

Environmental and Socioeconomic Impacts of Drought in India: Lessons for Drought Management

Chandra Prakash Kala *

Ecosystem & Environment Management, Indian Institute of Forest Management, Nehru Nagar, Bhopal, Madhya Pradesh, India
*Corresponding author: cpkala@yahoo.co.uk

Abstract The frequency and intensity of droughts have been elevated in the present century in India, and in 2016 alone, about 330 million people spread across 10 Indian states had affected by drought due to two consecutive years of weak monsoons. The agriculture sector, which is mostly rainfed in India, remains the centre of discourse on adverse effects of drought despite the fact that drought affects the larger ecological, environmental, social and economical settings. Since the impacts of drought are radiated to different sectors, it is imperative to study the consequences of drought on various sectors linked with human wellbeing. With this background, the present study aims to analyze various impacts of drought on ecosystems, environment and communities. Based on the review of information, the study further explores solutions for management of drought in India.

Keywords: *drought, impacts, agriculture, environment, natural disaster, drought management*

Cite This Article: Chandra Prakash Kala, "Environmental and Socioeconomic Impacts of Drought in India: Lessons for Drought Management." *Applied Ecology and Environmental Sciences*, vol. 5, no. 2 (2017): 43-48. doi: 10.12691/aees-5-2-3.

1. Introduction

The rainfall records reveal that severe droughts in India have been accompanied by El Niño events [1]. The strength of the South Asian monsoon that determines the rainfall in India, however, varies due to changes in internal boundary conditions, such as increasing tropical sea surface temperature and variations in Eurasian snow cover linking with the El Niño-Southern oscillation [2]. Despite western disturbances and regional influences of Himalayas on the climate, in India, the drought is generally monitored from the onset and the withdrawal of the southwest monsoon. The fact is that impacts of drought are unprecedented. The history indicates that in 1792 at least 600,000 people died in just one region of northern India due to severe drought [2].

There were 10 drought years during 1950-1990. Since 2000, there have been six drought years: 2002, 2004, 2009, 2014, 2015 and 2016. At present, the drought has become so prominent in India that Cherrapunji, one of the world's highest rainfall areas in north east of India having over 11,000 mm of rainfall, is considered facing drought like situation for about nine months of the year [3]. The increase in total dry days, prolonged dry spells, and decreasing light precipitation days are the causes of increasing drought risk in India. A quantitative analysis of information deciphers that there is 49% increase in prolonged dry spells and 33% increase in total dry days in India [4].

Insufficient precipitation, high evapo-transpiration and over-exploitation of water resources and/or combination of these parameters lead to severe water scarcity during

drought [5]. The frequency of drought is expected to be higher in the coming decades during 2020-2050 [6]. Most of the agriculture land in India being rainfed it is heavily dependent on climate and monsoon rainfall for yield. About 68% of India's cultivable area is estimated vulnerable to drought years [3]. The ground-water recharge is reduced due to continuous spell of poor rainfall and high temperature in successive years, which finally lead to severe drought in many parts of India [5]. Despite variability in rainfall for past years, the poor management of water resources and agriculture has also enhanced the impacts of drought.

In 2016, about 330 million people spread across 10 states were affected by drought in India after two consecutive years of weak monsoons [7]. About 163 million children were exposed to this calamity as their life was on stake to various risks like malnutrition, unhygienic conditions, dehydration due to shortage of drinking water, and unavailability of other social well beings [8]. The severe water shortage made to suffer farmers for their crop losses. There was also shortage of drinking water to some communities. The agriculture sector being heavily dependent on water sources it is affected severely due to drought. However, the impacts of drought are not restricted to the agriculture sector alone but they radiate to other sectors, as well. The forest and environment sectors do suffer from drought along with tourism and energy. The social sector is also affected in terms of trends in agricultural commodity prices, coping pattern, livestock holding capacity, flow in rural-urban migration and other measures of wellbeing. Since drought has widespread impacts on ecosystem, environment, economics and social conditions, it is imperative to review consequences of droughts on these important parameters of human survival.

With this background, the present study aims to analyze various impacts of drought on environment, economy and society, especially with reference to the drought year of 2016 in India. Based on the review of information and past experiences, the study further explores solutions for management of drought in India.

2. Environmental Impacts

Drought affects various components of ecosystems and environment. The availability of water level in the reservoirs, amount of rainfall, soil moisture and ground water depths are some of the environmental indicators of drought [3]. Drought does not only reduce water quantity in the wetland areas (e.g., lakes, rivers and ponds) and groundwater table but also reduces soil moisture contents. Biodiversity depends on various forms of water, including moisture in soil and atmosphere, for their survival. There may be permanent and temporal impacts on biodiversity depending on the duration, intensity and scale of drought. Reduction in water may alter the food supply to different life forms, which may subsequently alter the food web. Animals, especially wildlife, may become susceptible to diseases due to shortage of water and so that the foodstuff. There may be change in distribution of species due to short supply of water [9]. Species which have low population size and narrow range of distribution further decline in their number due to stressful climatic conditions [10]. Shrinking of wetlands may decline the aquatic flora and fauna. At the same time, increase in forest fires due to increasing temperature and low humidity may decline the forest and wildlife species.

There are ample examples, which approve the adverse impacts of drought on wildlife species. For instance, peacock, the national bird of India, reels under threat due to drought in Central India. Over 50 peacocks in 2013 and 16 peacocks in 2016 were died in Morena district of Madhya Pradesh during summer drought. Besides, there are reports, which claim loss of wild animals, including amphibian [11] and avifauna [12], due to drought. The poachers also take undue advantages of such adverse situations. Wild animals frequently visit limited number of waterholes during drought period. Poachers spread poison in such waterholes to trap the wildlife. Many waterholes also get dried in the jungles, which compel wildlife to move the nearby village water bodies where they become easy prey to the poachers.

The Himalayas in the north of India is not only a major source of water but also regulates the climate of India. Being a water tower which endows with number of glaciers, it functions as a unique drought-resilient entity by creating regional buffer against drought [13]. The Himalayan glaciers provide summer melt-water to rivers and aquifers. After melting away of seasonal snowpack, most glacial melt occurs in summer, which increases in drought summers. Increase in rate of glacial melt reduces the size of glaciers and so that the availability of water to the river basins over the years [14, 15]. Reduction in water may trigger number of risks to the survival of human populations.

Drought impacts the groundwater level, and frequent droughts compel farmers and other community groups to

extract aquifer, which deplete the groundwater table. Depleting groundwater further leads to ecological damage such as land subsidence and loss of springs and wetlands [16,17]. In Aravalli region of Rajasthan, the aquifer-stress shifts its position time to time, and in comparison to hydrological stress the vegetative stress is slower to begin but quicker to withdraw during drought [5]. Generally, the vegetation maintains normal health for longer duration as they are acclimatized to water deficit environment.

Change in environmental ingredients at one locality may affect the environment of other locality. There are records of abrupt elevation in dust and chloride levels during drought conditions [2]. The air pollution generated at one part of the world due to number of reasons affects the life of people on another. Sulfate aerosols offset some global warming by cooling atmosphere but at the same time they also contribute to drought in many regions [18]. There are reports which claim that air pollution from Europe contributes to drought in India [19]. The increase in temperature and subsequent loss of water is catastrophic to almost all the natural ecosystems, especially the sensitive ecosystems and so that the sensitive crops and species.

3. Social Impacts

The drought brings food crisis, which has number of social and economic ramifications. It affects people's health and safety besides inviting conflicts on the use of water resources. The high dust molecules density in the atmosphere due to prolonged drought may finally affect the people's respiratory system and may create allergy. The dried condition may give more space for forest fire, which threaten the people's life living in the forests and forest fringes. The anticipation and depression about the loss of economy due to drought may further create conflicts and disturb the peace of mind. There are reports which claim that people migrate from village to towns and cities in search of livelihood, which further aggravate the problems of employment. In a village of Damoh district of Madhya Pradesh 600 people out of 800 prefer to migrate to nearby Jabalpur city and district headquarter due to drying up of their water sources [20]. In Shivpuri town of the same state, out of 450 bore wells of Municipal Corporation 300 are dried during the drought of 2016 because fall of water table to 750 to 1000 feet. Water tankers, therefore, remained the major means to supply water for 2.5 lakh people of Shivpuri [21]. The dependency on water tankers have made people to wait most of time for water, which created ruckus among the people and also consumed their time. Besides, they consumed the bore well water without filtering which made them susceptible for diseases.

Since the traditional farming is interlinked with animal husbandry in India, drought reduces availability of fodder and so that the livestock. In Vangayan village, one of the drought affected villages in Bundelkhand region, 500 cattle died in 2016 due to fodder and water scarcity. In April 2016, the cost of fodder had increased from rupees 2000 to 8000 per trolley [22]. The area had become vulnerable to diseases due to several carcasses laid in the open field. In Shivpuri district, the villagers sold out their livestock at through away prices and whoever could not

manage to sell many of them left their livestock in the jungles [23]. Reducing livestock declines milk production and so that the people depend on earning from the milk. Reducing income from agriculture and milk may influence the people's purchasing power.

The widespread malnutrition due to low production during drought makes people vulnerable to diseases. Drought may also force people to sell their property in return of saving life. The weaker section of the society is more prone to suffer from the adverse impacts of drought because they do not have enough resources or stock to sustain during drought. At the same time, the rich people may exploit the poor people by taking undue advantage of prevailing drought and its aftermath. There are number of cases where farmers commit suicides due to extreme situations in India. In some drought-hit villages the girls even married off at the age below 15 due to scarcity of resources to feed her [24]. Apart from creating physical and mental stress, the reduced supply of water may create social conflicts within the community, which may become irreparable. People may be forced to reduce their daily water use, which make them to feel that they are in the low priority of the government.

In India, the cast system in communities still continues, which sometime invites social problems in the forms of untouchability. During extreme drought when every drop of water becomes precious for saving life, getting water sometime becomes a difficult task to the impoverished backward cast people due to social hierarchy. There are reports from some villages of Bundelkhand where some upper cast members created barricades around their private wells so that the backward villagers such as Kevats could not enter their territory for water collection [25].

The disputes over river water sharing between States peak during drought or summer months. For example, in southern India, the issues of Kaveri river water sharing between Tamil Nadu and Karnataka increases several folds during drought years. Many districts of Karnataka fall along the Kaveri river basin have been suffering from drought for past 3 consecutive years. In 2016 alone, out of 30 districts of Karnataka 20 districts were affected fully and 7 districts were affected partially by drought [26]. At the same time, Tamil Nadu also depends on Kaveri water hence expects Karnataka to release Kaveri water. This has surfaced disputes between the States hence the Supreme Court of India intervenes on many occasions to settle the disputes.

4. Economic Impacts

Drought impacts economic conditions of nations at local to global scale. It may affect the people not only living in the drought-stricken areas but also those who live outside the drought areas as they may also depend on drought stricken areas for their livelihood. The agriculture sector is most influenced by drought. About 43% of geographical area of India is utilized for agriculture sector, which is known to contribute, at present, about 17% to the National Gross Domestic Product (GDP) [27]. In 1950, the share of agriculture in India's GDP was nearly 52%. There are many causes for such a sharp decline in agriculture share in India's GDP, of which insufficient irrigation

facility and major dependency on south eastern monsoon are some of the major factors. Majority of people in India still live in rural areas, where agriculture is one of the major professions for livelihood. Around 70% populations depend on agriculture for their livelihood, either directly or indirectly in rural India. However, they have rain fed agriculture system, which is highly affected by drought. About 70% of agricultural crop production is affected by moderate drought. The direct impact of drought is reported in India's GDP as a study suggests that there is decline in GDP due to major dip in the food-grain production, which corresponds to large deficit in monsoon rainfall [28].

The impacts of drought are not uniform across India rather they change according to the geographical conditions and status of the society. Changing farming patterns in drought-prone areas are also subjected to increase adverse effects of drought. Many farmers in Marathwada region of Maharashtra have replaced certain drought resistant crops such as jowar (sorghum) and chana (chickpea) by farming sugarcane, which requires intensive water. Sugarcane needs 25 million litres of water per ha whereas traditionally grown crops such as moong and maize require 3.5 to 7 million litres water per ha [29]. The continuous expansion of sugarcane production area has created shortage of water in the region despite recommending ban on sugarcane production in drought prone areas by the Maharashtra Water and Irrigation Commission in 1999 [29].

The sugar industry in Maharashtra has recorded the lower sugarcane crushing and sugar production in 2016-17 in comparison to last 10 years, which is attributed to the drought. The area under the sugarcane has reduced to 6.3 lakhs ha in 2015-16 from 10.3 lakhs ha in 2014-15 [30]. The sugarcane crop sown in 2015 is harvested at the end of 2016 as it takes about one and half year to mature. Farmers receive about rupees 2000 from sale of one tonne of sugarcane. Shrinking of sugarcane farming has accrued heavy losses to the farmers as well as sugarcane industry. Similarly, the production of pulses in drought year of 2016 was estimated about 12% lower than the non-drought year of 2013-14 in India [31]. As per an estimate, the demand of pulses was around 23.6 million tonnes in 2016 whereas the production was around 17 million tonnes only [32]. Coincidentally, the United Nations had declared 2016 as the International Year of Pulses. The low production of pulses had increased the prices of pulses as the average price of urad (black gram) in May 2016 had gone up to rupees 170 per kg, for arhar (red gram) rupees 140 per kg and for chana it shot up to rupees 70 per kg. A study of the Associated Chambers of Commerce and Industry of India claims that the 2016 drought impacts the Indian economy at least by US\$ 100 billion (www.assochem.org).

Table 1. Number of farmers committed suicides in India during 2013-2015 (Source: National Crime Records Bureau, Ministry of Home Affairs <http://ncrb.nic.in/>)

Years	Number of farmers committed suicides
2013	11772
2014	12360
2015	12602

The loss of economy from agriculture sector due to frequent droughts has forced farmers across the country to take harsh steps, such as committing suicides. In 2015 alone, due to several reasons including crop failure and natural calamities a total of 12,602 farmers committed suicides in India of which 8007 were cultivators and 4595 were agricultural labourers (Table 1). Further, the drought reduces employment opportunities in agriculture sector, which at present, provides employment to 57% of the Indian work force [33]. Since the agriculture sector plays a vital role in the Indian economy, its performance is crucial for inclusive growth. Insufficient drinking water and forage for livestock affect the economy of their owners. Besides agriculture, the tourism sector is also affected by drought, which provides livelihood, employment opportunities and economic growth. The businesses associated with water sports attract tourists who enjoy streams, lakes, and other water bodies undergo returns deficit due to unavailability or reduced amount of water. The increase in food prices due to short supply during drought also reduce the flow of tourists and so that the economy.

The low availability of water during drought may force farmers to spend on arranging water and creating water sources for their crops and livestock. The companies that sell agriculture tools to farmers may also suffer because of low purchasing powers of farmers due to low crop yield. People, who depend on forest resources, including non timber forest produce, may not get such resources in order due to shortage of water for quality production of forest produce during drought years. The energy sector, especially the hydropower projects, may not produce the sufficient energy, as required, due to shortage of water. This may affect their consumers, as well, due to increase in cost of energy.

Besides agriculture industry, there are reports on adverse impacts of manufacturing products by other industries, as well. During drought period, water cuts begin due to shortage of water. To meet the requirement, industries begin to hire water tankers, but it increases the cost of water supply. In Maharashtra, some of the textile manufactures could not cope up with the increasing cost of water and hence they shut down the unit whenever the Maharashtra Industrial Development Corporation could not supply enough water [34]. Three categories of industries such as textiles, food products and beverages, and paper and paper products, suffer the most during the drought because of short supply of water. Besides, the sports industry was also in trouble due to drought as in 2016 the High Court of Maharashtra had asked the organizers of Indian Premier League to shift all the cricket matches scheduled in May out of the State due to disastrous water crisis [35].

Most of the States in the country demand funds from the Central Government whenever any natural or man-made disaster hits the country as the country's administrative structure, which includes the Federal and States, allow States for such demands. In 2016, many States including Maharashtra, Uttar Pradesh and Karnataka, therefore, sought increased funding under several central schemes. Accordingly, for improving the supply of drinking water and fodder Karnataka sought for rupees 12,272 Crore additional funds from the central government in 2016 as

the State was reeling under severe drought [36]. Water being the critical life saving necessity, the central government, therefore, allocated rupees 820 Crore to the States from Union budget as a first tranche in April 2016 for making arrangements at least for drinking water [37].

5. Drought Management

Unlike other disasters, drought being slow in speed gives sufficient time to act on warnings. To combat the negative effects of drought, two pronged strategies may be required. One which is short term and needs to be tackled immediately and second one is to initiate steps for establishing permanent solutions in long run. India has been reeling under severe droughts frequently and recently it has faced two consecutive droughts in 2015 and 2016. At the same time, during monsoon much of the drought affected areas experience heavy flooding [38]. Storing such excess water can help in mitigating adverse impacts of drought. Besides rain water harvesting and developing technically advanced structures for storing water, the excess water if stored in the aquifers it can be accessed via tube wells during the dry spells. The natural water bodies such as lakes, rivers, ponds and other wetland areas need to be conserved. Also there is a need to reserve water for drinking and manage water supply to industries. The farmers should be made aware in advance about the drought and anticipation of drought like situation so that they may consider sowing crops that require less water. A proper monitoring of local and regional climate is required to generate such information for onward transmission to farmers.

Different State Governments have been trying to cope up with the adverse effects of drought. Though, there are provisions for subsidies to the farmers, there is a need to mitigate the adverse impacts of drought by enhancing the share of irrigated land area. In 2016, when the country was facing severe drought, the crop production had increased in dry and arid region of Jaisalmer in Rajasthan due to continuous flow of water through Indira Gandhi Canal [39]. However, about 84% of available water in India is consumed for irrigation, which is very high in comparison to neighboring country China for production of one unit of major food crop [40]. Expanding drip irrigation facilities may be useful for proper utilization of available water. The drip irrigation may save 35-40% water as opposed to flood irrigation [41]. Since every drop of water is important, water management is an utmost significance in order to avoid water crisis during drought. The water leakages must be plugged in. Investment in rainwater harvesting, revival of traditional water conservation structures, and developing water conserving irrigation techniques in drought prone areas can help to combat the adverse impacts of drought [42]. Developing drought resistant crop varieties is also the need of hour to tackle the ever growing problems during drought.

Interlinking of rivers may be one of the solutions to deal with the adverse impacts of drought. One such proposal is to interlink the Ken and Betwa rivers flowing through some arid parts of Madhya Pradesh and Uttar Pradesh. This interlinking of rivers will help out the farmers of Bundelkhand region of central India, which

experiences severe impacts of drought repeatedly. Apart from river-linking, a water bank can be formed by linking private and public wells for use of everyone in the village. A village name Dhavadshi in Satara district of drought prone Maharashtra has come out with a model on its own through which 30 wells have been connected. Water is lifted using electric motors from one well and taken to another through pipes, and whenever requires it is circulated across patches of farms [43].

Collective efforts of the community may help to combat the adverse effects of drought. For instance, in Damoh village of Madhya Pradesh, which was facing severe drought in 2016, the villagers voluntarily cleared the debris and removed weeds and dug a village well further to strike water. An almost dying river in Latur was revived with the help of villagers, corporate, and civil society groups by removing the excess silt deposited in the river [44]. In the similar approach, the State Government of Telangana launched a project involving about 45,000 defunct water tanks to be revived, which were built about hundreds of years ago, at the cost of approximately rupees 20,000 Crore [45]. It is perceived that once this network of water tanks is restored, it will help in combating the adverse effects of drought in Telangana.

Drought management is a multidisciplinary area, which needs input from hydrologists, agriculturists, farmers, climatologists, soil scientists, engineers, social scientists, economists, etc. Various droughts related issues need to be sorted out at the Federal level of the country in consultation with different States because the impacts of drought are widespread across the States. The Mahatma Gandhi National Rural Guarantee Scheme and Corporate Social Responsibility Funds may be utilized to draw plans and execute relief operations in drought prone areas. Since the prices of commodities increase during the drought, attempts should be made to exempt taxes such as VAT and mandi fees on crops as a relief measures. Further to check the prices, the illegal hoarders of pulses, cereals, vegetables etc should be identified and punished as per the law of the land.

Often the Governments arrange to supply water through tankers and railways to the drought affected areas. However, many villages are not connected with railways hence they remain in disadvantage position as they cannot connect to such reliefs during drought. Developing road and railway network may help out such villagers. Lack of other facilities such as less availability and unavailability of electricity and diesel enhances the losses during drought as the farmers cannot lift underground water and channelize it to their farmlands. Therefore, proper supply of electricity should be ensured to reduce the adverse effects of drought.

Since the adverse impacts of drought often force farmers to commit suicides, there is a need to tackle this issue by consulting psychiatrists and counseling farmers constantly during such adverse situations. Besides, the farmers may be encouraged for group farming and also for adopting side businesses such as poultry and bee keeping where cases of committing suicides are high. Farmers should raise timber trees on the boundary of the farms. The traditional livelihood system needs to be revived which revolved around multiple activities comprising of agriculture, animal husbandry, agro-forestry, horticulture,

and collection of NTFPs in order to reduce the risks of natural disasters.

6. Conclusion

The Indian sub-continent has been facing the adversities of frequent drought for past couple of decades and recently in 2016 it reels under severe drought situation. Apart from over-exploitation of water resources, the increase in total dry days, prolonged dry spells, high evapo-transpiration, and decreasing light precipitation days are the major causes of increasing drought risk in India. Most of the agriculture land being rainfed, its productivity is heavily dependent on climate and monsoon rainfall. However, the impacts of drought are not restricted to the agriculture sector alone but they radiate to other sectors, including forestry, tourism, energy, health, environment, marketing and economics. In the developing country like India, the drought brings food crisis, affects people's health, invites social conflicts, and sometime compels farmers to take harsh steps such as committing suicides. Changing farming patterns in drought-prone areas are also subjected to increase adverse effects of drought, as observed in western India where certain drought resistant crops have been replaced by farming sugarcane, which requires intensive water. To combat the adversities of drought strategies at short and long term basis need to be planned and executed properly. Besides rain water harvesting, revival of traditional water conservation structures and development of technically advanced structures for water storage, the excess water during monsoon if stored in the aquifers it can be used via tube wells during the dry spells. Interlinking of rivers, crop diversification and development of drought resistant crop varieties can help to mitigate the adverse impacts of drought. Though, there are provisions for subsidies to the farmers in India, there is a need to increase the share of irrigated land area, especially by expanding drip irrigation facilities for proper utilization of available water.

Acknowledgements

Author thanks Dr. Tejinder Singh, Director, Indian Institute of Forest Management, Bhopal for intellectual support and encouragement.

References

- [1] Kumar KK, Rajagopalan B, Hoerling M, Bates G and Cane M. 2006. Unraveling the Mystery of Indian Monsoon Failure During El Niño. *Science*, 314 (5796): 115-119.
- [2] Thompson, L.G., Yao, T., Mosley-Thompson, E., Davis, M. E., Henderson, K. A. and Lin, P.N. 2000. A high-resolution millennial record of the South Asian monsoon from Himalayan ice cores. *Science*, 289 (5486): 1916-1919.
- [3] NIDM 2010. National Disaster Management Guidelines: Management of Drought. National Disaster Management Authority, Government of India, New Delhi.
- [4] Mishra, A. and Liu, S.C. 2014. Changes in precipitation pattern and risk of drought over India in the context of global warming. *Journal of Geophysical Research: Atmospheres*, 119 (13), 7833-7841.

- [5] Bhuiyan, C., Singh, R.P. and Kogan, F.N. 2006. Monitoring drought dynamics in the Aravalli region (India) using different indices based on ground and remote sensing data. *International Journal of Applied Earth Observation and Geoinformation*, 8(4): 289-302.
- [6] Kulkarni, A., Gadgil, S., and Patwardhan, S. 2016. Monsoon variability, the 2015 Marathwada drought and rainfed agriculture. *Current Science*, 111 (7), 1182-1193.
- [7] Choudhary, A.A. 2016. Over 25% of India's population hit by drought, Centre tells SC. *Times of India*, April 20, 2016.
- [8] Satyarthi, K. 2016. Save the children. *Times of India*, May 16, 2016.
- [9] Kala, C.P. and Mathur, V.B. 2002. Patterns of plant species distribution in the trans-Himalayan region of Ladakh, India. *Journal of Vegetation Science*, 13(6): 751-754.
- [10] Kala, C.P. and Silori, C.S. 2013. Biodiversity, Communities and Climate Change. The Energy and Resources Institute, New Delhi.
- [11] Daszak, P., Scott, D. E., Kilpatrick, A. M., Faggioni, C., Gibbons, J. W. and Porter, D. 2005. Amphibian population declines at Savannah River site are linked to climate, not chytridiomycosis. *Ecology*, 86(12): 3232-3237.
- [12] George, T. L., Fowler, A. C., Knight, R. L. and McEwen, L. C. 1992. Impacts of a severe drought on grassland birds in western North Dakota. *Ecological Applications*, 2(3): 275-284.
- [13] Pritchard, H.D. 2017. Asia's glaciers are a regionally important buffer against drought. *Nature*, 545: 169-174.
- [14] Kala, C.P. 2011. Save Ganga campaign and hydroelectric projects in Uttarakhand. *Current Science*, 101 (5): 596.
- [15] Kala, C.P. 2014. Deluge, disaster and development in Uttarakhand Himalayan region of India: Challenges and lessons for disaster management. *International Journal of Disaster Risk Reduction*, 8: 143-152.
- [16] Aldaya, M.M. 2017. Eating ourselves dry. *Nature*, 543: 633-634.
- [17] Dalin, C., Wada, Y., Kastner, T., and Puma, M.J. 2017. Groundwater depletion embedded in international food trade. *Nature*, 543: 700-704.
- [18] Levey, S. 2017. Earth day: Imperial event brings together experts to tackle air pollution. Imperial College London, 21 April 2017.
- [19] TOI, 2017. Europe pollution behind India drought. *Times of India*, April 22, 2017.
- [20] Saxena, D. 2017. Villagers prefer migration over 8 km walk for water. *Times of India*, April 15, 2017.
- [21] Gupta, S. 2016. Parched Shivpuri turns 'tanker town'. *Times of India*, April 25, 2016.
- [22] Sexena, D. 2016. Parched Bundelkhand: dead cattle lie sprawled on ground. *Times of India*, April 27, 2016.
- [23] Gupta, S. 2016. Thirsty cattle sold, dumped in forest. *Times of India*, April 25, 2016.
- [24] Jadhav, R. 2016. Drought shapes fate: Maha minors being married off. *Times of India*, May 3, 2016.
- [25] Sexena, D. 2016. Drought apartheid: Caste-aways bathe and reuse water to stay afloat. *Times of India*, April 25, 2016.
- [26] KSNDMC 2016. Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Bangalore, Karnataka. <https://www.ksndmc.org>.
- [27] Prasanna, V. 2014. Impact of monsoon rainfall on the total foodgrain yield over India. *J. Earth Syst. Sci.*, 123 (5), 1129-1145.
- [28] Gadgil, S. and Gadgil, S. 2006. The Indian Monsoon, GDP and Agriculture. *Economic and Political Weekly*, 41 (47): 4887-4895.
- [29] Jamwal, N. 2016. Marathwada's dry story. *Down To Earth*, 24 (24): 8-13.
- [30] Jain, B. 2017. 2015 drought effect: sugar yield sees worst fall in 10 yrs, prices set to rise. *Times of India*, April 3, 2017.
- [31] Verma, S. 2016. Output drought jacks up pulse prices. *Times of India*, April 26, 2016.
- [32] TOI, 2016. Centre to states: cut taxes to tame pulse prices. *Times of India*, May 22, 2016.
- [33] Siddiqui, K. 2015. Agrarian Crisis and Transformation in India. *Journal of Economics and Political Economy*, 2 (1): 3-22.
- [34] Sinha, P. 2016. Water shortage to hurt industry output. *Times of India*, April 14, 2016.
- [35] Rao, K.S. 2016. A logistical nightmare now for IPL bosses. *Times of India*, April 14, 2016.
- [36] TOI, 2016. CMs of 3 drought hit states meet PM, seek more funds. *Times of India*, May 5, 2016.
- [37] TOI, 2016. Centre okas release of Rs 820 cr for drinking water in rural areas. *Times of India*, April 12, 2016.
- [38] Kala, C.P. 2014. The degraded and disaster-prone Himalayan ecosystem calls for management interventions. *International Journal of Disaster Risk Reduction*, 10: 399-401.
- [39] Bhatia, V. 2016. Canal charisma: Bumper crop in dry Jaisalmer. *Times of India*, April 24, 2016.
- [40] Kant, A. 2016. India's great drying out. *Times of India*, September 21, 2016.
- [41] Amarnath, G. and Clarke, J. 2016. Uncertain water: Dealing with increasing floods and droughts demands new thinking and new technologies. *Times of India*, April 30, 2016.
- [42] Kala, R. and Kala, C.P. 2006. Indigenous water conservation technology of Sumari village, Uttarakhand. *Indian Journal of Traditional Knowledge*, 5(3): 394-396.
- [43] Jadhav, R. 2015. Farmers join hands to link wells, form water bank in parched Satara. *Times of India*, July 2, 2015.
- [44] Rizwanullah, S. 2016. In dry Latur, villagers revive a dead river. *Times of India*, May 11, 2016.
- [45] Gala, D. 2016. Recharging Telangana ground up: Mission Kakatiya is bringing back life giving water to the state. *Times of India*, May 31, 2016.