Journal of Geosciences and Geomatics, 2019, Vol. 7, No. 2, 88-96
Available online at http://pubs.sciepub.com/jgg/7/2/5
Published by Science and Education Publishing
DOI:10.12691/jgg-7-2-5

Earthquake - A Natural Disaster, Prediction, Mitigation, Laws and Government Policies, Impact on Biogeochemistry of Earth Crust, Role of Remote Sensing and GIS in Management in India - An Overview

Deepak Singh[1,*], D. N. Pandey[2], Usha Mina[1]

[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India
[2]Dyal Singh College, University of Delhi, New Delhi, India
*Corresponding author: deepaksingh1947@gmail.com

Received December 27, 2018; Revised February 11, 2019; Accepted February 19, 2019

Abstract The whole world from time to time is exposed to the unpredictable disaster called Earthquake which causes immense damage to the infrastructure, life and injury to the people. The present manuscript tries to discuss different aspects of the Earthquake in the present scenario in India and the role of government and its policies, society, schools and technology for the prevention and mitigation measures and impact on biogeochemistry of the earth crust. Due to location of India in tropics and happening of plate tectonic activities under and around the Indian plates has made India prone to the different types of disaster of which one of them is the Earthquake. The prediction of Earthquake is still not possible accurately. In India, during the 10th Five year plan, there has been paradigm shift in the laws and policies related to the disaster management. A separate act called Disaster Management Act-2005, has been passed by the Parliament of India. This act provides institutional, legal, financial and coordination mechanisms at the national, state, district and local levels for management of all types of disaster happening in India. This law made the role of government from relief oriented measures to the prevention and preparedness. During the Earthquake, there occurs a different type of impacts on the Biogeochemistry of the earth crust. Among them, there are the impacts on biodiversity of living organisms, variation in the water levels, folding and faulting in the crust of the Earth and generation of sea waves called Tsunami etc. Technology in the form of remote sensing and GIS can play important role and can be used before and after the occurrence of Earthquake for proper management. The Earthquake is a disaster which is unpredictable, untimely and we lack of mechanism and technology to predict its time of happening precisely. With regard to Earthquake disaster, we can only prepare our self, take preventive and preparedness measures, so that there is less damage to infrastructure and loss of life. This can be achieved by investing more in research and development of tools for prediction, proper understanding of Earthquake phenomenon, along with it there is need to concentrate more on prevention, preparedness and mitigation before and quick relief to the people after the occurrence of Earthquake.

Keywords: *Earthquake, natural disaster, remote sensing, GIS, government laws and policy, biogeochemistry*

Cite This Article: Singh Deepak, Pandey D. N., and Mina Usha, "Earthquake - A Natural Disaster, Prediction, Mitigation, Laws and Government Policies, Impact on Biogeochemistry of Earth Crust, Role of Remote Sensing and GIS in Management in India - An Overview." *Journal of Geosciences and Geomatics*, vol. 7, no. 2 (2019): 88-96. doi: 10.12691/jgg-7-2-5.

1. Introduction

From the time of origin, the earth was exposed to different types of hazards and disaster from time to time. The earth, due to its internal structure, is prone to different types of natural disasters. They come in different frequency every year in most part of the world. Natural hazard is threat while disaster is an event. The disaster can be natural or artificially created by the different types of activities of human beings [1,2,3]. Since the origin of the earth, due to different types of plate tectonic movement, the earth is exposed to different types of hazards. When the human civilisation came into existence, these events started affecting and became disaster for the human beings. Earth has very diverse type of climate, meteorological conditions existing above the surface of the earth along with it earth has very peculiar internal structure [4,5,6,7]. Different types of condition above the surface and below the types of natural hazards. When these hazards cause loss of human beings and cause economic damage, it becomes disaster.

There are different types of hazards which can be divided into two types:

Natural hazards:- These are those hazards which occurs due to the natural forces like climatic forces, meteorological forces and earth forces. In these hazards the human being does not have any role to play. Some of the frequently occurring examples are:- Earthquakes, Volcanic eruptions, Cyclonic storms, Tsunami, Floods, Droughts, Landslides. Of these hazards, due climatic conditions and meteorological conditions are Cyclones, Floods and Droughts. While hazards due to internal Earth forces are Volcanic eruptions, Earthquakes, Landslides and avalanches, Tsunami [3,8,9].

Manmade hazards:- These hazards are caused due to the involvement of human beings beyond certain limits and are following:- (1) Air pollution (2) Water pollution (3) Soil pollution (4) Solid waste pollution (5) Industrial and nuclear accidents.

The present article discusses about basic concepts, role of technology in prediction and mitigation, role of remote sensing and GIS and role of public awareness. [6,9,10,11].

In simple terms, Earthquake is sudden generation of vibrations in the crust and surface of the Earth which moves in all directions. The earth is made up of plates joined zig-zag manner at different places. These plates are moving is different directions due to the force provided by the molten mantle materials below the crust of the earth. [6,9,10,11]. The movement of the plates at some point of time loses the stain which results in sudden release of energy in the Earth's lithosphere which produces seismic waves in and out of the surface [6,12,13]. It is one of the dangerous natural hazard which when occurs with high intensity causes widespread damages and large scale loss human life [3,8,9]. Earthquake in India:- India is exposed to since very long time. The reasons have been the slow submergence of Indian plate below the Eurasian plate.

India is being divided into five zones based on MM scale (Modified Mercalli Intensity Scale) [8,9,14]:-

Zone I - Intensity V and below (called as Moderate level of Earthquake)

Zone II - Intensity VI (called Strong Earthquake)

Zone III - Intensity VII (called Very Strong)

Zone IV - Intensity VIII (called Destructive Earthquake)

Zone IX - Intensity IX and above (called Disastrous or Catastrophic)

2. Earthquakes in India

As per one estimate, Earthquake has claimed more than 23 thousand lives due to six major Earthquakes that occurred during the period 1990 to 2006, which occurred in the districts of Uttarkashi (Uttarakhand) Earthquake in 1991, district of Latur (Maharashtra) Earthquake in 1993, district of Jabalpur (Madhya Pradesh) Earthquake in 1997, Mountainous district of Chamoli (Uttarakhand) Earthquake in 1999, district of Bhuj (Gujarat) Earthquake in 2001 and Jammu and Kashmir in 8th October, 2005. In all these Earthquakes, the major impact was the damages caused to the residential and commercial buildings. Some of the Earthquakes that happened in last 70 years are mentioned in the Table 1 [15].

Depending on the history, frequency and intensity of Earthquakes, India into three broad zones [12,13]:-

(1) *Himalayan zone* - These are most prone and the occurrence is due to the submergence of Indian Plate below the Eurasian.

(2) *Indo-Gangetic zone* - These zones have Earthquakes due to the plate tectonics occurring in the Himalayan zones.

(3) *Peninsular zone* - The seismic activity in this zone occurs due to unevenness and deformities in the crust, movement of Indian Plate towards and subsidence of Eurasian plate and due to some type of human activity.

Table 1. Shows major Earthquake occurred in India in recent decade (source: Indian Meteorological Department and Map of India)

Date	Location	Magnitude
15/08/1950	Arunachal Pradesh	8.5
21/07/1956	Anjar Gujarat	7
10/12/1967	Koyna, Maharastra	6.5
19/01/1975	Kinnaur, Himachal Pradesh	6.2
06/08/1988	Manipur-Myanmar Border	6.6
21/08/1988	Bihar-Nepal Border	6.4
20/10/1991	Uttarkashi Hills	6.6
30/09/1993	Latur, Maharastra	6.3
20/05/1997	Jabalpur, Madhya Pradesh	6.0
29/03/1999	Chamoli, Uttarakhand	6.8
26/01/2001	Bhuj, Gujarat	7.7
10/06/2008	Tibetan plateau	6.4
27/06/2008	Andaman Island groups	6.7
28/06/2008	Andaman Island groups	6.1
25/082008	Tibet	6.4
08/10/2008	Andaman Islands	6
10/11/2009	Nicobar Island groups	6.1
30/03/2010	Northern Coast of Andaman Island group	6.8
12/06/2010	Western Coast of Nicobar Islands	7.8
18/06/2010	Andaman Island groups	6
10/11/2010	South-East Indian Ridge	6.3
18/09/2011	Indo-Nepal border in Sikkim	6.9

3. Measurement of Earthquake

When the Earthquake occur it generate different types of waves which create vibrations in the earth. To measure the Earthquake, there are two types of method first one is measurement of amount of energy released at the Earthquake shows that is epicentre while the second method is the measurement of intensity that is generation of vibration at a specific location the magnitude is measured on the Richter scale by intensity is measured on the Modified Mercalli Intensity Scale [16,17,18].

3.1. Intensity Measurement

The impact and the shock of the Earthquake is primarily felt on the surface of the Earth's called as intensity. The scale of the intensity consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally - total destruction and damage. Many intensity scales have been developed by different seismologist over the last hundred years to evaluate the effects of Earthquakes. Of all the intensity scales the most authentic one which is currently used in the United States of America is the Modified Mercalli (MM) Intensity Scale. It was first developed by the American seismologists Harry Wood and Frank Neumann in 1931. This scale, composed of increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects [1,17,19].

The value assigned on the Modified Mercalli Intensity Scale to a specific location after an Earthquake occurred and has a more meaningful measure of severity to the non-scientist than the magnitude measurement since intensity refers to the impacts actually experienced at that location. The lower numbers of the intensity scale generally deal with the manner in which the Earthquake is felt by people residing at the site where the Earthquake has happened. The higher numbers of the scale are based on observed structural damage. The services and contribution of the people who have expertise in structural engineering are needed to interpret and assigning intensity values of VIII or above [17,19,20,21].

The intensity is measured on the Modified Mercalli Intensity Scale which ranges from I to IIX and it is based on the evidences provided by the eyewitnesses of the damages due to the Earthquakes. Near the earth surface i.e., the epicentre, the damages to the life and infrastructure are more as compared to the areas away from the epicentre. The area having sparse population with very few houses and buildings is calculated largely based on the effects that tremors have on human-made structures. In other words, it is the measure of destructive power of Earthquake. The Table 2 show the Modified Mercalli intensity scale and its impact [17,19,21,22].

3.2. Magnitude Measurements

To measure the magnitude we apply a complex mathematical formula to convert motion recorded on the Earthquake monitor which is called as seismometer which is called a number. This number represents amount of energy released during the Earthquake event. The number ranges from 1 to no upper limit. In an actual, it is a measurement of energy. The particular number represents the energy released is 31 times (i.e., increase in each unit increases the energy release by 31 times) greater than the energy released at the lower number on the scale and is called as Richter scale. Table 3 shows the scale of Richter magnitude, Description and impact on the manmade infrastructure. The scale was first given by the Charles F. Richter in the year 1935 which is known by the famous name “Richter Scale” [16,21,23,24,25].

Table 2. Shows twelve classes of Modified Mercalli Intensity Scale, Category of vibration and Impact of Earthquake (Source: http://Earthquake.usgs.gov/.php)

S.No.	Intensity	Shaking	Description/Damage
1.	I	NOT FELT	Vibration is felt by a very few people.
2.	II	WEAK	Felt by people living on the upper floors building shaving in the rest position.
3.	III	WEAK	Felt by few persons present indoors, especially on upper floors of buildings.
4.	IV	LIGHT	Felt by many people living indoors and outdoors by few during the day.
5.	V	MODERATE	Felt by most of the people, sleeping people awakened. Unstable objects overturned. Pendulum clocks may stop.
6.	VI	STRONG	Felt by everyone, many gets frightened. Some heavy furniture starts moving, there is slight damage to the property.
7.	VII	VERY STRONG	Felt strongly by everyone, Earthquake proof buildings don’t get damaged while considerable damage occurs in poorly built or badly designed structures.
8.	VIII	SEVERE	Damage slight in specially Earthquake proof designed buildings and infrastructures, considerable damage in ordinary constructed buildings while heavy damage great to poorly built structures.
9.	IX	VIOLENT	Considerable damage to Earthquake proof specially designed structures, Great damage to substantial buildings.
10.	X	EXTREME	Heavy damage to all well constructed and designed buildings and damage to infrastructure like bending of Rail lines.
11.	XI	EXTREME	Few structures remain standing. Bridges are destroyed and fully damaged. Broad fissures open on earth surface. Earth slump and land slips on soft ground. Rail lines bent to great levels.
12.	XII	EXTREME	Full and total damage to all structures irrespective of its design and strength. Waves can be felt and seen on earth surfaces. Objects thrown upward into the air.

Table 3. Showing the Richter scale magnitude, Description and the Impact on infrastructure (Source: http://Earthquake.usgs.gov/.php)

Richter Scale Magnitude	Description	Impact of Earthquake on the man-made infrastructures
1.0 - 1.9	Micro	Not felt but monitored by seismograph
2.0 - 2.9	Minor	Felt slightly and no damages to infrastructures
3.0 - 3.9	Minor	Often felt by people, Vibration is observable
4.0 - 4.9	Light	Vibration is very well felt, No damage to infrastructure
5.0 - 5.9	Moderate	Felt by all people, causes damages to weak infrastructure
6.0 - 6.9	Strong	Felt very well by public, strong vibration in buildings felt by everyone
7.0 - 7.9	Major	Very high level of vibration, causes damage to most of the buildings, felt across wider area
8.0 - 8.9	Great	Standing People fall on the ground due to shaking of earth, wide damage to the infrastructure even to Earthquake resistant buildings
Greater than 9.0	Great	Total Collapse of buildings and infrastructure

4. Earthquake Prediction

It is not possible to predict Earthquakes through seismic precursor predictions because it is not possible to predict precursors itself. But taking into account the non-seismic precursors, it is possible to predict the Earthquake to some extent but studies are to be authenticated. Some of the methods for the early predictions are mentioned below:-

(1) Animal behaviour - Just before the Earthquake, some animals, birds start behaving strangely and unusually. The strange behaviour of the animals is due to the feel of the P-waves which reaches before the destruction S-waves [26,27,28,29,30].

(2) *Radon emission* - Radon gas can be used for the Earthquake prediction because of its radioactive properties which can be easily predicted. Radon is present in the underground water, most types of the rocks. Before the Earthquake there is increase in the concentration of the gases in underground water and air which can be easily detected due to its radioactive properties [31,32,33,34].

(3) *Changes in the hydro-chemical properties of subsurface water* - Before the occurrence of the Earthquake, there occurs changes in the concentration of minerals and gaseous minerals dissolved in the subsurface water [35,36,37].

(4) *Seismic foreshocks* - It has been observed that major Earthquakes are preceded by the micro Earthquake which is called as foreshocks [38,39,40].

(5) *Seismic waves* - During the occurrence of Earthquake, three types of seismic waves are generated i.e., P, S and L waves. P-waves also called Primary waves or Compressional waves, S-waves are called Secondary waves or Transverse waves or shear waves while L-waves or Rayleigh waves or surface waves which is confined to the surface of the earth. The changes in the Vp/Vs (Vp is the velocity of P-waves which passes through rocks while Vs is the velocity of secondary waves) are also indicators of the Earthquakes. The changes in the ratio of the two velocities i.e., Vp/Vs occurs at the place of fracturing [32,41,42].

(6) *Changes in the Earth's magnetic field* - It has been found that the Earthquakes are accompanied by changes in the geomagnetic field of the localised regions. This occurs due to the phenomenon called the Piezo-magnetic effect, in which there is release of extensive amount of energy due to stress relaxation of the fault which causes the variation in magnetic field in the region [43,44,45,46,47,48].

(7) *Variation in water levels* - Before the occurrence of the Earthquake, there has been found in the variation of water table, increase or decrease in the subsurface water in the wells. For the prediction purpose, a well of depth 500 - 1000 m is needed to predict the Earthquake [35,36,49,50].

5. Impacts of Earthquake

5.1. Natural Impacts

Due to the sudden vibration, the rocks and the materials below the earth undergoes certain changes which lead to changes in the rocks structure like faults, fold and fissures, scarps, changes in the rocks structure etc. It may cause landslide also in the mountains region. There may be flooding due to damages to dam, changes in the river courses [51-56].

5.2. Social and Economic Impacts

There may be wide scale economic impact like damages to buildings, transportation system, like railways, road, flyover etc., damages to water pipelines, oil pipelines, sewage pipelines etc, fire which may be due to damages due to LPG cylinders, fire due to electrical short circuits, wires coming in touch with water etc damages to crops. Also there is loss of economic trades in the fields of industrial goods, agricultural goods, banking services, freight services, transportation services etc. On the social front, face the people may face the problems of food, shelter, medicine, diseases, trauma, loss of own relatives [57-63].

6. Impact on the Biogeochemistry of the Earth Crust

Occurrence of Earthquake leads to many changes in the geochemistry of the earth crust. There may be changes in the river courses due to upliftment and downward movement or fault and folding of the upper surface of the crust [53,64]. The may be incidences of Tsunamis which is generation of massive sea waves in oceans or seas due to the occurrence of Earthquake beneath the sea water [53,65,66]. At the time of the Earthquake occurrence there may be water fountains mixed with mud may occur. Due to the strong shaking of the earth along the river banks or sea shores may lead to changes in the sticking strength which may lead to the sinking of the infrastructure buildings [50,64,67]. The Earthquake also affects the groundwater levels in the form of oscillation in the form of up and down levels [68] (Haugen et al., 2005). This may happen in the water levels in the wells where the well may go dry or may overflow due to the Earthquake. There may also be changes in the water capacity of the aquifers lying below the earth surface [69]. The theory behind the changes in the levels of the underground water was explained by the theory given by the Cooper et al., Liu et al. and Roeloffs [35,36,49]. This theory says that when Earthquake occurs there is expansion and contraction in the aquifers below the wells which supplies the water to the well which leads to the oscillation phenomenon. The Earthquakes also affect the biodiversity of the underground water. Diana et al. [70] in their study found that the fauna present in the underground water are flushed away which leads to the decrease in the subterranean species numbers and population turnover rates decreased. They also found that the Earthquake impacts negatively on the reproduction and survival rates of the species which may lead to the extinction of the species [71,72,73].

7. Government Laws and Policies and the Earthquake

The centre and the state government are the major stakeholders along with the public in the Earthquake disaster management. Different departments of the state government like Revenue department, Panchayat and rural housing, energy department, Industries department, National disaster management authority, state disaster management authority etc [74,75].

They play role in reconstruction of building, making relief norms and packages, prepare departmental Earthquake management plans, rehearsals and review of plan, integration of all departments of state, identify human, financial and equipment for Earthquake at different levels like state, district, taluka, village, identification of gaps of resources, procurement of lacking resources, compilation and update the data, selecting vulnerable community and most vulnerable groups. At the local self government i.e., at panchayat level, they can be advice and issue direction necessary for community Earthquake, prevention, mitigation and preparedness, giving training to the peoples of the taluka and villages, carryout mock drills.

At district levels, the police, fire and emergency services, civil defence, NGO, NCC, NSS etc can be trained to carryout mock drills in association with the district administration. Also there can be dissemination of advertisement, hording, booklets, leaflets, banners, carryout street plays, audiovisual, school campaigns etc. The centre has initiated programme called disaster risk management programme under the ministry of home affairs in collaboration with the United Nations Development Programme in the year 2002 [76].

7.1. A Case Study of Gujarat

After the Earthquake of Bhuj in 2001, the state of Gujarat prepared comprehensive strategies to deal with any type of disaster happening in the state. The state government department prepares three kinds of reports to assess the life threatening situations, need for emergency food, water, shelter and medicinal assistance. The state government also prepares preliminary report within the seven days, which carries the information about. Later on prepare detailed report within 21 days which contains information about the area sector wise detailed damage report, recovery and rehabilitation plan [77]. The government also plays role in short term and long term relief measures along with interim measures. The state government plays role in recovery by carrying out activities relating to rehabilitation and reconstruction at village, district levels by involving all the departments of state and districts. The state government also helps in repair and restoration by providing compensation or repairing the damaged houses. The state government may impose taxes and surcharges so as to recover the relief and reconstruction cost. At the centre level, national disaster response fund was made through legal framework of National Disaster Management Act-2005. Also there is Prime Minister's national relief fund (PMNRF) which provides immediate relief to the people killed in the Earthquakes which is a fund raised by entirely by public contribution [75]. At the state level, there is state disaster response fund, chief minister relief fund. The state government may get funds from public-private partnership, grant-in-aid from central government, receives donation from philanthropists [75,76,77].

From time to time, centre and state government may carry out mock exercise, review and update the plan as per the changing needs of the centre and state are the major stakeholders during the Earthquake disaster. They play important role in response, relief, recover and rehabilitate the Earthquake affected regions and the people. The national disaster management plan working under Ministry of Home Affairs, Govt. of India, works in consistent with the framework prepared by United Nations called Sendai Framework for Disaster Risk Reduction 2015-2030, adopted at the third UN world conference in Sendai, Japan, on March 18, 2015 as a successor to the Hyogo Framework for action 2005-2015, which is a non-binding agreement. India is signatory to this framework [78,79]. The Sendai framework defines disaster risk management as the "systematic process in using administrative decision, organisation, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities, to lessen the impacts of natural hazards and related environmental and technological disasters [78,79,80]. It comprises of all forms of activities including structural and non structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards. United Nations International strategy for Disaster Reduction (UNISDR) defines as "a serious disruption of the functions of a community or a society involving widespread human, material, economic or environmental losses and impacts which exceeds the ability of the affected community or society to cope using its own resources [3,74,75,81].

Later on, India, with the formation of legal framework under the Disaster Management Act, 2005, which defined disaster as a catastrophe, mishap, calamity or grave occurrence in any area arising from natural or manmade causes or by accident or negligence which results in substantial loss of life or human suffering or damage to and destruction of property to or degradation of environment, and is of such a nature or magnitude as to be affected area. At the centre level, overall coordination of disaster management vests with the ministry o home affairs. Also Cabinet Committee on Security (CCS) and the National Crisis Management Committee (NCMC) are the key committees involved in the top-level decision making with regard to disaster management [74,75].

In case of Earthquake, Indian Meteorological Department (IMD) plays important role in Earthquake monitoring services like real time monitoring of Earthquake, hazard and risk assessment, seismic zonation, in collaboration with Ministry of Forest and climate change, Geological Survey of India, National Disaster Management Authority, Council for Scientific and Industrial Research etc [74,75,82,83,84].

8. Paradigm Shift in Disaster Management Policy in India

The government of India in the year 2005, took a major policy and legal decision by promulgating Disaster Management Act, 2005, which creates the Natural Disaster Management Authority, whose chairman is Prime Minister, State Disaster Management Authority is headed by the Chief Ministers and District Disaster Management

Authority is led by District Magistrate for the holistic and integrated approach towards the disaster management. This act created a paradigm shift in the approaches of government from erstwhile relief centric response towards proactive prevention, mitigation and preparedness driven approach for conserving developmental gains and to minimise loss to human life, livelihood and economic property [74,79,85].

8.1. Disaster Management Act, 2005

The act gives institutional, legal, financial and coordination mechanisms at the national, state, district and local levels for management of all types of disaster happening in India under the institutional framework, there is provision of making authorised body called National Disaster Management Authority at national level, National Executive Committee, State Disaster Management Authority, District Disaster Management Authority and Local Authorities. To carry out the research in the field of disaster there is national institute of disaster management which in collaboration with institutes and Universities creates capacity development along with training, research, documentation and development of national level information base. NDMA also mandates for the creation of National Disaster Response Force led by Director General [74,75,76,85].

8.2. Role of Curriculum in Schools and Disaster Management

Schools are the places where mass education about anything can be given to the students who are in their learning phase. When a student is educated at a school and when he/she comes out of the school, he discusses and spread all the knowledge which he has learned in the schools to the family and the community in which he is living or whose part he is. In India, Central Government for the first time allocated separate finances for the disaster and its management i.e., in Tenth Five Year plan [85]. To fulfil the mandate of Central Government, the Ministry of Human Resource and Development, prepared the guidelines and asked all the board is boards to implement it at school levels in its curriculum, In 2006, Central Board of Secondary Education (CBSE) initiated and integrated a course related to the disaster management in the curriculum of schools. The reason behind including the course related to disaster management is being the proneness of our country. Nearly 85% of our country is prone to different types of natural and artificial disaster the curriculum contains different aspects of disaster and its management like type and nature of hazards, disaster, role of community and schools, use of technologies and things need to do to survive during occurrence and post disaster times [78,80,86-91].

At school levels, only bookish knowledge is not sufficient. There is need to carryout regular mock drill and exercise in case of disaster happens Parents should also be called on that day of drill. Also nearby communities should also be allowed to participate and watch how the disaster management in done. The curriculum of the school should be revised and updated every year as per the changing needs and circumstances. The disaster management plan is a work-in-progress i.e., it should evolve continuously with time [79,80,92,93,94].

9. Technology (Remote Sensing and GIS) and Earthquake

GIS is a tool which provides management and analysis of short and long-term data. The GIS tool or software works very well in combination with remote sensing data. It plays very important role in managing areas of land and hazard risk identification [95,96,97]. GIS along with remote sensing database helps in analysing various factors over large areas or remote and inaccessible areas where there is risk of potential hazards or exposed to possible disaster of Earthquake [98,99].

Although occurrence of Earthquake is not stoppable and it's early warning prediction is not possible. Even though, the role of technology in the form of remote sensing and GIS tool are still important from the point of view of preparedness, mitigation, response and recovery [100,101,102]. The use of remote sensing can be used for the estimation of number of people injured or died. This estimation is necessary for the government bodies to carry out rescue and relief operations. The remote sensing database can be used for the estimation of economic loss, human loss, area of total damage or demarcating the damaged area at the Earthquake devastation site [103,104]. High resolution satellite imagery provides fast estimation of the damage to the human, infrastructural loss, economic loss, environmental loss etc [105,106,107].

10. Prevention and Mitigation Measures for Earthquake

The Earthquake is unstoppable, so prevention efforts will not be helpful instead we have to concentrate preparedness and relief measures i.e., on the proper understanding of the hazard and disaster and concentrate on prevention, preparedness and quick relief information. The information related to the Earthquake prone areas should be disseminated to the public through different mediums [78,80,86,108]. For the future and to assess the damages caused due to the Earthquake, we have to use the remote sensing satellite and to prepare data base we need GIS tools [78,80,97]. In the process, print and electronic media, hoarding and advertisement, stage shows etc should be organised to spread the information related to Earthquake so that the public become aware about do’s and don’ts. Government agencies, institutes, local urban municipalities and panchayats should be involved because they are in direct touch with the people of the area [74,77]. Today, the Social Medias (Facebook, Twitter, Instagrams etc) have become more important tool in spreading information and awareness which can also be used to spread awareness among the public prone to the Earthquakes. On the prevention front, the government agencies should prepare hazard mapping, building code funding for research etc, so as to predict Earthquake [76,78,100,104].

11. Conclusions

Earthquake is such a disaster which we cannot predict it even today, when we have developed us so much technologically. India has made paradigm shift in dealing with the disaster in 2005 by making legal and institutional mechanism which is called Disaster Management Act-2005 and National Disaster Management Authority under the chairmanship of Prime Minister. The government shifted its focus from relief oriented approach to prevention and prepared approach. This has been done to take into account the themes of United Nation and Sendai Framework. Technology in the form of remote sensing and GIS can play role in different aspects of the Earthquake. Since Earthquakes are unpredictable so we have to concentrate more on prevention and preparedness measures. Schools, people, societies, NGOs can play major role in spreading the awareness about the prevention and preparedness measures before the Earthquake and relief measures after the happening of Earthquake. The manuscript also discusses some methods to predict the Earthquake; these methods are needed to be authenticated by providing more funding to the scientists involved in the researches on Earthquake. We have to invest more in research and development, develop some kind of monitoring system and technological development so that Earthquake can be predicted in short and long term. As we are living over a land which is very prone region with respect to Earthquake, so we have to prepare us accordingly so as we get exposed to lesser damages due to Earthquake.

Conflict of Interest Statement

All authors hereby declare that there is no conflict of interest.

References

[1] Bolt, B.A., 1993. Earthquakes and geological discovery, Scientific American Library, ISBN 071675040-6.
[2] Bindi, D., Parolai, S., Oth, K., Abdrakhmatov, A., Muraliev, A., Zschau, J., 2011. "Intensity prediction equations for Central Asia", Geophysical Journal International, 187, 327-337.
[3] WHO, 1999. The world health report 1999: Making a difference. World Health Organization 1211 Geneva 27, Switzerland.
[4] Bormann, P., Saul, J., 2009. Earthquake Magnitude, Encyclopedia of Complexity and Applied Systems Science, 3, 2473-2496.
[5] Johnston, A., 1996. Seismic moment assessment of Earthquakes in stable continental regions - II. Historical seismicity", Geophysical J. International, 125 (3), 639-678.
[6] Burton, I., Kates, R.W., White, G.F., 1993. The environment as hazard. Guilford Press. ISBN 9780898621594.
[7] Gill, J.C., Malamud, Bruce, D., 2017. Anthropogenic processes, natural hazards, and interactions in a multi-hazard framework. Earth-Science Reviews. 166: 246-269.
[8] Hemmady, A.K.R., 1996. Earthquakes, National Book Trust, New Delhi.
[9] GOI, 2004. Disaster Management in India - a status report - Government of India Ministry of Home Affairs, National Disaster Management Division.
[10] QSDM Plan, 2018, Queensland State Disaster Management Plan. Australia.
[11] Gupta, M.C., Sharma. K., Gupta, L.C., Tamini, B.K., 2001. Manual on natural disaster management in India, National centre for disaster management, Ministry of Agriculture, Govt of India.
[12] Smith, K., 1992. Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge Physical Environment Series (first ed.). Routledge. ISBN 9780415012171.
[13] Kappes, M.S., Keiler, M., von Elverfeldt, K., Glade, T., 2012. Challenges of analyzing multi-hazard risk: a review". Natural Hazards, 64(2), 1925-1958.
[14] NDMA, 2016, National Disaster Management Plan, 2016, National Disaster Management Authority, Ministry of Home Affairs, Government of India.
[15] IMD, 2009, Indian Meteorological Department. Ministry of Earth Sciences, Govt. of India, New Delhi.
[16] Chung, D.H., Bernreuter, D.L. 1980. Regional relationships among Earthquake magnitude scales, Nureg, CR-1457.
[17] Dewey, J., Glen, R.B., Dengler, L., Moley, K., 1995. Intensity Distribution and Isoseismal Maps for the Northridge, California, Earthquake of January 17, 1994, USGS Open-File Report 95-92.
[18] Stover, C.W., Coffman, J.L. 1993. Seismicity of the United States, 1568-1989 (Revised): U. S. Geological Survey Professional Paper 1527, 418.
[19] Wood, H.O., Neumann, F., 1931. Modified Mercalli Intensity Scale of 1931: Seismological Society of America Bulletin, 21(4), 277-283.
[20] Hutton, L. K. and Boore, D. M., 1987). The M_L scale in Southern California, Nature, 271, 411-414.
[21] Gutenberg, B., Richter, C.F., 1956b. Earthquake magnitude, intensity, energy, and acceleration (Second Paper)", Bulletin of the Seismological Society of America, 46 (2), 105-145.
[22] Gutenberg, B., Richter, C.F., 1936. Discussion: Magnitude and energy of Earthquakes, Science, 83 (2147), 183-185.
[23] Richter, C.F., 1935. An Instrumental Earthquake Magnitude Scale, Bulletin of the Seismological Society of America, 25 (1): 1-32.
[24] Boore, D.M., 1989. The Richter scale: its development and use for determining Earthquake source parameter. Tectonophysics, 166 (1-3), 1-14.
[25] Hough, S.E. 2007. Richter's scale: measure of an Earthquake, measure of a man, Princeton University Press, ISBN 978-0-691-12807-8.
[26] Kagan, Y.Y., 1997b. Are Earthquakes predictable?, Geophysical J. International, 131 (3), 505-525.
[27] Lighton, J.R.B., Duncan, F.D., 2005. Shaken, not stirred: a serendipitous study of ants and Earthquakes. J. of Experimental Biology, 208 (16), 3103-3107.
[28] Lott, D.F., Hart, B.L., Howell, M.W., 1981. Retrospective Studies of Unusual Animal Behavior as an Earthquake Predictor, Geophysical Research Letters, 8 (12), 1203-1206.
[29] Rikitake, T., 1979. Classification of Earthquake precursors. Tectonophysics, 54 (3-4), 293-309,
[30] Davies, D., 1975. Earthquake prediction in China. Nature, 258 (5533), 286-287.
[31] Allegri L., Bella F., Della, G., Ermini, S., Improta, S., Sgrigna, V., Biagi, P.F., 1983. Radon and tilt anomalies detected before the Irpinia (South Italy) Earthquake of November 23, 1980 at great distances from the epicenter. Geophysical Research Letters, 10, 269-272.
[32] Cicerone, R., Ebel J.E., Britton, J., 2009. A systematic compilation of Earthquake precursors. Tectonophysics, 476, 371-396.
[33] Gregoric, A., Zmazek, B., Vaupotic J., 2008. Radon concentration in the thermal water as an indicator of seismic activity. Coll. Anthropology., 32, 95-98.
[34] Friedmann, H., Aric, K., Gutdeutsch, R., King, C.Y., Altay, C., Sav H., 1988. Radon measurements for Earthquake prediction along the North Anatolian Fault zone: a progress report. Tectonophysics, 152, 209-214.
[35] Liu, L.B., Roeloffs, E.,. Zheng, X.Y., 1989. Seismically induced water level fluctuations in the Wali well, Beijing, China, J. of Geophysical Research, 94 (B7), 9453-9462.
[36] Roeloffs, E., Persistent water level changes in a well near Parkfield, California, due to local and distant Earthquakes, J. Geophysical Research., 103 (B1), 869-889, 1998.
[37] Hartmann, J., Levy, J.K., 2005, Hydrogeological and gasgeochemical Earthquake precursors: a review for application. Natural Hazards, 34, 279-304.

[38] Felzer, K.R., Abercrombie, R.E., Ekström, G., 2004. A Common Origin for Aftershocks, Foreshocks, and Multiplets. Bulletin of the Seismological Society of America. 94 (1), 250-259.

[39] Kayal, J.R., 2008. Micro Earthquake seismology and seismotectonics of South Asia. Springer. p. 15.

[40] McGuire, J.J., Boettcher, M.S., Jordan, T.H., 2005. "Foreshock sequences and short-term Earthquake predictability on East Pacific Rise transform faults". Nature. 434 (7032): 457-461.

[41] Scholz, C.H., Sykes, L.R., Aggarwal, Y.P., 1973. Earthquake prediction: a physical basis. Science, 181, 803-810.

[42] Whitcomb, J.H., 1977. An update of time-dependent vp/vs and ^Vp in an area of the Transverse Range of southern California. Science, 58(5), 305.

[43] Allen, C.R., 1982. "Earthquake Prediction - 1982 Overview", Bulletin of the Seismological Society of America, 72 (6B), S331-S335.

[44] Lomnitz, C., Nava, F., Alejandro., 1983. The predictive value of seismic gaps. Bulletin of the Seismological Society of America, 73 (6A), 1815-1824.

[45] Varotsos, P.; Sarlis, N.; Skordas, E., 2011. Natural time analysis: the new view of time ; Precursory seismic electric signals, Earthquakes and other complex time series, Springer Praxis.

[46] Varotsos, P., Alexopoulos, K., Nomicos, K., Lazaridou, M., 1986. Earthquake prediction and electric signals. Nature, 322 (6075): 120.

[47] Varotsos, P., Lazaridou, M., Eftaxias, K., Antonopoulos, G., Makris, J., Kopanas, J., 1996a., Short-term Earthquake prediction in Greece by seismic electric signals in Lighthill- A Critical review of VAN, World Scientific, 29-76.

[48] Uyeda, S., Nagao, T., Kamogawa, M., 2009. Short-term Earthquake prediction: Current status of seismo-electromagnetics. Tectonophysics, 470(3-4), 205-213.

[49] Cooper, H.H., Bredehoeft, Jr,J.D., Papadopulos, I.S., Bennett, R.R., 1965. The response of well-aquifer systems to seismic waves. J. Geophysical Research, 70, 3915-3926.

[50] Woodcock, D., Roeloffs, E., 1996. Seismically-induced water level oscillations in a fractured-rock aquifer well near Grants Pass, Oregon, Oregon. Geology, 58(2), 27-33.

[51] Meunier, P., Hovius, N., Haines, J.A., 2008. Topographic site effects and the location of Earthquake induced landslides. Earth and Planetary Science Letters, 275, 221-232.

[52] Bird, J.F., Bommer, J.J., 2004. Earthquake losses due to ground failure. Eng. Geology, 75(2), 147-179.

[53] Kanamori, H., 2003. Earthquake Prediction: An Overview, International Handbook of Earthquake and Engineering Seismology. International Geophysics, 616, 1205-1216.

[54] Parasuraman, S., 1995. The impact of the 1993 Latur-Osmanabad (Maharashtra) Earthquake on lives, livelihoods and property. Disasters, 19(2), 156-169.

[55] Gutierrez, E., Taucer, F., De Groeve, T., Al-Khudhairy, D. H. A., & Zaldivar, J. M. (2005). Analysis of worldwide Earthquake mortality using multivariate demographic and seismic data. American J. of Epidemiology, 161(12), 1151-1158.

[56] Malamuda, B.D., Turcotteb, D.L., Guzzettic, F., Reichenbachc, P., 2004. Landslides, Earthquakes, and erosion, Earth and Planetary Science Letters, 229, 45-59.

[57] Thomas, L.M., 1983). Economic impacts of Earthquake prediction, Proceedings of the Seminar on Earthquake Prediction Case Histories, Geneva, 12-15 October 1982: UNDPRO, 179-185.

[58] Daniell, J.E., Khazai, B., Wenzel, F., Vervaeck, A., 2012a. The worldwide economic impact of Earthquakes. In: 15th WCEE, Lisbon, Portugal. Paper No. 2038.

[59] Khazai, B., Daniell, J.E., Wenzel, F., 2011. The March 2011 Japan Earthquake analysis of losses, impacts, and implications for the understanding of risks posed by extreme events. Technikfolgenabscha ¨tzunge Theorie Praxis, 20 (3).

[60] Marano, K.D., Wald, D.J., Allen, T.I., 2010. Global Earthquake casualties due to secondary effects: a quantitative analysis for improving rapid loss analyses. Natural Hazards, 52(2), 319-328.

[61] Srivastava, H.N., Gupta, G.D., 2004. Disaster mitigation vis-a-vis time of occurrence and magnitude of Earthquakes in India. Natural Hazards, 31(2), 343-356.

[62] Alexander, D., 1996. The health effects of Earthquakes in the mid-1990s. Disasters, 20(3), 231-247.

[63] Toyoda, T., 2008. Economic impacts of Kobe Earthquake: a quantitative evaluation after 13 years. In: Proceedings of the 5th International ISCRAM Conference. Washington, DC, USA, 606-617.

[64] Wang, C., Manga, M., 2010. Hydrologic responses to Earthquakes and a general metric. Geofluids, 10(1/2), 206-216.

[65] Polet, J., Kanamori, H., 2000. Shallow subduction zone Earthquakes and their tsunamigenic potential. Geophysical J. International. 142(3), 684-702.

[66] Voit, S.S., 1987. Tsunamis. Annual Review of Fluid Mechanics. 19(1), 217-236.

[67] King, C.Y., 1986. Gas geochemistry applied to Earthquake prediction. An overview. J. Geophysical Research, 91, 12269-12281.

[68] Haugen, K., Lovholt, F., Harbitz, C., 2005. "Fundamental mechanisms for tsunami generation by submarine mass flows in idealised geometries". Marine and Petroleum Geology, 22(1-2), 209-217.

[69] Michetti, A.M., Okumura, K., Porfido, S., Reicherter, K., Silva, P.G. and Vittori, E., 2015. Earthquake environmental effects, intensity and seismic hazard assessment: the lesson of some recent large Earthquakes. Mem. Descr. Carta Geol. D'It. XCVII, 5-8.

[70] Diana M.P., Galassi, P.L., Barbara. F, Alessia, D.C, Tiziana, D.L, Marco, P., Piero, D.C., 2011. Earthquakes trigger the loss of groundwater biodiversity. Scientific Reports, 4, 6273.

[71] Ikeya, M., Yamanaka, C., Mattsuda, T., Sasaoka, H., Ochiai, H., Huang, Q., Ohtani, N., Komuranani, T., Ohta, M., Ohno, Y., Nakagawa, T., 2000. Electromagnetic pulses generated by compression of granitic rocks and animal behavior. Episodes, 23, 262-265.

[72] Tributsch, H., 1984. When the Snakes Awake: Animals and Earthquake Prediction; MIT Press: Cambridge, MA, USA, p-264.

[73] Galassi, D.M.P., Huys, R., Reid, J.W., 2009. Diversity, ecology and evolution of groundwater copepods. Freshwater Biology. 54, 691-708.

[74] NDMA, 2004. National Disaster Management Plan, Management of Earthquakes, National Disaster Management Authority, Govt of India.

[75] NDMA, 2007. National Disaster Management Plan, Management of Earthquakes, National Disaster Management Authority, Govt of India.

[76] NDMP, 2016. National Disaster Management Plan, A publication of the National Disaster Management Authority, Government of India, New Delhi.

[77] GSDMA, 2015. Earthquake Management Plan 2015-16 Report, Vol-1, Govt of Gujarat, India.
UNISDR, 2008. United Nations International Strategy for Disaster Reduction, School Disaster Prevention: Guidance for Educational Decision-Makers, 2008. http://www.preventionweb.net/english/professional/publications/phpid=7556.

[78] UNISDR, 2015. United Nations International Strategy for Disaster Reduction, Sendai Framework for Disaster Risk Reduction 2015-2030. http://www.unisdr.org/we/inform/publications/43291.

[79] UNISDR, 2005. United Nations International Strategy for Disaster Reduction, Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disaster, (2005), ⟨https://www.unisdr.org/we/coordinate/hfa⟩.

[80] Birkland, T.A., 1996. Natural Disasters as Focusing Events: Policy Communities and Political Response. International J. of Mass Emergencies and Disasters, 14(2), 221-243.

[81] DMI, 2004. Disaster Management in India-a status report 2004, National Disaster Management Division, Ministry of Home Affairs, Government of India.

[82] Arya, A.S., Karanth, A., Agarwal, A., 2005. Hazards, disasters and your community - A primer for parliamentarians. National Disaster Management Division, Ministry of Home Affairs, Govt. of India.

[83] Gupta, M.C., Sharma.K., Gupta,L.C and Tamini, B.K., 2001. Manual on natural disaster management in India, National centre for disaster management, Ministry of Agriculture, Govt of India.

[84] Planning Commission, 2002. Tenth Five Year Plan (2002-2007), Vol.-1, Planning Commission, Government of India; New Delhi.

[85] IFC, 2009, Disaster and Emergency Preparedness: Guidance for Schools IFC, a member of the World Bank Group.

[86] Parkash, S., Irfana, B., Rita., 2013. Activity Book on Disaster Management for School Students. National Institute of Disaster Management, New Delhi - 110002.

[87] NPDM, 2009, National Policy on Disaster Management, National Disaster Management Authority, Ministry of Home Affairs, Government of India.

[88] Kano, M., Ramirez, M., Ybarra, W.J.G., Frias, L.B., 2007. Bourque, Are schools prepared for emergencies? A baseline assessment of emergency preparedness at school sites in three Los Angeles County school districts, Educ. Urban Soc. 39 (3), 399-422.

[89] Smith, S.T., Kress, E., Fenstemaker, M., Ballard, G., Hyder., 2001. Crisis management preparedness of school districts in three southern states in the USA, Safety Science, 39, 83-92.

[90] Deshpande, V., 2011. Disaster management as part of curriculum for undergraduate and postgraduate courses: The Symbiosis model. Indian J. Occup. Environ. Med. 15(3), 97-99.

[91] Elangovan, A.R., S. Kasi., 2015. Psychosocial disaster preparedness for school children by teachers. International J. Disaster Risk Reduction, 12, 119-124.

[92] Hosseini, M., Izadkhah. Y.O., 2006. Earthquake disaster risk management planning in schools. Disaster Prev. Management Int. J. 15 (4) (2006) 649-661.

[93] Chung, S., Danielson, J., Shannon, M., 2017. School-based emergency preparedness: A national analysis and recommended Protocol, agency for healthcare research, International J. Disaster Risk Reduction, 25, 324-333.

[94] Van der Meer, F., 2012. Remote-sensing image analysis and geostatistics. International J. Remote Sensing, 33, 5644-5676.

[95] Zerger, A., 2002. Examining GIS decision utility for natural hazard risk modeling, Environmental Modeling and Software 17, 287-294.

[96] Merrett, H.C., Chen, W.W., 2013. Applications of geographical information systems and remote sensing in natural disaster hazard assessment and mitigation in Taiwan, Geomatics, Natural Hazards and Risk, 4(2), 145-163.

[97] Li, P., Xiaxin, T., 2009. Integrating RS technology into a GIS-based Earthquake prevention and disaster reduction system for Earthquake damage evaluation. Earthquake Eng. and Eng. Vib, 8:95-101.

[98] Eguchi1, R.T, Huyck, C.K, Ghosh, S. Adams, B.J., 2008. The Application of Remote Sensing Technologies for Disaster Management the 14^{TH} World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[99] Rathje, E.M., Eeri, M. Beverley, J.A., 2008. The Role of Remote Sensing in Earthquake Science and Engineering: Opportunities and Challenges. Earthquake Spectra, 24(2), 471-492.

[100] Mansouri, B., Shinozuka, M., Huyck, C., Houshmand, B., 2005. Earthquake-induced change detection in the 2003 Bam, Iran Earthquake by complex analysis using Envisat ASAR data. Earthquake Spectra, 21, S275-S284.

[101] Chen, J., Li, J., Qin, X., Dong, Q., Sun, Y., 2009. RS and GIS-based statistical analysis of secondary geological disasters after the 2008 Wenchuan Earthquake. Acta Geologica Sinica, 83, 776-785.

[102] Hamid, R.R., Dehghani, H., Ardalan, A.R.A., Saradjian, M.R., 2017. A GIS-based approach for Earthquake loss estimation based on the immediate extraction of damaged buildings geomatics, Natural Hazards and Risk, 8(2), 772-791.

[103] Bendimerad, F., 2001. Loss estimation: a powerful tool for risk assessment and mitigation. Soil Dyn Earthquake Eng, 21, 467-72.

[104] Liu, J.G, Mason, P.J. Eric, Y, Meng-Che, W, Chuan, T, Runqiu, H, Hanhu, L, 2010. GIS modelling of Earthquake damage zones using satellite remote sensing and DEM data. Geomorphology, 139-140, 518-535.

[105] Voigt, S., Giulio-Tonolo, F., Lyons, J., Kučera, J., Jones, B., 2016. Global trends in satellite-based emergency mapping. Science, 353, 247-252.

[106] Feng, T., Hong, Z., Wu, H., Fu, Q., Wang, C., Jiang, C., Tong, X., 2013. Estimation of Earthquake casualties using high-resolution remote sensing: a case study of Dujiangyan city in the May 2008 Wenchuan Earthquake. Natural Hazards, 69, 1577-1595.

[107] Wynona, K.B., Adrienne, E.H., 1997 Disaster preparedness planning: policy and leadership issues. *Disaster Prevention and Management: An International Journal*, 6(4), 234-244.