40-50% global yield losses (Basu *et al.,* 2004; Jha *et al.,* 2014; Devasirvatham and Tan, 2018; Muruiki *et al.,* 2018; Sinha *et al.,* 2019). Drought stress leads to stunted growth, non-uniform plant stand, pale colored lower leaves, early senescence, reduction in days to maturity, chlorophyll content, Rubisco activity, sucrose synthesis, average reduction of 23% in number of seeds per pod, upto 54% reduction in seed size and increased incidence of dry root rot and black root rot (Kumar, 1997; Awasthi *et al.,* 2014; Sinha *et al.,* 2019). Though there had been reduction in the relative water content, photosynthetic apparatus was not impacted showing ability of chickpea to maintain turgor even under water stress conditions (Basu *et al.,* 2004). Drought stress in pigeonpea led to reduction in relative water content, stomatal conductance, transpiration rate, total chlorophyll content, enhancement in proline content, superoxide dismutase, malondialdehyde and peroxidase activity, reduction in specific nitrogenase activity and leghaemoglobin content (Nandwal *et al.,* 1991; Kumar *et al.,* 2011; Vanaja *et al.,* 2015). Flowering stage is most sensitive stage for drought stress in pigeonpea leading to 48% reduction of yield and upto 62% when combined with drought at pre-flowering (Lopez *et al.,* 1996; Nam *et al.,* 2001). Pigeonpea owing to its long duration nature will see least reduction in area under drought incidence as its sowing can be adjusted according to receipt of rainfall (Kumar *et al.,* 2014). Moisture stress at seed filling in lentil significantly reduced above ground biomass, pod number, pod weight, seed number by 41%,71%,71%,77%, respectively (Sehgal *et al.,* 2017). In greengram and blackgram, drought stress leads to reduced leaf number, plant height, shoot and root biomass, leaf area index, leaf water potential, protein content, yield and increased proline, anthocyanin, flavnoids (Baroowa and Gogoi, 2015; Baroowa and Gogoi, 2016).

Impact on livestock

Livestock has an important role in the Indian agriculture. This is more important in dryland areas where the crop yields are unpredictable and these serve as a income assurance during stress period. Drought incidence reduces the availability of the green forage as well as the dry reservoirs makes a scarcity of water for the livestock. Around 113.5 million bovines were affected in nine states of India, with seven states facing fodder shortage (except Odisha and Tamil nadu) in drought year of

2002 (Patil, 2012). Purchase of fodder and crop residues like legume hays, rice straw and sorghum stover increases with simultaneous increase in fodder cost and there is reduction in purchase of concentrate feed and rice bran (Biradar and Sridhar, 2009; Chand and Biradar, 2017). During drought years there is decrease in feed intake, loss of body weight, decline in fertility, disturbance in reproductive performances, average lactation length and yields, worsening of milk to adult female cattle ratio, increase in dry and unproductive cattle, decrease in livestock population probably due to animal death due to lack of quality fodder, distress sale of cattle and unbearable cost of livestock; it also leads to migration of livestock especially cattle and sheep (Patil, 2012; Maurya and Tripathi, 2013; Mishra, 2017; Kanwal *et al.,* 2020). To lessen the drought impact, farmers practice distress sale of cattle fetching lower prices than normal (Toulmin, 1986; Biradar and Sridhar, 2009; Udmale *et al.,* 2014; Chand and Biradar, 2017).

Mitigation measures

Agriculture is the foremost sector where mitigation should receive the priority. Singh *et al.* (2011) concluded that Indian food grain production is more vulnerable to drought than floods and among the two major seasons, kharif food grain production is more vulnerable than rabi season. Various agronomic measures for drought proofing includes availability of quality seeds, optimizing plant population, spray of anti-transpirants, application of polymers e.g. Pusa hydrogel, practicing life saving irrigation, nutrient management, practicing conservation tillage, intercropping to reduce runoff losses, selection of efficient varieties, shifting sowing according to expected rainfall pattern, mulching and *in-situ* moisture conservation, use of zero till seed drill to accomplish late sowing of wheat (Gautam and Bana, 2014; Tyagi *et al.,* 2020). Application of pusa hydrogel had improved growth and physiological parameters in rice; significantly higher yields in cotton; pusa hydrogel @ 2.5 kg/ha + organic mulch @ 5tonnes/ha in pigeonpea recorded highest yields and net return (Sen *et al.,* 2019; Ashraf *et al.,* 2020; Jadhav *et al.,* 2020).

Krishna and Ramanjaneyulu (2012) reported effectiveness of life saving irrigation through sprinkler, ridge and furrow method over flatbed method and intercropping of Castor+redgram (1:1) in terms of yield and net returns. Some of the critical stages for irrigation in pulses are given table 1. However, the drought areas should have supplementary irrigation scheduled on the basis of incidence of dry spell rather than critical stage concept, generally 10-15 days depending on the soil texture (Reddy and Reddy, 2016). Water harvesting for this supplemental irrigation can be done by construction of some feasible system like earthern dam on gully head, community tanks, small tanks for individual farmers preferably located at the lowest point of the catchment, with capacity to completely full at the end of monsoon, maximum volume with minimum exposed surface so as to reduce evaporation losses and lining for reducing the seepage losses (Verma, 1981).Mulching is effective under drought stress. Yield levels were significantly higher with plastic mulch under 75% moisture stress in capsicum; with double mulching with organic material for crops in rotation with maize; fruit yield in ber with black polythene or date palm leaves mulch along with supplementary irrigation; 24-28% higher okra yields with organic mulches compared to no mulch under moisture stress; mulching with crop residues along with compartmental bunding reported highest groundnut yield and water use efficiency (Thakur *et al.,* 2000; Bahadur *et al.,* 2013; Meghwal and Kumar, 2014; Ngangom *et al.,* 2020; Pandian *et al.,* 2020). *Insitu*water conservation measures involving alteration in land configuration also proved successful in enhancing yield in drought prone rainfed areas (Table 2).

Mineral nutrition has an important role in inducing drought tolerance in plants. The metabolic role of nutrients is presented in table 3. Moderate nitrogen supply in maize enhanced drought tolerance through enhanced nitrate concentration, nitrate reductase activity, abscisic acid content; higher N supply increased cell membrane stability in soybean; foliar application of N at flowering enhanced seed yield and protein content under terminal drought stress in chickpea; moderate dose of nitrogen recorded highest wheat yield under drought stress (Palta *et al.,* 2005; Premachandra *et al.,* 2009; Song *et al.,* 2019; Sedri *et al.,* 2019). Phosphorus application enhanced relative water content, photosynthetic rate and yield of mothbean under drought stress; grain yield was compensate by application of P, Fe and Si under moisture stress with that of irrigated rice crop; number of tubers

Table 1: Critial stages for various pulses for yield maximization under limited irrigation water availability (Praharaj*et al.,* 2016)

Pulse crop	Critical stage
Chickpea	1 irrigation at 50% flowering/ pod development stage; 2 irrigations at branching and pod formation.
Pigeonpea	2 irrigations at branching and pod formation.
Fieldpea	50% flowering.
Lentil	Early pod filling stage.
Rabi pigeonpea	25 days crop stage.

Table 2: Yield gain by practicing various in-situ moisture conservation practices under drought conditions

Conservation measures	State and crop	Yield gain over control (%)	Reference
Trenching	Uttarakhand; Rice	32.9- 58.4	Kumar *et al.,* 2014
Continous Trenching	Maharashtra; Mandarin	29.2	Panigrahi*et al.,* 2009
Modified Crecsent bund	Karnataka; Cashew	32.2	Rejani and Yadukumar, 2010
Scooping	Karnataka; Sorghum	11-12	Mishra and Patil, 2008
Field Bunding	Rajasthan; Chickpea	18	Regar*et al.,* 2010
Field Bunding	Rajasthan; Sorghum	10.5	Rao *et al.,* 2010
Paired row planting with conservation furrow between two rows	Telangana; Pigeonpea	34.25	Rao *et al.,* 2018

Table 3: Specific metabolic functions of various mineral nutrients under drought stress in plants (Hawkesford *et al.,* 2012; Broadley *et al.,* 2012)

Nutrient	Specific metabolic functions under drought conditions.
Nitrogen	Synthesis of betaine which act as compatible solute and counteracts high vacuolar concentration of inorganic ions like Na^+ and Cl^- which inhibits Cytoplasmic metabolism.
Potassium	Regulates the stomatal movement by changing turgor of guard cells; maintaining osmotic pressure in vacuole; avoidance of oxidative stress; pH stabilization of chloroplast stroma.
Sulphur	Strong disulphide bridge (-SH group) in proteins which provides cellular resistance to dehydration caused by drought.
Magnesium	Deficiency leads to impairment of root growth and thus impacting drought resistance.
Calcium	Increase in cytosolic Ca concentration act as signal under drought stress.
Manganese	Mn SOD induces enhanced drought tolerance.
Molybdenum	Component of aldehyde oxidase enzyme which causes coversion of abscisic aldehyde to abscisic acid (ABA) which is important for inducing drought tolerance in plants.

and yield was increased with P application under moisture stress (Garg *et al.,* 2004; Motalebifard *et al.,* 2013; Kumar *et al.,* 2019). Spray of 2 % KCl at flowering and siliqua formation stage in toria recorded significantly higher yields and yield attributes under rainfed conditions (Sarma *et al.,* 2015); ameliorating effect of K application on relative water content and chlorophyll in sugarbeet (Aksu and Altay, 2020); K application at pre-flowering and pod development stage improved mungbean performance under drought (Umar *et al.,* 2019); split K application improved yield parameters in groundnut under drought stress (Patro *et al.,* 2018); enhanced seed yield of mustard and sorghum under drought stress with higher K dose and of groundnut under moderate K dose (Umar, 2006). Crop diversification can be practiced in form of crop rotation and intercropping/ mixed cropping. Mixed/ intercropping have variable adaptations to climate threats and can enhance the productivity in extreme weather and low input farms whereas crop rotation can reduce soil degradation, can improve water use efficiency and can enhance productivity (Patel *et al.,* 2020). Substituting maize with sorghum, sesame, blackgram, groundnut, greengram, clusterbean under low and erratic rainfall pattern proved efficient increasing maize equivalent yields, rain water use efficiency and B:C ratio (Jat *et al.,* 2011). Strip cropping was most suited for pearlmillet+ legumes compared to their mixed and intercropping under severe moisture stress giving yields greater or at par to the sole pearlmillet and LER value> 1 (Singh and Joshi, 1994).Selection of genotypes has a larger role in mitigation. A drought tolerant variety developed by IRRI, released as *Sahbhagidhan* in India, is short duration variety, have genetic drought tolerance and more efficient in extracting moisture (Dar *et al.,* 2020) and its short duration nature escapes high temperature and allow farmer to grow another crop after harvest (Yamano *et al.,* 2018). Some other drought tolerant varieties developed are CR Dhan-201, CR Dhan 801 an CR Dhan, 802 for rice (MoEFCC, 2021). Birthal *et al.* (2012) reported 23 per cent yield advantage with ICGV91114 compared to dominant groundnut variety TMV-2 in Ananthpur district. Among eight varieites, SPV-1591 and among six hybrids, CSH 15R had significantly higher yields under rainfedrabi season at Bellary (Patil, 2007). Among the fifteen wheat varieties, NI-5439, WH-1021, HD-2733 found to be best suited for moisture stress conditions (Meena *et al.,* 2015). Livestock has important role to play in drought prone regions, some of the important breeds of dry areas are *Tharparkar, Rathi, Kankrej*(Cattle);*Marwari, Jaisalmeri, Patanwadi, nail* (sheep);*Marwari, kutchi*(goats) and *Bikaneri, Jaisalmeri*(camel) (Patil *et al.,* 2006). The various measures suggested for feed maintenance are thinning of the crop to increase their vegetative growth, increasing grass production in fallow and community areas, maximum utilization of the green herbage and agro-industrial waste, chaffing of forage, feeding of chopped forage for better digestion, hay making, enriching forage with urea treatment (Mishra, 2017). Some other important measures for livestock management includes controlled grazing, introduction of high yielding perennial grasses, silvipastoral system for areas having rainfall< 200mm,strategic feeding of cattle includes preferential feeding to productive stock such as pregnant and lactating cattle, feed supply for maintenance of minimum body weight, urea/ ammonia treated straw saves the cost of concentrate feed; multinutrient bricks/ blocks of molasses, urea, mineral and vitamins as lick for large animals and feed for small ruminants (Patil *et al.,* 2006).

Conclusion

Drought has serious implications for the agriculture and livestock sector and thus, can disrupt the life in vulnerable areas. It is possible to avert the dark consequences of spontaneous drought through the preparedness in form of early warning and drought proofing. Drought has varying impact on production of crops depending on the adaptation of the particular state. In the drought year of 2009, there was rainfall deficit of 23, 34 and 35 % for the Jharkhand, Punjab and Haryana respectively, however, Punjab and Haryana has shown a net increase of paddy production (6.6 and5.8 respectively) from triennium (2006-08) average and Jharkhand had witnessed reduction of 52.6 % owing to only 8 % of net sown area under irrigation compared to 86 and 98 % in Haryana and Punjab, respectively. Though we have discussed the specific impacts of drought on agriculture and livestock, it is needed to have holistic approach in its management considering availability of timely credit, other non farm employment, food grain supply. Long term area wide planning in form of water shed, water harvesting structures etc are necessary, however, short term mitigation measures such as availability of drinking water, fodder and concentrates, seed and technical inputs, government intervention are equally desirable.

Conflict of interest

The authors declare that they have no conflict of interest.

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