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Research Article

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Applications of Geospatial Science and Technology in Disaster Risk Management

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Abstract

Disasters are an uncertain and unavoidable event in nature, which affect adversely social, economic, environmental and humanitarian sectors. Geographic information system (GIS) and remote sensing (RS) are very useful and effective tools in disaster management. Various disasters like earthquakes, landslides, floods, fires, tsunamis, volcanic eruptions and cyclones are natural hazards that kill lots of people and destroy property and infrastructures every year. Remotely sensed data can be used very efficiently to assess severity and impact of damage due to these disasters. The main objective of these research is to identify a significant application of geospatial science and technology for disaster risk management over time using these application and technology to understand its nature which will help to respond and solve complex disaster risk management problem and decision making. In the disaster relief phase, GIS, grouped with global positioning system (GPS) is extremely useful in search and rescue operations in areas that have been devastated and where it is difficult to find one's bearings. Disaster mapping is the drawing of areas that have been through excessive natural or man-made troubles to the normal environment where there is a loss of life, property and national infrastructures. The success of disaster management depends to great extent on decision taken on information at the right time and right place.

Keywords: Geospatial science & technology, Satellite image, GIS &remote sensing, disaster risk management, limitation of using geospatial technology

Introduction

A disaster is a serious disruption on the functioning 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 [1]. Disaster have become an issue of growing concern throughout the world, whether its natural disaster or through human factor. Disaster management is a general term used to stand for processes involved in strategic planning and procedures administered in controlling occurrences of natural disasters. According to the United Nations, the global average annual losses caused by disasters such as earthquakes, floods, droughts, and tornadoes were 250 to 300 billion USD in 2015 [2]. In addition, the World Bank reports, natural hazards accounted for an annual loss of up to 520 billion USD in 2016 globally, 60% larger than the usually reported losses [3].

To minimize disaster, risk the role of geospatial science and technology is unlimited. Geospatial technologies broadly include remote sensing, photogrammetry, cartography, geographic information system (GIS), global positioning system (GPS), and information technology (IT). Geospatial technologies deal with the acquisition, storage, processing, production, presentation, and dissemination of geoinformation. Geographic information system (GIS) may be a terribly helpful and necessary technique for hazard zone mapping throughout emergency conditions for mitigation. GIS and Remote sensing techniques square measure a lot of helpful in mitigation ways and preparation plans. Real-time geographic knowledge will improve the allocation of resources for response.

GIS technologies are often a lot of helpful in modeling of disaster risks and human variations to hazards. Remote sensing can be used to assist reduction initiatives through identification of hazards zones associated with flood plains, coastal inundation and erosion and active faults. Also, high resolution, temporal and spatial, satellite imagery applications such as forest fire detection and flood monitoring can be helpful for initiating effective response in case of an occurrence of an actual disaster. The biggest challenge to date, which is faced by many countries are developing an effective plan during disasters. Estimation of a particular place and land that is prone to a natural disaster can help to better analyze the particular area's vulnerability and risk. This informative insight can equip planners and operators with adequate knowledge so that they can prioritize target mitigation and required activities for the affected areas. Both satellite and aerial remote sensing technologies are available, satellite-derived remote sensing techniques are majorly used as it provides a synoptic view that is essential for disaster risk management studies. Aerial remote data is majorly used for natural hazard management when the focus of disaster management planning is to focus on the priority areas, providing information that is too small to detect in satellite imagery, and verifying small-scale data verifications.

Furthermore, spatial analysis and GIS aids in designing a highly accurate interactive system that provides a comprehensive understanding of disasters, damage caused by them, and their outcomes [4]. The geographical information system can act as a decision support aid as all disasters are spatial in nature. With detailed information obtained through various GIS layers, decision making has become simpler. This information is critical for a quick and effective response to any emergency disaster. Remote sensing is thus becoming ubiquitous in disaster response, preparedness, and recovery missions. Geospatial science and technology help in managing a disaster at various stages as follows:

1. Prevention: Prevention refers to the outright avoidance of adverse impacts of hazards and related disasters (ISDR, 2009). Remote sensing and GIS help in managing huge data that is essential for hazard and vulnerability assessment of the area.
2. Preparedness: Preparedness refers to the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions [1]. Geospatial technology acts as a useful tool for meticulous planning of evacuation roots and designing areas for emergency operations in part of the city where it is required and suitable [5].
3. Relief: Relief is the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. When GPS is used along with GIS, it provides useful information essential for rescue and search operations. This is critical as every minute is so valuable that it can make a difference in life and death.
4. Rehabilitation: Here remote sensing aids in organizing the damage information and provide with essential insight for future use. The available post-disaster census information and analysis data of sites for reconstruction can be centralized and managed efficiently.

Disaster Risk=(Hazard X Vulnerability)/Capacity (1)

Figure 1: Disaster risk management cycle.

Finally, remote sensing or earth observation system (EOS) and GIS are among many tools available to disaster management professionals today making the effective technology to monitor, plan and respond on disaster risk very much possible and more accurate now than ever before. Although none of the existing satellites and their sensors has been designed solely for the purpose of observing natural hazards, the variety of spectral bands in VIS (visible), NIR (near infrared), IR (infrared), SWIR (short wave infrared), TIR (thermal infrared) and SAR (Synthetic Aperture Radar) provide adequate spectral coverage and allow computer enhancement are the mostly used for disaster risk management.Furthermore, the aim of the study is to review the current usage and the role of geospatial science and technology for disaster risk management and to describe the application area of geospatial science and technology for disaster risk management phase analysis.

Literature Review

The Role of Geospatial Science and Technology for Disaster Risk Management

The role of geospatial technologies for disaster management has provided the ease of producing meaningful information products that can otherwise be time and resource intensive. Modeling, simulation and visualization of geospatial data provides disaster management decision makers with the ease of using embedded information in effective knowledge generation and decision support process, on the basis of modeling geospatial data. In addition, using geospatial technology can have great effect on disaster management to aid in the delivery of critical decision during disaster. The advantage of this technology is better understood when the effects of its practical lack or application is highlighted. A few scenarios have been outlined by [6]. For example, during the 1992 Hurricane Andrew disaster, authorities were unable to deploy resources because it was unable to do a near- real time assessment. Again, damage assessment and recovery of the World Trade Center assault proved the need for remote sensing technologies. Geospatial Information has become a great tool in identifying hazards and even for risk assessment, which values is efficiently exhibited in the utilization of a GIS database or a database that is accessible to a GIS platform.

Furthermore, geospatial science and technology can play a vital role in decision making and also important to increase transparency of decision and it contribute to better governance [7]. About 80% of daily decisions on national level, either in economy, finance/taxation, demography, spatial planning, environment, hazard areas, infrastructure, housing, cultural heritage etc are spatial or georeferenced [8]. That demonstrate clearly, geoinformation(location) is the central pillar or each country and economy. According to (Kohler,2005) geospatial technology provides an enormous variety of information that can be used in the context of disaster management. Geoinformation products such as thematic mas, GIS based hazard maps, land use maps, satellite images, aerial photographs play a role in all phases in disaster management [7,9,10-12].

Materials and Methods

For disaster risk management different software techniques and satellite imagery was used to identify areas that are disaster prone, zoning them according to risk magnitudes, inventory populations and assets at risk, and simulating damage scenarios [13]. Firstly, the disaster risk area was delineated by using different satellite imageries and software's like ILWIS 4.2 used for image processing. Then it was converted into a shapefile and exported into Arc GIS 10.8 for analysis. Next, the satellite imagery was georeferenced and registered to the geographic space. On this georeferenced image, image classification algorithms like, NDVI were applied to extract the land cover and vegetation information. All the classified and processed images were then exported into ArcGIS for conducting overlay analysis at the third stage to identify risky area. Some extra GIS operations like buffering were applied on some of the below obtained data to derive some new significant data which in turn used in overlay analysis. Also, all the data were integrated in a GIS environment. Finally, for effectively disaster risk management different software's will be used like ENVI 5.0, ERDAS IMAGINE 2015, ILWIS 4.2, ArcGIS10.8, ArcPro 2.9 Spatial Analysis Extension with Model Builder, Arc GIS-3D Analyst Extension. Analytical Hierarchical Process (AHP) is a multi- criteria decision-making technique, which provides a systematic approach to assessing and integrating the impacts of various factors, involving several levels of dependent, qualitative as well as quantitative disaster risk information.

Satellite Data

Data preparation involved the digitization or creation of a GIS database which included the topographical, geomorphological, geological and land cover data. The type of disaster largely determines the kind of satellite imagery or sensors that is effectively applied to the management of the disaster. The basic necessary data used for disaster risk management induced like slope, aspect, curvature, proximity to drainage, lithology, proximity to faults, land cover and geomorphologic/terrain units were used.

Results

Applications of GIS and Remote Sensing in Disaster Management
An increasing number of studies have elaborated on the importance and application of GIS and remote sensing in disaster management Vin Jiping 2006, [14,15]. A major reason for the adoption of remote sensing and GIS is that is one of the fastest means of acquiring data for pre disaster and post disaster study. In addition, the application of remote sensing and GIS has become a well-developed and successful tool in disaster management, hazard mitigation and monitoring by using satellite imagery. GIS allows for the combination of different kinds of data using models. It allows for the combination of the different kinds of spatial data with non-spatial data, attribute data and use them as useful information in the various stages of disaster management. In disaster management, remote sensing and GIS has various applications. These are called potential application area of geospatial science and technology in disaster risk management.

Tracking wind patterns

The wind is one of the causes of disaster in the environment. Hurricane disasters can be sensed and be predicted by the use of remote sensors. These sensors pass the early warning to people living in the affected area, and they can relocate to avoid damages.

Table 1: Wind speed and direction (polarimetric radiometer and scatterometers) remote sensing data

Instrument	Period of Operation	Uses
WindSat	2003 - present	To measure the ocean surface wind vector from space.
QuikScat	1999 - 2009	To measure winds near the ocean surface.
SeaWinds	2003: Apr - Oct	Is a specialized microwave radar that measures near-surface wind velocity and cloud cover over Earth's oceans?
Advanced Scatterometers(ASCAT (Metop-A and -B)	2007 - present	Measure winds over the oceans to improve weather forecasting and climate research.

Figure 1: Sample satellite data used for wind tracking and ***Figure 1. Sample satellite data used for wind tracking and mapping (Source: www.remss.com)***

Detecting earthquake

Earthquakes are one of the most serious types of natural disaster, causing great loss to people's lives and land property [16,17]. Remote sensing and GIS gradually have become an important means to assist earthquake prediction. Remote sensors can detect the onset of an earthquake. Thus, they provide useful information that can be used to predict areas to be affected. Satellite-assisted earthquake and monitoring has developed into a hot spot in recent years [16,18]. These advantages help to better understand the laws of earthquake preparation, occurrence, and development. The remote sensing techniques that are most applicable to earthquake science/engineering are optical satellite imagery, synthetic aperture radar (SAR), and light detection and ranging (LIDAR). These remote sensing techniques generate imagery using different sensing approaches and as such, provide different information about the area being investigated.

Table 2: Satellite data used for earthquake disaster risk management

Wavelength	Waveband	Applicable for	Sensor Examples
Visible (VIS)	0.4-0.7mm	Vegetation mapping	SPOT; Landsat TM
Near infrared (NIR)	0.7-1.0mm	Vegetation mapping & Flood mapping	SPOT; Landsat TM; AVHRR; MODIS
Shortwave infrared (SWIR)	0.7-3.0mm	Water vapour	AIRS (Atmospheric Infrared Sounder)
Thermal infrared (TIR)	3.0-14mm	Active fire detection, Burn scar mapping, Hotspots &Volcanic activity	MODIS, AVHRR & Hyperion
Microwave (Radar)	0.1-100cm	Earth deformation and ground movement	Radar sat SAR; PALSAR

Relief operations

The space technology and disaster mitigation communities work together in developing effective and accurate methods for prevention, preparedness and relief measures. The coordination of humanitarian relief, e.g., in a natural disaster or a conflict situation, is often complicated by a scarcity of data to inform planning. Satellite maps and Geographic Information Systems are now regularly used in emergency response and humanitarian relief, including for logistics, staff security, distribution, transport and the setting up of telecommunication networks and refugee camps. Remote sensing imagery, from satellites or drones, can give important insights into conditions on the ground, including in areas which are difficult to access [19]. The best satellite data for relief operations are given in table 3 below.

Table 3: Remote sensing satellites used for relief operations

Satellite system	Mission start/ completion	Number of bands	Resolution	Repeat Cycle	Revisit Frequency	Description of Use
Terra SAR-X (Spotlight Mode)	2007	6	0.6 m	12 days	12 days	It uses for up-to-date information regarding the ice conditions, to observe the ocean and frozen waters, topographic mapping, surface movement, defense and security applications and rapid emergency response
Advanced Land Observing Satellite (ALOS PALSAR),	2006	5	3 m to 25 m	46 days	46 days	Contribute to field mapping, precise regional land-coverage observation, disaster monitoring, and resource surveying

Wildfires

Wildfires are major and recurring phenomena that have serious impacts on property and human health, affecting many countries including our country Ethiopia. Wildfires like other disasters pose risks to life, property and they also contribute to carbon emission. Geospatial technology and data are useful in fire detection, monitoring, modelling and burnt area mapping. Especially, optical remote sensing and GIS tools utilize for wild fire disaster risk management by using visible and infrared sensors located on high-resolution earth observation satellites [20]. The near-infrared, mid-infrared and thermal bands are susceptible to changes in vegetation health. They are frequently used for an accurate evaluation of fire-affected areas and burn severity to support forest management activities. Green, healthy vegetation reflects radiation in the near-infrared (NIR) region. It absorbs red light in the visible part of the electromagnetic spectrum. Meanwhile, burn-affected areas expend more energy in the visible and shortwave infrared (SWIR) region while absorbing energy in the NIR region.

Normalized burn ratio (NBR) is the index that is used to measure burn severity by distinguishing areas that have been significantly altered in their spectral signature after a wildfire event. It is calculated using the energy intensity from the NIR and SWIR wavelength bands from the remotely sensed satellite imagery. The formula for NBR is similar to the Normalized Difference Vegetation Index (NDVI), which is based on the intensity of light coming from NIR and red wavelength bands. NBR uses the ratio between NIR and SWIR bands. High NBR values reflect areas covered with healthy vegetation, whereas low values indicate bare ground and recently burned areas. Near-zero values represent areas that are not affected by the fire event. NBR for Sentinel 2 data is calculated as:

$$NBR=((NIR-SWIR))/((NIR+SWIR))=((Band\ 8-Band\ 12))/((Band\ 8+Band\ 12)) \quad (2)$$

Burn severity is a term used to represent the degree to which an ecosystem is impacted by a wildfire event. It is estimated as the difference between pre-fire and post-fire NBR derived from satellite images. To identify severity of burned areas and differentiate them from bare soil and other non-vegetated areas, the main method used by remote sensing to differentiate between pre-fire and post-fire NBR, also known as the delta normalized burn ratio (dNBR) index is frequently used.

The delta normalized burn ratio computed as: -

$$dNBR=NBR_{Pre-Fire} - NBR_{Post-Fire} \quad (3)$$

In addition, perpendicular moisture index is important for wildfire disaster management because, vegetation moisture is one of the factors that dictate the susceptibility to fire ignition and propagation in forests. The satellite remote sensing data used for wildfires risk management is given in the table 4 below.

Table 4: Description of remote sensing data used for wildfires

S. No	Name of Datasets	Product ID	Spatial Resolution	Temporal Resolution
1	Land Surface Temperature	MOD11A2& Landsat	60m to1 km	8 to 16 days
2	Surface Reflectance	MOD09A1	500 m	8 days
3	Fire and Thermal Anomalies	MOD14	1 km	Daily

The dNBR value can be more useful than the NBR alone to determine what is burnt as it shows change from the baseline state. A burnt area will have a positive dNBR value while an unburnt area will have a negative dNBR value or a value close to zero. DNBR can also be used to describe burn severity (although this notebook does not look at burn severity). A higher severity fire will burn more vegetation, resulting in a higher dNBR. The figure below showed us the burnt and non-burned area of Semein Mountain national park and its surroundings by using Python notebook to calculate the change in Normalized Burn Ratio between a baseline composite image of the pre-fire condition of a selected area and a post-fire event image, in order to find burnt area extent by using Sentinel -2 Satellite image.

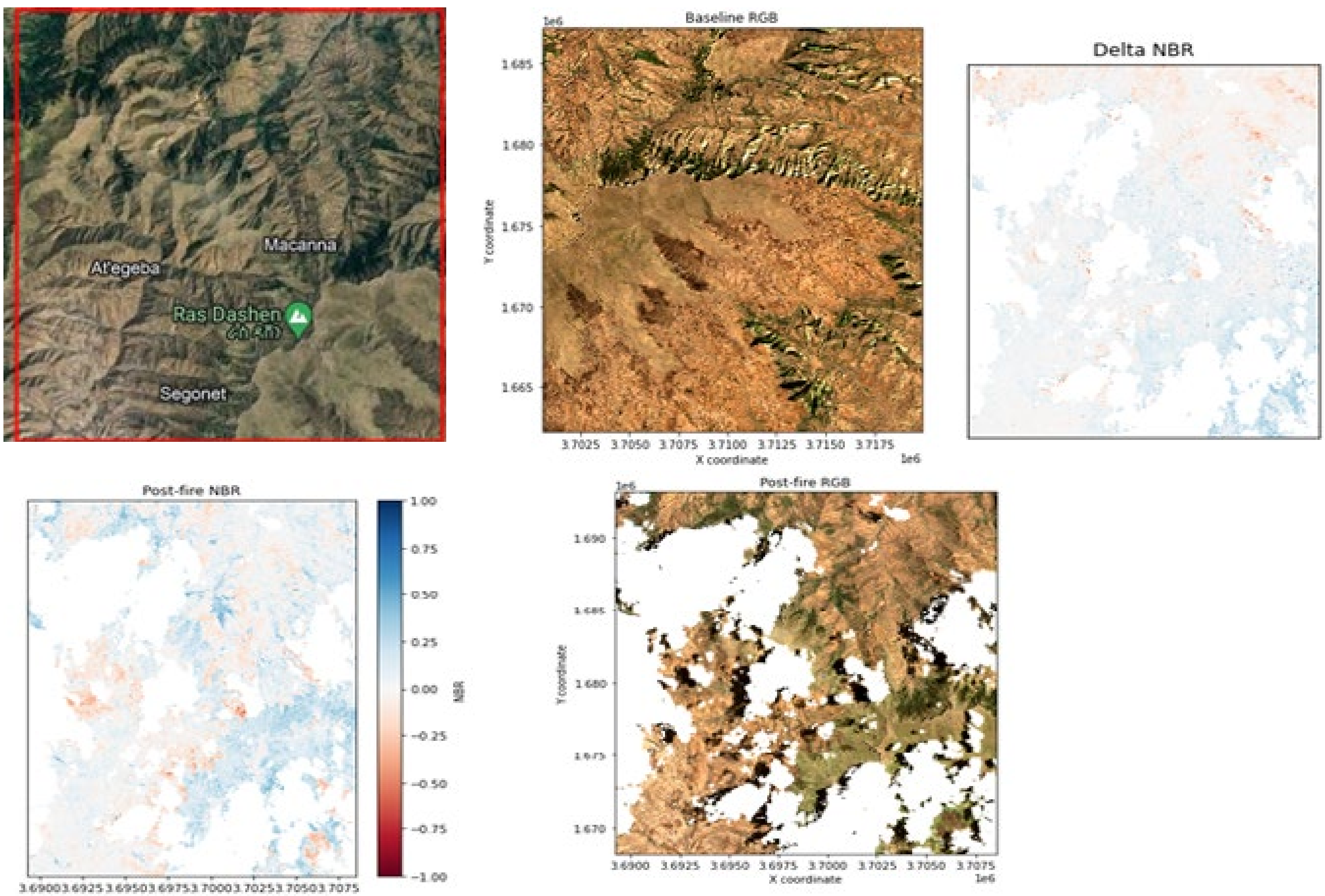


Figure 2: Burned and nun burned area map of Semein Mountain National Park 2019 result of Python Notebook.

Floods management

Flood is one of the most destructive natural disasters, which causes more economic loss than other natural or technological disasters [21]. Flood caused by extreme rainfall events can be mapped using remote sensing data. Remote sensing has a key function now in the assessment and monitoring of natural disasters. Optical images were used before to distinguish flooded and non-flooded area.

The causes of floods can be due to various reasons, such as natural, man-made and Effect of climate change. These are categorized into, Natural: Flash floods, Flood, Coastal Flood (due to cyclones/ typhoons) Man-made: Urban development/ drainage congestion, Dam failures, Watershed activities (deforestation) & Climate Change Effect. Flash flood: The result of heavy or excessive amounts of rainfall within a short period of time, usually less than 6 hours, causing water to rise and fall quite rapidly. The concept of

Flash flood Precipitation Index (FFPI) is fairly simple and the goal is to quantitatively describe a given sub-basin's risk of flash flooding based on the process involved acquiring or developing raster (gridded) datasets that represent the type of physiographic characteristics i.e., slope, land use/ land cover and soil type/texture that influence the hydrologic response and flash flood potential. The FFPI is composite index value the physiographic characteristics of a basin represented by the layers of Slope, Soil and Land Use/ Cover (L) and Vegetation Cover/Forest Density (V). These datasets can be compiled from the available local or global datasets. FFPI is composite index value of the layers of the different dataset index maps averaged together, as given in the equation below by Smith (2011).

$$FFPI = (M+L+S+V)/N \quad (4)$$

Phases of Flood Management

Flood disaster management cycle has three main phases viz. flood preparedness (before flood occurs), flood response (during a flood) and the last phase called flood mitigation (after flood has occurred). Flood preparedness involves identification of chronically flood prone areas, identification of areas that are liable to be affected by a flood and planning of optimum evacuation plans. Flood response involves the immediate action taken once the flood disaster has occurred in terms of the identification of the region affected, spatial extent of inundation, flood damage statistics, flood progression and recession etc. which can help in carrying out the relief and rescue operations on ground. Flood mitigation phase starts after the flood has occurred by identification of the changes in the river course due to flooding, status of flood control works, river bank erosion, drainage congestion, flood hazard and risk vulnerability assessment.

Flood Hazard Assessment Methods

Flood hazard assessment can be conducted in various ways depending on the data availability. The method of carrying out the assessment depends on the information, technology and resources available. Most commonly used methods are: identifying the probability of flood occurrence ,flood Modelling (Hydrological and Hydraulic) approach and temporal satellite data analysis.

Identifying the probability of flood occurrence:

The return interval, or return period, places magnitude of floods in terms of their expected frequency giving a probability of a particular flood occurring. There are a vast number of methods that can be used to calculate or determine return intervals based on the data or lack of data available. This is assessed using the historical data of past flood events and popularly known as flood frequency analysis. Compute the recurrence interval (or return period) of each flood using the formula:

$$Tr = (N+1) / M \quad (5)$$

M = rank; N = total number of floods; The units of Tr are years.
Flood Hazard is usually categorized as high, medium and low and very low intensity as per the magnitude of maximum river discharge return period / probability indicated in the following table.

Table 5: Classification of Probability

Flood Hazard Category	Return Period (years)	Probability (%) of occurrence
High	< 10	> 0.1
Medium	10 to 50	0.1 to 0.02
Low	50 to 200	0.02 to 0.005
Very low	>200	< 0.005

Source: Review of Flood hazard Mapping, EU, 2008

Drought prediction

Drought is a multi-faceted phenomenon caused by a shortage of precipitation due to climatic and hydrological shifts. The rise in the earth's temperature may result in drought and other high temperature-related defects. However, sensors may be used to predict the temperature rise. Since they are sky-based, they are able to measure the temperature of the reflected radiation from the earth's surface; the information obtained may be compared with the previous ones. In case of an increase in temperature, a warning is passed to the vulnerable group, and relevant activities are taken to reverse the temperature rise. Categorizes drought in to meteorological/climatological, agricultural, hydrological and socio-economic drought [22].

Meteorological drought refers to monitoring of rainfall conditions and where rainfall is below normal conditions. Agricultural drought links the various characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortfall, soil moisture deficit, evapotranspiration or crop failure as the derivatives. Socioeconomic drought is associated with the supply and demand of some economic good with elements of meteorological, agricultural, and hydrological drought.

The spatial and temporal advantage that remote sensing and GIS can offer, data from a range of satellite-based platforms have played an increasingly important role in drought studies and analysis over the last decade. In addition, state that the spatial and temporal dimensions of drought create problems in generating a drought index because not only must an anomaly be normalized with respect to location, but the anomaly must also be normalized in time if it is to produce a meaningful estimate of drought; the SPI accomplishes both. It also provides spatial and temporal drought vulnerabilities from the point of rainfall scarcity.

SPI based drought hazard assessment

Standardized Precipitation Index (SPI) can be calculated as a function of the difference between current rainfall condition and Long-Term Average (LTA) and normalized by standard deviation of the rainfall for the years under consideration.

Table 6: Standardized Precipitation Index (SPI)

Standardized Precipitation Index Values	
2.0+	Extremely Wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately Wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
-2 and less	Extremely Dry

Vegetation anomaly-based drought hazard assessment

Vegetation condition monitoring is an important activity and can be done in many different ways. The vegetation health index (VHI) represents overall vegetation health and it is a combination of vegetation condition index (VCI) and temperature condition index (TCI). While VCI indicates the short-term weather related NDVI fluctuations from the long-term mean, the TCI shows the relative change in thermal condition of brightness temperature [23]. Compared to ground-based and NDVI-based (two-channel algorithm) detection systems, this new method provides earlier drought warnings. It also makes it possible to estimate areas under droughts of different severity, and to diagnose the potential for drought development prior to the actual start of drought conditions. One of the important advantages of this method is that it makes use of a combination of the normalized difference vegetation index (NDVI), normally used alone, and the 10.3-11.3-µm thermal channel. Assessment of temperature conditions permits one to identify subtle changes in vegetation health because the effect of drought is more dramatic if a shortage of moisture is accompanied by excessive temperatures. This method was validated in all major agricultural countries around the world [24].

The VCI and TCI were useful to assess the spatial characteristics, the duration and severity of drought, and were in a good agreement with the precipitation patterns [25]. NOAA STAR website stated that the VHI reflects indirectly a combination of chlorophyll and moisture content in the vegetation health and also changes in thermal conditions at the surface. This new approach combines the visible, near infrared, and thermal radiances in a numerical index characterizing vegetation health. This approach is extremely useful in detecting and monitoring such complex and difficult-to-identify phenomenon as drought. The VH is very useful for early drought detection, assessing drought area coverage, duration, and intensity, and for monitoring drought impacts on vegetation and agricultural crops. Vegetation condition index (VCI). VCI was first suggested by Kogan [26]. It shows how close the NDVI of the current month is to the minimum NDVI calculated from the long-term record.

VCI= (NDVI max- NDVI min) *100 (6)
(NDVImax -NDVImin)

Vegetation Health Index (VHC): The satellite-based global VHI System is designed to monitor, diagnose and predict long and short-term land environmental conditions and climate dependent socioeconomic activities. The System is based on satellite observations of the earth, biophysical theory of vegetation response to the environment, set of algorithms for satellite data processing, interpretation, product development, validation, calibration and applications.

VHI=a*VCI + (1- a) *TCI, where a is a coefficient determining contribution of the two indices. VHI is a proxy characterizing vegetation health or a combine estimation of moisture and thermal conditions.

Drought, vulnerability and risk assessment

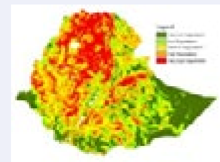
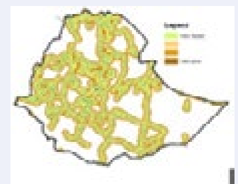
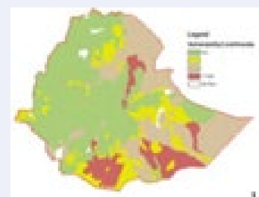
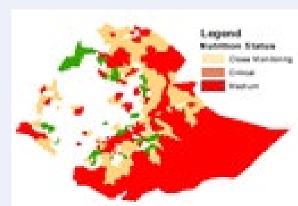
Elements at Risk

One of the most important aspects of vulnerability assessment is to identify the elements that are at risk of an impending disaster. Depending on the nature of the hazard we can list a number of elements that can be at risk and in this case, we are working on drought hazard. Let’s consider human and livestock population as two elements at risk to further make a meaning to our hazard and risk assessment. This information is also key for preparedness, mitigation and response plans.

Vulnerability

The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Some countries are more vulnerable to a certain hazard than others. Even in one country some regions and districts can be more vulnerable to a specific type of hazard than the others. This is due to several factors including physical, economic, social, cultural etc. factors. Mapping vulnerability requires to look at several factors including those mentioned above and even more. For now, we will be using the following indicators.

Table 7: Sample of Vulnerability Indicators in Ethiopia

Factor	Indicator	Range/threshold/criteria	Remark
Environmental	Land degradation (data source: MESA)	Severe, High, Medium, Low, none/minimal	
Physical	Access to major Roads (Primary, Secondary and tertiary roads only) (data source: Roads/HDX)	- Very poor (>25km) - Poor Access (20-25km > 4/5hrs) – Medium Access(15-20km3/4hrs), - Good Access(10-15km-2hrs) - Very Good Access (<10 km) 1 ½ hrs.	
Economic	Livelihoods (data source: FEWSNET)	Very highly, High low Very low Null	
	Level of Poverty	Extreme Very high (>50)High (40-50%),Medium (20- 40%) Very Low	

Emergency mapping

In the field of emergency management, the demand for RS and GIS has significantly increased over the last few decades. Researchers and decision-makers increasingly seek to use this technology to gain explicit and intuitive information about disaster scenes. Different type of GIS and remote sensing sensors, platforms and techniques can be considered in the framework of emergency mapping the choice is mainly based on the activation details and the end-user requirements, e.g., the type of disaster to be mapped, the approximate extent of the affected areas, the required level of detail of the analysis and the need for monitoring the event [29]. Remote sensing technique has a vital role in emergency mapping to promote an easy and quick disaster response. The sensors provide large, widely, and timely data used by the emergency team to plan how they will carry out the rescue mission.

Table 8: List of Geospatial data source for emergency mapping

Data set	Data source (free)
Administrative boundaries	GADM (Database of Global Administrative Areas)
Transportation networks (roads, railways, bridges, etc.)	OpenStreetMap (OSM), collaborative data updates available from Humanitarian OSM
Critical facilities (hospitals, fire stations, police stations, schools, government offices, etc.)	OSM, Collaborative data updates available from Humanitarian OSM and Humanitarian Data Exchange
Land use and land cover (LULC)	Glob Cover, Moderate Resolution Imaging Spectroradiometer (MODIS) Global Land Cover, OSM

Population	World Pop, Land Scan, Gridded Population of the World, Global Rural-Urban Mapping Project
Digital Elevation Model (DEM)	Shuttle Radar Topography Mission, Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version, Advanced Land Observing Satellite Global Digital Surface Model
Satellite images (pre-disaster)	United States Geological Survey Earth Explorer, Sentinel Asia (restricted), SciHub (Sentinel data)
Satellite images (before, during and after a disaster)	United States Geological Survey Earth Explorer, Sentinel Asia (restricted), International Charter on Space and Major Disasters (restricted), Sci-Hub (Sentinel imagery)
Rainfall data	ICPAC, CHIRPS BLENDED, Global Satellite Mapping of Precipitation (GSMaP), Tropical Rainfall Measuring Mission, Global Precipitation Measurement

Challenges For the Application of Geospatial Science and Technologies for Disaster Risk Management

The effective application of geospatial technologies for disaster risk management is faced by significant challenges. These challenges are mostly operational, policy and applications related. Challenges motivate for more advanced research in order for geospatial technologies for disaster and management community to be able to provide optimum solutions for the daily rising demand for efficient solutions. It also requires high levels of systems and operational interoperability and the effective capacity building to improve or enhance current capacities mainly for vulnerable communities. Challenges in the operational side include the lower levels of interoperability, lower data integration capabilities and conflicting stakeholders' needs and expectations. These challenges are among many that limit the complete utility of geospatial information for disaster and emergency management. In particular, it makes the process of sharing, analyzing or acquiring specific datasets for specific application a difficult task.

Finally, the most significant policy challenge is securing consistent access to geospatial data from different parts of the world. The United Nations Office for Outer Space (UNOOSA) is leading global efforts in standardizing the process of sharing global data during disasters called the International Charter "Space and Major Disasters". This is in addition to the conflicting interests for disaster management stakeholders during extreme situations, where efficient models are highly needed. In the applications side, challenges are in the limited geospatial data modeling and processing capabilities in different parts of the world and constraints of internet bandwidth as well as the availability of trained human resource all have led to in-effective disaster and emergency management process in many parts of the world.

The Future of Geospatial Science and Technologies for Disaster Management

Disaster management community will continue to explore new means of data integration, modeling and simulation, as the advances in geospatial technologies continue. Considerable developments are expected to emerge in spatially enabled integrated incident management and response systems, where different multi-modalities of spatial information systems can be used to provide multi-tier modeling, simulation, processing and visualization in handheld devices, on computer screens and on large displays in Emergency Operation Centers (EOCs), including virtual reality modeling and simulation. Among the growing trends in information technology, geospatial information technologies for disaster and emergency management are the techniques that combine data visualization with human factors to provide effective analytical and decision support approaches, also known as "geovisual analytics". This application area is on the rise and provides disaster and emergency management community with near real-world simulations for displaying and analyzing large and heterogeneous volumes of datasets. Finding effective means for field data collection, for better data and systems integration, for rapid analysis of most emerging 3D data including LIDAR, and for providing fast and feasible solutions for Disaster Management Location Based Services (DM-LBS), includes issues like addressing multi-tier vulnerability analysis and assessment. There is a need for a broader scope for using public participation GIS (PPGIS) for disaster and emergency management. This will help with acquiring geospatial data, data analysis and processing [30-32].

Conclusions

Disaster management begins with discovering and identifying emergency issues and how they relate to the current environment. Geospatial science and technology play an important role in disaster management especially during the preparedness, response and monitoring phase. Although, the current usage of geospatial science and technology in disaster management is very limited in application, because majority of disaster management conduct based on local knowledge. This creates the gap between actual and potential usage of geospatial science and technology. Therefore, an integrated approach using scientific and technological advances must be adopted to mitigate and to manage disaster risk effectively, precisely and timely. Finally, we should make use of the technology to support our society in times of crisis and make a pathway for sustainable development and resilient communities.

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