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Role of ICTs in improving drought scenario management in India

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Abstract

Drought is a natural phenomenon that affects social, economic and environmental sectors. It is caused due to low or no rainfall in the specific region and for some duration of time. Reduced soil moisture and ground water level are the other causes for drought. Based on its intensity, drought has impacts on various sectors like agriculture, transportation, forest fire, environment and many more. Agriculture is the major sector being affected by drought resulting in low crop production and having great detriment to economy of the country. In this paper, an attempt is made to study the different causes and effects of drought, their impact on agricultural sector, various strategies for drought monitoring, prevention and management keeping the focus on Indian Agricultural Sector. This study examines the extent of use of Information and Communication Technology (ICT) for drought assessment, prediction, preparedness and management scenario in India. The paper aims in portraying how the application of ICT in drought events is helpful in managing drought and thus helpful for researchers and farmers as well.

Keywords-Agricultural drought, assessment, monitoring, management, ICT

Introduction

Drought is a complex, natural, slow-onset hazard which affects large geographical area for long period of time. It is a condition of dry weather which results in hydrological imbalance. Drought has serious impacts on agricultural, economic, social and environmental sectors (Gupta et al. 2011, Jeyaseelan 2003). According to India Meteorological Department (IMD), drought situation is when the rainfall is less than 25% of the normal rainfall in any area. The drought intensity is based on the rainfall. It is classified as moderate drought, if the rainfall deficiency is between 26 to 50% and the drought is severe if the rainfall deficiency is more than 50% (Shewale 2005). Areas with drought probability more than 20% is said to be chronically drought affected, droughts in such areas occur at least once in 4 years. Drought probability between 10 to 20% is frequently drought prone region. These areas expect drought once in 6 to 10 years. And those with probability of less than 10% are least drought affected areas (Shewale 2005).

As drought affects large geographical area, its conditions are spread all over the world covering North Africa, Mid-East, West Asian Countries, India, China, North, Central and South America. Drought has impacts on transportation, tourism, energy sectors, forest fires and environment in many Nations all over the world (Kanda 2010). Droughts has frequent occurrence in India (Nandakumar 2009).

Drought prediction, preparedness and management phases may lack in accuracy and timeliness. Application of modern computational technologies and ICT in drought monitoring, prevention

and management is the better approach to overcome the same (Jiwan 2012). This study was an attempt to examine drought causes and effects of droughts, overall impact on agricultural sector, use of ICT for various aspects of drought conditions and management strategies for the drought scenario in India.

Drought: Causes and Impacts

Drought occurrence is due to the influence of number of factors like low and uneven distribution of rainfall, duration of rainfall deficiency, loss of soil moisture, depletion of ground water level. Drought conditions remain for extended period when rainfall deficiency occurs for consecutive years (Kanda 2010, Kumar 1998, Nandakumar 2009). Drought is classified as (i) Meteorological Drought: It is deficiency of precipitation from normal level. (ii) Hydrological Drought: It is the condition when the surface and ground water level falls below normal. (iii) Agricultural Drought: It occurs when the soil moisture and rainfall are not adequate for crop growth (Nandakumar 2009, Roy et al. 2007). Also, based on the time of onset, drought is classified as early season, mid season and late season (Kanda 2010). A permanent drought is caused due to extremely dry climate and the agriculture is possible only by irrigation; the seasonal drought is the one where the crop durations is not synchronized with the rainy season, the contingent drought's occurrence is irregular and the invisible drought occurs in humid regions in presence of frequent rainfall (Karunakaran 2008).

Droughts are also characterized based on various indices like rainfall, soil moisture, temperature, evapotranspiration and many more (Nandakumar 2009, Roy 2011). These indices provide the extent and severity of droughts in the particular region. Based on the indices, different drought indicators are being developed. Some of them are: (i) Aridity anomaly index: It is based on rainfall, evapotranspiration and soil moisture. It is used to assess the moisture stress over the crops. (ii) Standardized Precipitation Index: It is based on precipitation and is useful in agricultural and hydrological applications. (iii) Palmer Drought Severity Index: It indicates moisture conditions. (iv) Crop Moisture Index: It is the degree to which the crop moisture requirements are met. (v) Surface Water Supply Index: It gives the measure of water availability over the selected region. (vi) Normalized Difference Vegetation Index: It shows effect of climate on vegetation (Nandakumar 2009, Roy 2011).

As drought conditions remain for some time period, it leaves an impact on the affected area. There are many direct and indirect impacts of drought on social, economical and environmental sectors over large spatial area resulting in reduction of agricultural production and damage to wild life as well as harm to economy and society (Gupta et al. 2011, Jeyaseelan 2003, Nandakumar 2009). The drought intensity is measured by monitoring agricultural sectors, economic conditions, water levels, internal and external conflicts (Kanda 2010, Roy et al. 2007).

Modern technologies such as wireless sensor networks have proved to be helpful for predicting drought severity as they can assist in preparing for the future impact of drought occurrence. Use of traditional practices for severity prediction is complex due to continuous change in natural parameters. Wireless sensor network monitor drought parameters constantly and provides this information to decision makers and users (Dappin 2009). Remote sensing techniques along with Geographic Information Systems (GIS) may also be useful for drought impact assessment. They have been used for the assessment of land use, stressed conditions, demographics and

infrastructure of affected areas and the agricultural yield. High resolution satellites sensors form LANDSAT, SPOT, IRS, etc are being used for this purpose. Geostationary satellites like GEOS, METEOSAT, GMS, INSAT are useful for monitoring and prediction of weather and climatic conditions for drought events (Jeyaseelan 2003).

Impact of Drought on Agriculture

Agriculture is the major sector on which the Indian economy is dependent. 70% of the Indian population is directly or indirectly dependent on agriculture for their livelihood (Roy et al. 2011). More than 55% farmers in India depend on rainfall for raising crops (Aijaz 2013). Late onset, prolonged break and early withdrawal of the monsoon may result in frequent drought occurrence which affects the crop production. There is direct impact of drought on crop area, crop production and crop employment. About two third of the geographical area in India receives low rainfall and has uneven rainfall distribution (Roy et al. 2011). Thus, inspite of available technologies for agricultural activities, Indian agricultural is affected on large scale due to drought conditions. Agricultural drought conditions are characterized by the parameters like rainfall, temperature, crop sown area, crop quality and crop yield (Roy et al. 2011).

Mainly kharif crops suffer huge loss due to less or no rainfall. Delay in monsoon onset, break in mid-season also affects on crop sowing as well as crop yield (Aijaz 2013). Frequent occurrence of drought results in low production. Nearly all developing countries are agrarian and depend on seasonal rainfall and climatic conditions for cropping. Uneven rainfall pattern results in drought. On an average, severe drought occurs once in five years and thus affects the agricultural system. The more and more water requirement for agriculture and the frequently occurring droughts in drought prone areas is the major problem (Singh 2013).

Drought Scenarios in India

Around 68% of the area in India is drought prone (Nandakumar 2009). Droughts are classified based on timing of rainfall occurrence in India (June to September). About 33% of the total area is chronically drought affected and 35% is normal drought prone areas (Nandakumar 2009, Roy et al. 2011). IMD declares the type of drought based on rainfall conditions. Table 1 gives brief information of the classification based on rainfall condition.

Table 1. Drought classification based on rainfall condition(Kanda 2010)

Drought Type	Rainfall Condition
Drought week	Rainfall is less than normal
Agricultural Drought	Four consecutive drought weeks
Seasonal Drought	Seasonal rainfall is less than normal
Drought Year	Annual rainfall is less than 20 % of the normal
Severe Drought Year	Annual rainfall is less than 25-40% of the normal

Till now, India has experienced twenty four large scale droughts in 1891, 1896, 1899,1905, 1911, 1915, 1918, 1920, 1941, 1951, 1965, 1966, 1972, 1974, 1979, 1982, 1986, 1987,1988, 1999, 2000, 2002, 2009 and 2012 with increasing frequencies during the periods1891-1920, 1965-1990 and 1999-2012 (Singh 2013).

Remote sensing techniques along with the use of sensors make it possible to obtain information over large area. Computer technologies and GIS help to process this information gained from remote sensing and prepare maps. Satellite observations prove useful to obtain maps (Jeyaseelan 2003). Table 2 gives the list of available satellites in India for drought monitoring and assessment.

Table 2. Satellites for Monitoring and Assessing Drought in India (Jiwan 2012)

Satellite	Sensor	Application
IRS-1C	WIFS	Agricultural Drought Assessment
IRS-1D	WIFS	Agricultural Drought Assessment
IRS-P5	CartoSat-1	Cartography
IRS-P6	ResouceSat-1 (AWiFS)	Natural resources census
Landsat-5	Thematic Mapper (TM)	Soil moisture and biomass survey
Landsat-7	Enhanced thematic mapper (ETM+)	Soil moisture and biomass survey
Terra	ASTER	Vegetation census
SPOT	MSS	Natural resources Observation
ERS	Synthetic Aperture	Natural resources Observation
Terra/Aqua	MODIS	Drought assessment
SPOT	VGT	Drought assessment
NOAA	AVHRR	Agri-drought assessment NADAMS projects

Drought Management

Drought can be managed into three phases i.e. preparedness, prevention and mitigation. First is preparedness phase which consists of identification of drought prone area and prediction of drought and its intensity in that area. This phase takes place before the occurrence of drought. The drought prone area can be identified based on historical data of various drought indicators such as rainfall, temperature, crop yield and many more (Jeyaseelan 2003). Second is prevention phase consisting of drought monitoring and early warning. Drought monitoring is necessary in order to get pre-warning of droughts. The major factor to be monitored is keeping track of rainfall in the target region and comparing it with previous rainfall history. Along with rainfall, evapotranspiration, and soil moisture are the other factors to be monitored (Jeyaseelan 2003). The early warning systems are designed to keep track of various indicators (agricultural, climatic, hydrological) in order to predict drought conditions. The effective early warning system should have all the meteorological, hydrological and agricultural information in order to address various indices (Gupta et al. 2011). Third is mitigation phase. Drought can be mitigated in two ways, either by following preventive measures or by using preparedness plans (Gupta et al. 2011). There are some preventive measures in the mitigation phase. Some of them are building dams and reservoirs for storing water, watershed management, cattle management, proper selection of crops for drought affected areas, applying soil conversation techniques, reducing deforestation, education and training to the people.

There are some activities in the preparedness plan as well comprising of modifying cropping patterns and introducing drought resistant crops, improvement in grazing patterns, protection of

shrubs and trees, improvement in irrigation, protection of surface water from evaporation and introduction of drop irrigation system (Gupta et al. 2011).

Drought Management Strategies in India

Government of India has many strategies to manage and overcome the drought effects. The drought management mechanism includes institutional mechanisms, employment generation, social welfare practices, support from Central and State Government and Early Warning Systems (Gupta et al. 2011). Drought management cycle is followed in India for managing droughts at various stages as shown in Figure 1.

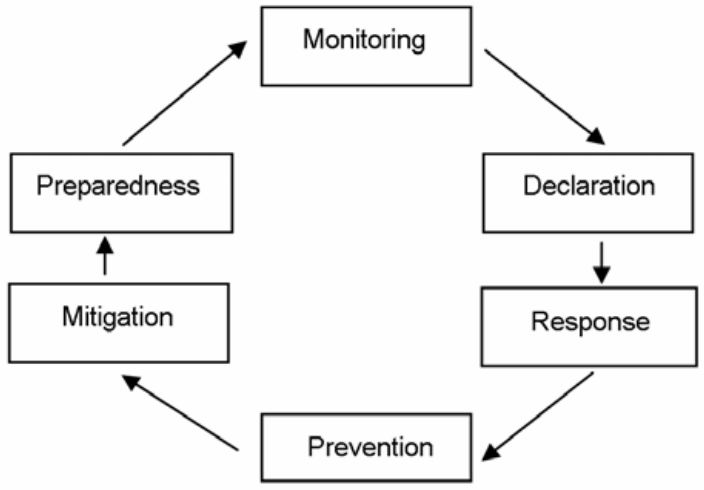

Fig. 1 Drought Management Cycle in India (Gupta et al. 2011, Sharma 2004)

Drought monitoring is the responsibility of both state and federal Governments in India. The monitoring and forecasting is carried out by IMD, which prepares aridity maps on weekly basis. It compiles weekly rainfall and precipitation at district level. Drought declaration is the responsibility of State Government. Once the drought is noticed, it is mandatory for the central government to look for the losses and claims done by states (Sharma 2004). The Department of Agriculture and Cooperation (DAC), Ministry of Agriculture (MoA) and National Institute of Disaster Management (NIDM) has the responsibility of preparing the National manual for drought management which has guidelines for drought management in India (Kanda 2010).

Drought management requires various governmental organizations and institutions to work together. Various institutions work at national as well as state level for drought management. Table 3 lists various national level institutions and their roles for drought management.

Table 3. National level institutions for drought management in India (Kanda 2010).

Sr. No.	Institution Name	Role
1.	National Disaster Management Authority (NDMA)	Responsible for laying down policies, plans and guidelines for drought management and implementation for timely and effective response to disasters. The guidelines assist the Central Ministries, Departments and States to formulate their respective drought management plans
2.	National Executive Committee (NEC)	Has administrative control of drought management. Preparation of national plan based on national policy of drought management
3.	National Disaster Response Force (NDRF)	For response on threatening disaster situation
4.	Central Government	Looks after all the measures for the purpose of drought management. It ensures that all ministries and departments are working on preparedness, prevention and mitigation of droughts
5.	National Institute for Disaster Management (NIDM)	Works on training, research, documentation and the development of a national level information database
6.	India Meteorological Department (IMD)	Responsible for the National Meteorological Service
7.	National Rainfed Area Authority (NRAA)	Addresses the issue of drought mitigation on a long-term basis
8.	India Drought Management Centre (IDMC)	Help in selecting appropriate drought mitigation and preparedness measures and methodologies

The government agencies support in drought management in India and along with the agencies there has been a good adoption of ICT and other technologies for same purpose. Both space technologies along with ICT are applied in monitoring the drought conditions, prevention from drought and mitigating the same (Jiwan 2012).

Effective management of drought is reliant on preparedness strategies. ICT is proved to be an important tool to transform information for a learning process. Information dissemination process in remote areas is carried out by using mobile phones, audio and video conferencing. Such practice is carried out in South Central India by International Crops Research Institute for the Semi Arid Tropics (ICRISAT), in order to inform the rural communities about the vulnerability of their area to drought. Drought map images with the help of satellite imagery and GIS platforms are communicated and explained to the communities so that they stay prepared for drought condition in the area (Neelam et al. 2010). This practice is best example of use of ICT for drought preparedness.

Remote sensing imageries support in identifying drought area by collection of information based on soil, water, land use pattern, crop area, etc. Remote sensing data from IRS and EOS satellites is used to create database. This data is used by Government sponsored programme like Drought

Prone Area Development Programme (DPAP) for watershed planning. IRS satellite uses LISS and PAN sensors for gaining data from natural resources and geo-satellites are used to obtain meteorological and climate data. INSAT consists of satellites for drought warning (Jiwan 2012).

ICT along with human support like watershed development, afforestation, ground water development and many more is helpful for recovery from drought conditions (Jiwan 2012). Indian Institute of Technology Bombay has developed a GIS based framework to develop drought vulnerability colored map in order to identify and understand how vulnerable the area is (Neelam et al. 2010).

Challenges in Drought Management

In order to accomplish the three phases of drought management, i.e., preparedness, prevention and mitigation, hard efforts are required. Carrying out these tasks, multiple challenges are to be faced. The major and first challenge is to identify the target and appropriate drought prone region. After the identification, it is again a difficult task to practice standard procedures for declaring a drought in specific area and on particular time. Other challenges include assessment of drought vulnerability and generation of vulnerability maps, drought proofing of chronically affected areas, development and organization of centralized database at state as well as national level for drought assessment and management, application of ICT for drought monitoring and finally, the identification of global and national practices for managing droughts (Kanda 2010).

ICTs for Drought Monitoring and Management

ICT along with other emerging technologies like remote sensing is helpful for drought monitoring and management. Use of mobile phones and Internet, for providing early warnings and drought conditions to the farmers and residents in drought areas help managing drought conditions. Audio and video conferencing is another way to provide information to remote farmers and residents of drought prone areas (Neelam et al. 2010). Radio and television are traditional media for drought like disaster management and provides one-to-many communication in low price. Fixed and mobile telephones are used to distribute the early warning information of drought conditions. Internet and email services are helpful at the time of drought like disaster (Yap 2011).

Drought can be monitored and assessed using technologies like Remote Sensing and Geographic Information System (GIS). Remote sensing based methods are used for identification of drought prone areas, climate variability prediction and soil moisture estimation (Jeyaseelan 2003). High resolution satellites sensors from LANDSAT, SPOT and IRS are used in India for drought impact assessment and relief management (Jeyaseelan 2003). GIS is a wide application that handles large amount of data to find various aspects of drought vulnerability and risk (Gupta et al. 2011). Satellite remote sensing along with semantic sensor web and GIS can be used to monitor water level of rivers and reservoirs which may help in prediction of drought conditions. ICT provides information about physical and environmental variables associated with droughts like temperature, soil moisture level and rainfall with the help of sensors and communication networks (Mauree 2010).

Table 4 Available web resources in India.

Website	Usage
http://www.iwmi.cgiar.org/	Drought Monitoring
http://www.archive.india.gov.in/	Weather situation related to drought and crop advisory
http://www.nrcs.usda.gov/	Help educate tribes on Drought Management
http://www.icar.org.in/	Planning, Preparedness and Management of drought
http://www.imdpune.gov.in/	Drought monitoring
http://www.cdrn.org.in/	Web based chain management to provide emergency humanitarian relief
http://india.gov.in	Web based platform, for managing the inventory of equipments, skilled human resources and critical supplies for emergency response
http://www.saarc-sadkn.org/	Provides disaster profile and disaster management framework
http://nidm.gov.in/	A web portal that offers resources and services related to natural disasters
http://bhuvan.nrsc.gov.in/	Weather and disaster services

Some of the examples are available showing use of computational techniques in various phases and management of drought. Use of Association Mining is done in Bhopal district of India to check the severity status of Drought (Rajput et al. 2013). Fuzzy clustering and linear regression methods are been used to monitor and predict future precipitation which is one of the important factor responsible for drought condition (Mujumdar et al. 2009). Another technique is use of wireless sensor networks to predict drought severity. This takes various drought parameters like temperature, wind pressure, humidity, precipitation and many more in order to minimize human involvement in the process of knowing drought severity (Dappin 2009). Monitoring rainfall is another way of predicting drought. Artificial Neural Networks have been used to predict rainfall as well as other weather conditions in order to monitor drought (Taksande et al. 2014)

Along with preparedness and management, ICT has also be used to provide financial assistance to farmers by raising funds for drought assistance from donors like various agencies, government and individuals (Yap 2011).

Conclusion

Drought is the condition of water deficiency for long period which has an adverse effect on agriculture. India is a drought prone country where, occurrence of drought is frequent. Its impact remains for long period harming the economic growth of the country. The management phase of drought needs to be strong in order to handle drought conditions. The direct impact of drought is over agricultural sector so preventive measures needs to be strengthened. Drought monitoring and preparedness must use emerging technologies in order to identify drought prone regions. Proper measures, if taken, the drought conditions can be handled and mitigated. Training and

education to deal with drought situation will be helpful. Overcoming the challenges for drought management is the prime requirement. Strong planning for management of drought will ensure less harm or early recovery from drought condition. Use of ICT in drought phases has its specific and important role for obtaining pre-drought information, early warning systems and post-drought management. Remote sensing along with GIS and ICT has a big share in drought monitoring and management in India.

References

R. Aijaj (2013), Monsoon Variability and Agricultural Drought Management in India, Published by Observer Research Foundation, Issue Brief (53), 2013.

S. Dapin (2009), Severity Prediction of Drought in A Large Geographical Area Using Distributed Wireless Sensor Networks, 2009 IEEE International Advance Computing Conference (IACC 2009) Patiala, India, 6–7 March, 2009.

A. K. Gupta, P. Tyagi and V. K. Sehgal (2011), Drought disaster challenges and mitigation in India: strategic appraisal, Current Science, 100 (12), 2011.

A.T. Jeyaseelan (2003), Droughts & floods assessment and monitoring using remote sensing and GIS, Satellite remote sensing and GIS applications in agricultural meteorology, Proc. Train. Workshop, Dehra Dun, India. Geneva, Switz: World Meteorol. Org., pp. 291-313, 2003.

J. Jiwan (2012), Converging Information, Communication and Space Technologies in Drought Management in India, International Journal of Social Science Tomorrow, 1 (5), 2012.

D. John, K. Sindhu, B. Meshram (2012), Two Stage Data Mining Technique for Fast Monsoon Onset Prediction, International Journal of Advanced Research in Computer Science and Software Engineering, 2 (6), June 2012.

M. Kanda (2010), National Disaster Management Guidelines: Management of Drought, A publication of the National Disaster Management Authority, Government of India, ISBN 978-93-80440-08-8, New Delhi, 2010.

N. Karunakaran (2008), Drought in India: Challenges and Initiatives, Poorest Areas Civil Society Programme, Infochange, Pune, PACS Programme, New Delhi, India, 2008.

V. Kumar (1998), An early warning system for agricultural drought in an arid region using limited data, Journal of Arid Environments, 40, pp. 199-209, 1998.

V. Mauree (2010), ICT as an enabler for smart water management: ITU-T technology water report, ITU-T Technology Watch, published by ITU Telecommunication Standardization Bureau, 2010.

P. Mujumdar, S. Ghosh, D. Raje (2009), Hydro-meteorological predictions from GCM simulations: downscaling techniques and uncertainty modeling, New Approaches to Hydrological Prediction in Data-sparse Regions (Proc. of Symposium HS.2 at the Joint IAHS & IAH Convention, Hyderabad, India, September 2009). IAHS Publ. 333, 2009.

T. Nandakumar (2009), Manual for Drought Management, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2009.

L. K. Neelam, R. N. Vangala, S. Ganapuram, A. G. Sylvester, B. Venkataraman (2010), Fostering Community Preparedness to Cope with Drought: new initiatives and results from a study involving ODL and ICT from South Central India, International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru, AP 502324 India,2010.

A. Rajput, P. K. Purohit, R. Sharma, R. Prasad Aharwal (2013), Association Rule Mining In Drought Data With Special reference To Bhopal District, Asian Journal Of Mathematics And Physics, 2013 (Amp0095), pp. 1-9, ISSN 2308-3131, 2013.

A. K. Roy and I. Hirway (2007), Multiple impacts of droughts and assessment of drought policy in major drought prone states in India, Project report submitted to: The Planning Commission, Government of India, New Delhi, Centre for Development Alternatives, Gujarat, India, 2007.

P. S. Roy, R. S. Dwiwedi and D. Vijayan (2011), Remote Sensing Applications, National Remote Sensing Center, Published by NRSC, ISRO, Hyderabad, India, 2011.

J. S. Samra (2004), Review and Analysis of Drought Monitoring, Declaration and Management in India, Working paper 84, Colombo, Sri Lanka: International Water Management Institute, ISBN: 92-9090-576-X, 2004.

M. P. Shewale and S. Kumar (2005), Climatological features of Drought incidences in India. Meteorological Monograph, Climatology, 21, India Meteorological Department, Pune, 2005.

N. B. Singh, R. S. Saini (2013), Contingency and Compensatory Agriculture Plans for Droughts and Floods in India 2012, Position paper No.6, National Rainfed Area Authority, New Delhi, India, 87P, 2013.

A. A. Taksande, Dr. S. P. Khandait, M. Katkar (2014), A Data Mining Approach Using Artificial Neural Network to Predict Indian Monsoon Rainfall, International Journal of Research in Advent Technology, 2 (2), E-ISSN: 2321-9637, 2014.

N. T. Yap (2011), Disaster Management, Developing Country Communities & Climate Change: The Role of ICTs, Manchester: Report, eds. R. Heeks and A. Ospina for IDRC, Centre for Development Informatics, Institute for Development Policy and Management, University of Manchester, 2011.