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Review

Geoinformation Technologies in Support of Environmental Hazards Monitoring under Climate Change: An Extensive Review

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Abstract: Human activities and climate change constitute the contemporary catalyst for natural processes and their impacts, i.e., geo-environmental hazards. Globally, natural catastrophic phenomena and hazards, such as drought, soil erosion, quantitative and qualitative degradation of groundwater, frost, flooding, sea level rise, etc., are intensified by anthropogenic factors. Thus, they present rapid increase in intensity, frequency of occurrence, spatial density, and significant spread of the areas of occurrence. The impact of these phenomena is devastating to human life and to global economies, private holdings, infrastructure, etc., while in a wider context it has a very negative effect on the social, environmental, and economic status of the affected region. Geospatial technologies including Geographic Information Systems, Remote Sensing—Earth Observation as well as related spatial data analysis tools, models, databases, contribute nowadays significantly in predicting, preventing, researching, addressing, rehabilitating, and managing these phenomena and their effects. This review attempts to mark the most devastating geo-hazards from the view of environmental monitoring, covering the state of the art in the use of geospatial technologies in that respect. It also defines the main challenge of this new era which is nothing more than the fictitious exploitation of the information produced by the environmental monitoring so that the necessary policies are taken in the direction of a sustainable future. The review highlights the potential and increasing added value of geographic information as a means to support environmental monitoring in the face of climate change. The growth in geographic information seems to be rapidly accelerated due to the technological and scientific developments that will continue with exponential progress in the years to come. Nonetheless, as it is also highlighted in this review continuous monitoring of the environment is subject to an interdisciplinary approach and contains an amount of actions that cover both the development of natural phenomena and their catastrophic effects mostly due to climate change.

Keywords: environmental monitoring; climate change; geohazards; geoinformation; geographical information systems; earth observation

1. Introduction

Significant social, economic, and environmental changes, as well as rapid advances in technology mark the 21st century. A characteristic landmark of this century is climate change and its effects, a global phenomenon that directly and indirectly affects human life and the environment. The most important effects of the phenomenon are climate change in many areas, the rising average global temperature, rising sea levels locally, melting ice, etc., and the effects of these changes, such as the steadily increasing incidence of natural hazards and disasters (Figure 1), changes in biodiversity of areas, changes in natural processes, etc.

An important contributor to the proper management and response to this reality is the modern and highly effective tools that have been created, developed, tested, and implemented in recent years through the technological and scientific explosion that has taken place alongside climate change.

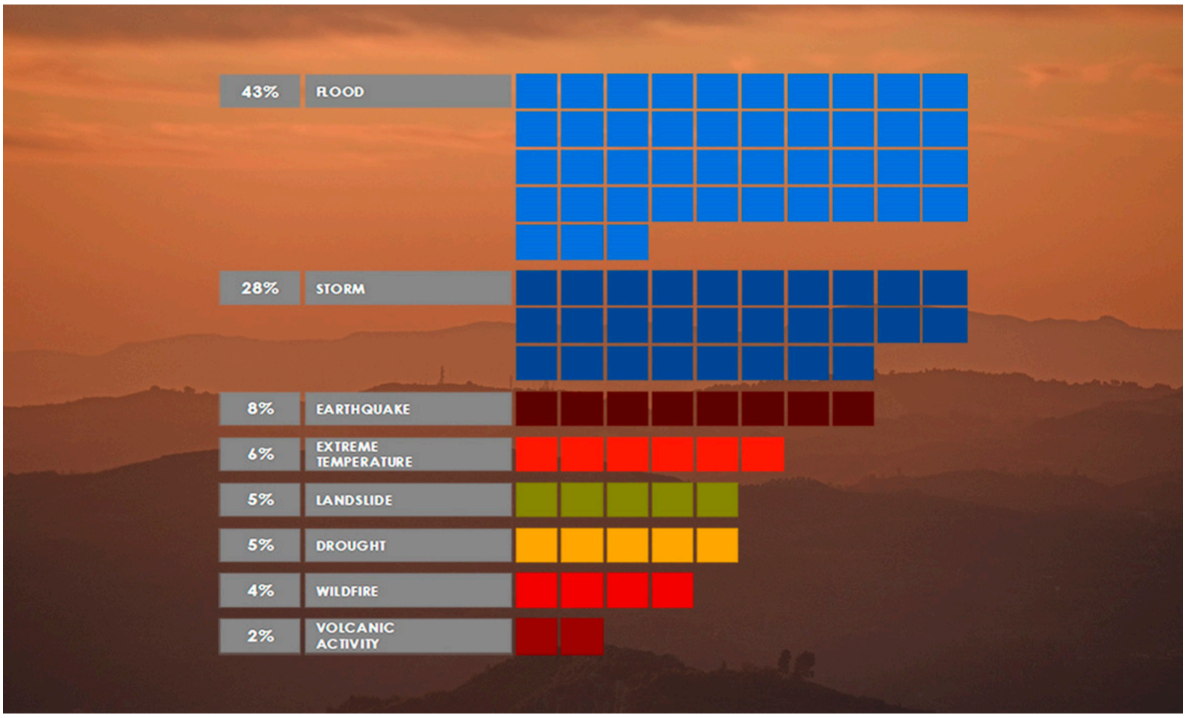

Figure 1. Worldwide Disaster Rates by Type (1995–2015) (Source: https://www.weforum.org/, (accessed date: 20 December 2020), modified figure by the authors of this work, photo: Vasilis Pappas).

Research, management, and response to natural disasters and processes has been the center of interest and engagement of the scientific community and decision makers for the past decade. The current environmental, social and economic challenge (Figure 2), among others due to climate change, is the prediction of natural disasters, and the protection of vulnerable areas, against imminent natural hazards and ever-increasing natural processes with negative impacts. A striking example of this is the European Union Directive 2007/60, which aims to update and upgrade flood prevention, management and rehabilitation methods in the Member States. More generally, this directive seeks to set environmental objectives for Member States' water management policies, with an emphasis on groundwater, which is also threatened by natural factors, in combination with human over-exploitation, with deterioration in their quantitative and qualitative characteristics. Corresponding initiatives have been taken worldwide with very significant results.

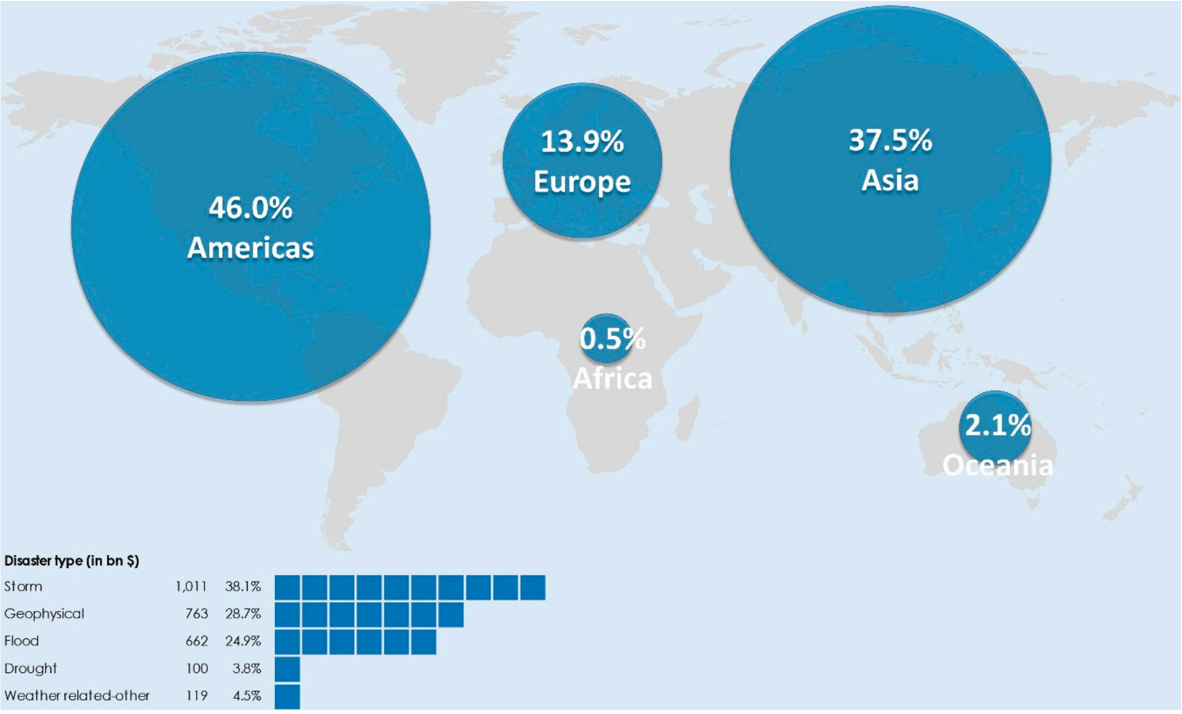

Figure 2. Worldwide Disaster Rates (1995–2015) (Source: https://www.weforum.org/, (accessed date: 20 December 2020), modified figure by the authors of this work).

Modern requirements in the research, design and management of the above geo-environmental risks are very high. A major contributor to these efforts is the significant advancement of science and the rapid technological development of the last decades, which seems to continue to grow in the coming years. In the areas of geosciences, and more specifically in natural processes, risks and disasters, the scientific, and technological spearheads are Geographic Information Systems (GIS) and Remote Sensing. The evolutionary explosion of recent years in these two fields has opened up new avenues, ways, and methods for approaching and researching the environmental issues that concern the lives of modern humans.

At a global level, there is a huge boom in satellite programs for monitoring the earth and the natural (and not only) phenomena that take place. Many countries, either autonomously or cooperatively, are developing satellite systems designed for specific applications.

The main expressers of these efforts are passive optical satellites (e.g., Landsat) and active RADAR satellites (e.g., Sentinel-1), which are designed for environmental applications, such as vegetation capture, recording of flooded areas, monitoring of earthquakes (e.g., by applying the technique of interferometry to satellite images), etc. Over time and in conjunction with the evolution of technology, satellite data is continuously improving in both frequency and spatial resolution.

At the same time, spatial information processing and analysis tools are constantly being improved, adopting new methods and techniques, while becoming more user-friendly. In recent years, open source free software (e.g., QGIS) has competed with commercial packages (e.g., ArcGIS), giving the researcher the ability to create their own tools, according to their needs, within their environment.

Consequently, GIS along with open satellite databases and other free spatial databases cover modern research needs, significantly reducing its cost, as well as time to analyze and extract results, compared to traditional methods. In addition, they overcome obstacles that in traditional field research were inaccessible, such as accessibility to inaccessible areas, weather conditions, etc.

It is understood that 21st century's geo-environmental challenges can be explored and addressed with the modern tools provided by technological and scientific progress. Within the next sections there will be a variety of thematic issues related to environmental monitoring and in particular drought, floods, soil erosion, groundwater, frost, and sea level rise. Techniques and tools (GIS and Earth Observation—EO) for observing and researching the environment will be presented as well as ways to deal with each individual phenomenon.

Specificity of the Review Methodology of This Paper

This review work aims to point out some of most devastating hazards from the view of environmental monitoring, covering a wide area in the use of geospatial technologies in that respect. This work presents specific hazards in terms of environmental monitoring. The selected disasters are as follows: i. drought, ii. soil erosion, iii. groundwater degradation, iv. floods, and v. sea level rise. The selection of the papers presented in this work has been made based on some objective criteria, but also on some subjective criteria. It must be mentioned that all referred and described publications were selected based, mostly, on their citations in an attempt to quote the ones with the highest impact in the disciplines discussed in this review work (objective criteria). For this purpose Scopus citation index was used. In addition, the expertise of each author on each presented subject was also a guide for the selected papers (subjective criteria).

In addition, the contribution of Geospatial Technologies such as GIS, Spatial Data Infrastructures, and EO in natural disasters is presenting as well, as the main research keys in the field of environmental monitoring. Thus, the next section (Section 2) is presenting the review of the bibliography concerning drought, soil erosion, groundwater degradation, floods and sea level rise, respectively. All the cited manuscripts were subject to a good survey on the scientific community for each of them. Table 1 presents the list of cited studies in this work.

Table 1. The list of the cited studies per section in this work.

Hazard	List of References
Drought Monitoring	[1–43]
Soil erosion monitoring	[44–121]
Groundwater monitoring	[122–150]
Frost Monitoring	[151–170]
Flood Monitoring	[171–236]
Sea level rise monitoring	[237–250]
Contribution of EO in Natural Disasters	[251–278]
Geospatial Data and Spatial Data Infrastructures (SDIs)	[279–304]

2. Environmental Monitoring

2.1. Drought Monitoring

With its stability and durability, nature can introduce extreme changes in the variables and factors of human systems. Extreme changes or extreme events, such as earthquakes, floods, and droughts, often called natural hazards, can present insurmountable obstacles and difficulties in how human societies deal with them [1–5]. In this context, it is argued that droughts are one of many natural hazards that can affect domestic use and irrigation—in other words, the water supply of an area [6,7]. The current trend among broad technical and professional circles, administrators, politicians, and decision-makers and generally among common citizens is to regard drought as something transient, a random and remote risk that requires only an extraordinary mobilization [8,9]. However, the accumulated experience of scientific research and observations in recent decades shows that droughts are inevitable, as these phenomena appear to be inescapable and permanent elements of the global climate [8,10–14]. Drought issues can turn into a water crisis and will play a crucial role in the next years in defining both development and environmental policies on a world level [15–17]. As far as Europe is concerned, the droughts in Greece in 1989–1993, in Spain in 2003, in France in 2005, and again in Greece in 2007–2008, confirm this trend, as well as the urgent need to implement common strategies to the problem across Europe and not just in the Mediterranean countries [1,11,18–24]. The next figure (Figure 3) presents such a context [21].

Drought and its consequences must be recognized and taken into account from the early stages of water resources planning and management efforts [25–29]. Accordingly, measures and efforts to tackle droughts should begin by studying the phenomenon's dimensions [1,30–32]. Functional definitions allow the determination of the beginning and end, as well as the degree of severity of drought [1,11,33,34]. These definitions are categorized based on four different approaches: meteorological, hydrological, agricultural, and socioeconomic drought. GIS and Expert Systems (E.S.) can respond timely to identify and recognize drought events over large areas through satellite data, gridded datasets, and measured values from meteorological stations. However, the calculation of Drought Risk and Vulnerability Assessment require spatial data on specific time step (monthly or yearly). Thus, using geoinformation solutions improve the observation visualization of drought hazards. [5,10–12,14,20,35–37].

Drought is a temporary state (months/years), instead of aridity, which is a permanent climate feature [38,39]. Additionally, seasonal drought, i.e., a well-defined dry season, must be distinguished from the drought that occurs with different characteristics [5,6]. There is considerable confusion between scientists and policymakers about diversifying these terms. A typical example is the Greek territory, especially in the island regions, where the rainfall season begins in October and ends in April [19,21,22]. Thus, a large part of the islands appears barren, and drought is an inevitable climate feature. However, the seasonal drought on these islands is almost certain to occur over time due to the failure to meet water needs over a given time horizon. Drought usually occurs when rainfall in a region is less than average and is followed by large evaporation rates for prolonged periods [20,37,40–42]. The drought varies from other natural disasters because of its leisureliness and long duration. In most cases, drought is caused either by a decrease in rainfall or a shortage of water resources reserves. The concept of deficiency is relevant and determined by a specific water demand by sector or by specific activities. Nevertheless, drought analyses and drought assessments should include all the available data from the investigated study area. These results composing drought indices (indicators or indexes) were visualized on a GIS environment to portray spatial distribution. There are efforts and they use geo-statistical techniques to transform the point values form meteorological stations to a spatial distribution in a specific time frame, namely, kriging and co-kriging methods and Inverse Distance Weighting (IDW) are the most common approaches it is referred to as having a better fit for indices or climate parameters [1,4,7,10,14,43].

To address drought phenomena, the development of a strategy and a Master Plan of these phenomena is recommended as an effective means of improving the ability to assess and respond to state mechanisms for action. Unanimity between state agencies and private and public interest groups is also an important part of the process. Composite indicators and indices can help recognize a drought promptly and achieve this goal. Additionally, in combination with forecasting models, a short-term prediction of the phenomenon and its effects can be successfully made for decision-makers to be able to better prepare by reducing or minimizing the effects and reaction time to them. An important helper in this direction is the promotion and integration of contingency planning.

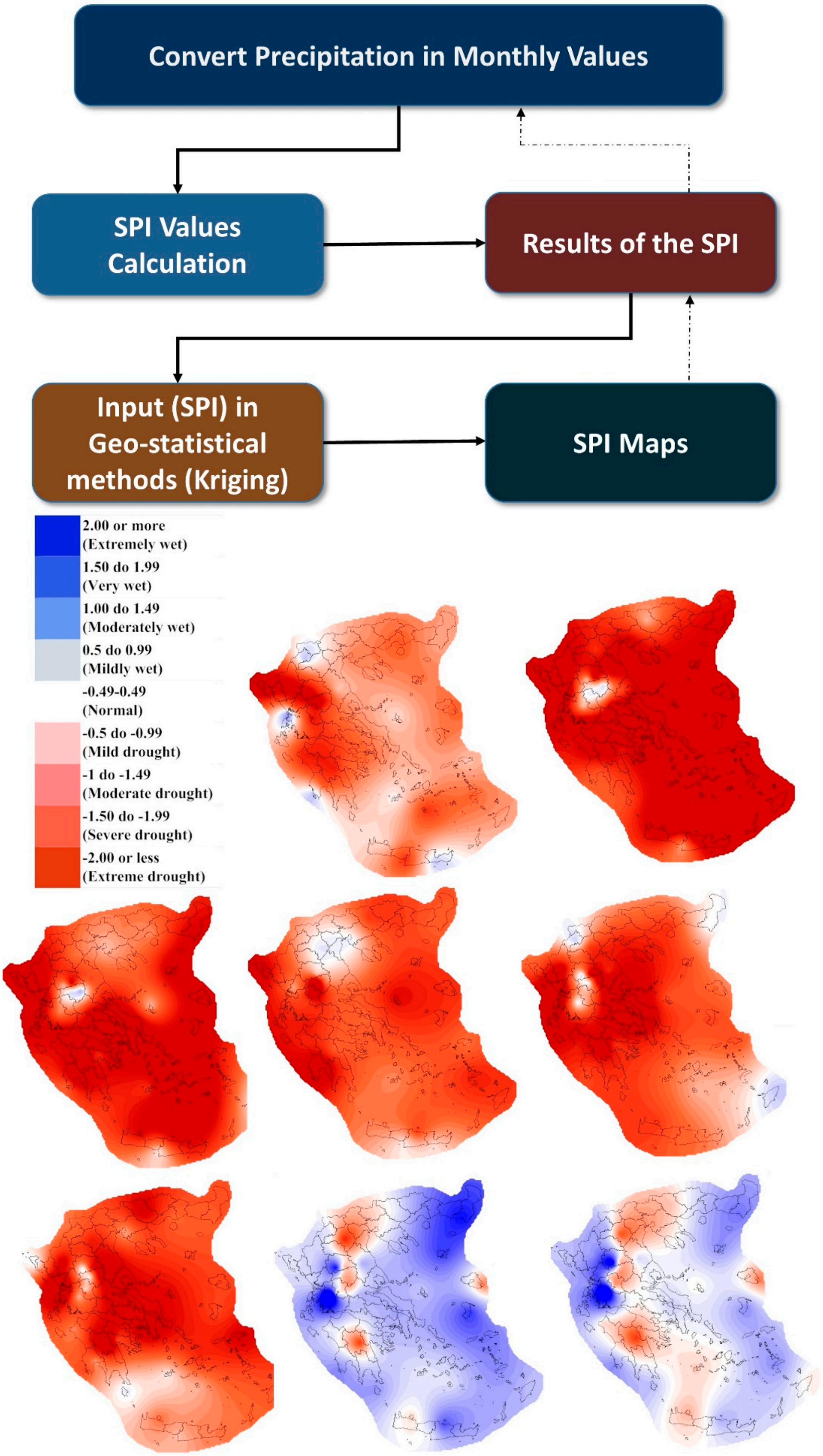

Figure 3. Example of Geographic Information Systems (GIS) technique for monitoring/simulate drought [21].

2.2. Soil Erosion Monitoring

Soil erosion is a complex and dynamic phenomenon that affects many areas around the world. It is one of the most serious problems of land degradation and a major source of environmental deterioration, as it is the largest environmental problem the world is facing after population growth. Indicatively, it is reported that the United States loses soil 10 times faster than the rate of natural replenishment, while the corresponding loss for China and India is 30–40 times faster [44].

Worldwide, the total area of land affected by water erosion is 10,940,000 km^2, of which 7,510,000 km^2 are significantly degraded [45]. The annual sediment transport to the ocean from rivers around the world has been estimated to be 15 to 30 billion tonnes [46,47]. In addition, soil erosion affects the geomorphological characteristics of an area in terms of soil fertility, agricultural productivity, water quality, water reservoir capacity, and the evolution of coastal areas in sedimentary environments [48–50].

The current evolution of the erosion phenomenon is directly related to global warming, which results in a more intense hydrological cycle in several regions, including more total rainfalls and more frequent events of high intensity rainfall (combined or not). These changes in rainfall, as well as changes in temperature, solar radiation, and atmospheric CO_2 concentrations, have significant effects on soil erosion rates. In general, the processes associated with the effects of climate change on soil erosion by water are complex and include changes in the volume and intensity of rainfall, number of days of rainfall, ratio between rain and snow, production of biomass from plants, decomposition rates of vegetable residues, evapotranspiration rates, and land use changes that are necessary to adapt to a new climate regime [51].

In addition, degradation of agricultural land by soil erosion is also a global phenomenon leading to the loss of nutrient-rich surface soil, increased runoff in the more impermeable layer of the ground and reduced availability of water to plants [52]. About 85% of soil degradation worldwide is associated with soil erosion and causes up to 17% reduction in crop productivity [53].

Effective monitoring, modeling, and analysis of the soil erosion phenomenon can provide information on the current erosion state, trends, and allow the analysis of different scenarios [52]. Furthermore, these actions can be important sources of information for land management decisions through the development of alternative land use scenarios and the evaluation of their results [54]. Quantitative monitoring and evaluation [55] is often required to extract the extent and magnitude of soil erosion problems in order to develop sound regional management strategies along with field measurements.

Soil erosion monitoring and analysis models are classified [56] into three main categories: empirical, conceptual (partly empirical/mixed) and physical. Examples of the three categories include the empirical model USLE and its modifications, the conceptual ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation), CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), and MODANSW (Modified ANSWERS), as well as the physical models EUROSEM (European Soil Erosion Model) and MIKE SHE ("Systeme Hydrologique Europeen" or European Hydrological System). Since 1930s, soil experts and decision-makers have been developing and using erosion models to monitor and calculate soil loss [57]. Over 80 erosion models have been created over the last fifty years [58].

One of the most widely used empirical models for monitoring and estimating erosion is the Universal Soil Loss Equation (USLE) model developed by Wischmeier and Smith in 1965, based on soil erosion measurements in the USA [57]. It has been developed mainly for the assessment of soil erosion on arable land or on slightly sloping topographies and is still used in a large number of studies to estimate soil loss [52]. With the revised version RUSLE, which takes into account the upstream areas that contribute to the downstream surface runoff and is thus considered to have better predictability than USLE [59], and modified version MUSLE [57,60,61], USLE is still widely used in soil loss assessment studies and is the most common tool for large-scale soil erosion assessment and monitoring in Europe [62–65].

In recent years, with the development and significant evolutions in GIS and remote sensing, as well as the progress made in computing power, efforts to spatially model soil erosion have been intensified and greatly upgraded [66]. The widespread dissemination of GIS and the use of satellite data has greatly facilitated the development of erosion models, since they allow the use of multiple data sources, easy modification of the structure of erosion models and unconditional reshaping of their scale [67,68]. The use of conventional methods for monitoring and assessing the risk of soil erosion is costly and time consuming. The integration of existing soil erosion models, field data and data provided by remote sensing technologies through the use of GIS has proved to be particularly advantageous, while enabling the spatial distribution of erosion to be presented through hazard maps, which are necessary for the design of protective measures [50,52,65,69–71].

The importance of continuous monitoring of soil erosion and application of integrated river basin management practices has been enhanced by the independent use of remote sensing data, such as aerial photos, LiDAR, UAV, and satellite data such as Landsat (ETM +, TM, MSS), IRS-P6 LISS (III, IV), ASTER GDEM, GeoEye, QuickBird, WorldView, MODIS, Hyperion, etc., but also by their combined analysis and evaluation with other types of data, such as rain gauges, soil samples, topographic maps, etc., in GIS environment [72–82]. A typical example of the above is the soil erosion risk mapping on a monthly basis by Nigel et al. [83] for the Mauritius region via GIS, decision rules, rainfall, and soil data, and SPOT satellite imagery. They developed the MauSERM model, which produces high resolution soil erosion monitoring maps for the whole area of Mauritius every month.

The combined use of remote sensing data (and indicators derived by these like NDVI), GIS and soil loss assessment models, such as USLE, RUSLE, RUSLE3D (a modification of RUSLE for composite soil), USPED (Unit Stream Power-based Erosion Deposition), PESERA (Pan-European Soil Erosion Risk Assessment), etc., has proven to be extremely important and effective in monitoring and predicting soil erosion [52,84–100]. A good and recent example supporting the previous argument is the implementation by Karydas et al. [101] of the G2 soil erosion model in five study areas in south-eastern Europe and Cyprus aiming to estimate soil loss on a monthly basis. This model operates in a GIS environment utilizing a wealth of satellite data such as Sentinel-2, MERIS, PROBA-V and SPOT-VGT. Based also on the above, a very useful reference would be the work of Leh et al. [102], who created scenarios for predicting future land use allocation and soil erosion levels for a US catchment area for 2030. This research combined remote sensing, GIS and modeling techniques and created land use maps through analysis of Landsat satellite images every five years for a period of 20 years (1986–2006). The studies were based on these maps for the synthesis of future scenarios that predict an increase in urbanization with a consequent increase in erosion risk for the study area.

Steps forward in the development of the previous logic were the utilization of the aforementioned data, models and methods along with the use of other techniques such as Frequency Ratio (FR), Analytical Hierarchy Process (AHP), Logistic Regression (LR), Multiple Linear Regression (MLR), Potential Erosion Index (PEI), Sediment Delivery Ratio (SDR), the GIS model GWLF (Generalized Watershed Loading Function), the TLSD (Transport Limited Sediment Delivery) function, etc. [103–107]. A worth noting and recent example is the work of Macedo et al. [108], who developed the Environmental Fragility Index (EFI) through GIS procedures and its ability to monitor and predict sediment deposition was evaluated on 148 rivers in Brazil. The index takes into account geoclimatic factors as well as anthropogenic pressures and utilizes geospatial, rainfall and Landsat TM satellite data.

In conclusion, taking into consideration all previous references, GIS and Remote Sensing are proven very useful tools with great potential in monitoring and estimating soil erosion reliably. These can be based on either models as for example USLE/RUSLE [91,109–113], or in other methods like for example Multi-Criteria Evaluation Techniques—MCE [114–121], or in combinations of the above.

Finally, spatial information analysis is an ever-evolving approach capable of monitoring evaluating, managing and analyzing the complex problems, such as soil erosion, of river basins and lake basins. In recent years, GIS has proven to be a good alternative as they are better decision support tools in soil monitoring, planning, management and sustainable development.

2.3. Groundwater Monitoring

Groundwater is one of the most valuable natural resources and is related, directly, to human health, economic development, and ecological diversity [122]. They are a vital resource for reliable and affordable drinking water supply in urban and rural environments and play a fundamental role in human well-being, sustainable agriculture, and the conservation of aquatic and terrestrial ecosystems [123]. Groundwater quality is usually very good, as it is filtered naturally through the soil and is clear, colorless, and free of microbial contamination, requiring minimal treatment [124].

Effective groundwater management and monitoring is of particular importance in areas with hard rocky soil, which are deprived almost everywhere and permanently of surface water. In these areas, where ever-growing human populations live, finding water supply zones is increasingly difficult [125]. In addition, in many areas groundwater availability is limited, and aquifer development is mainly associated with fractured and disintegrated horizons and secondary porosity created [126]. Moreover, exposure to various pollutants can render groundwater unsuitable for consumption and can endanger human life, fauna, and the environment [127].

Assessing the impact of climate change on a country's water resources is the most important assessment that has to be carried out before planning any long-term water potential project. Numerous studies have been conducted worldwide on the trends of river flows in relation to water filtration in the face of climate change and potential pressures on groundwater aquifers [128]. In recent years, researchers around the world, have conducted numerous studies to assess groundwater reserves and groundwater aquifers, as sustainable groundwater management is increasingly necessary. Investigation of groundwater presence and delineation of groundwater aquifers can be achieved by indirectly analyzing some directly observed soil characteristics, such as tectonics [129].

Unlike traditional methods, remote sensing (RS) technology, with the benefits of spatial, spectral, and temporal data availability covering large and inaccessible areas in a short period of time, has proved to be a very useful tool for evaluation, monitoring and the management of groundwater resources [130,131]. In addition, it is widely used to map land surface features (such as linear tectonic elements, lithology, etc.), as well as to monitor groundwater supply zones [129].

Hydrogeological interpretation of satellite data has proven to be a valuable research tool in areas where little geological and cartographic information is available (or not accurate) as well as inaccessible areas [130]. Since satellite sensors cannot directly detect groundwater, the presence of groundwater results from the interpretation of different surface features derived from satellite images, such as geology, soil geomorphology, soil characteristics (texture, roughness, etc.), land uses/land cover, surface water bodies, etc. [132,133]. In recent years, the widespread use of satellite data in combination with conventional maps and corrected terrain data has facilitated the extraction of baseline information [134–139].

Alongside remote sensing, GSPs have emerged as powerful tools for spatial data management and decision making in various fields, including engineering and the environment [140,141]. The application of GIS for the assessment of groundwater resources has been reported several years before [142–144].

GIS and remote sensing tools are widely used to manage various natural resources [145,146]. Since groundwater zoning and simulation require large amounts of interdisciplinary data, the combined use of remote sensing techniques and GIS has become a valuable tool and important studies have been conducted in recent years [122]. One such example is the integration of remote sensing with GIS to prepare various thematic levels, such as lithology, drainage density, curvature of the basin, rainfall, slope, soil and land uses, etc., in is defined as a weight of importance, a method that can successfully support the identification of potential groundwater areas [123].

In similar research efforts, the combined application of remote sensing and GIS in groundwater management and the delimitation of potential aquifer zones has been implemented by various researchers worldwide [129,147–149]. The first corresponding studies include the work of Gustafsson [150], who used GSPs to analyze SPOT satellite data to map potential groundwater presence.

2.4. Frost Monitoring

The prevalence of low air temperatures and frost conditions in an area is a major factor controlling vegetation zonation and biodiversity. Frost has been globally identified as a leading hazard, as it can occur in almost any location, outside the tropical zones, especially at high altitudes [151]. It has significant impact on agriculture, forestry, pasture as it affects most biotic processes such as plant phenology, growth, evapotranspiration, moisture requirements, carbon fixation and decomposition in natural and cultivated mountain ecosystems [152–155]. Moreover, frost can cause significant damage to infrastructure works and inhibit their smooth and safe operation due to road closures, or even endanger their stability [156–158]. The next figure (Figure 4) presents such a context [158].

Two criteria are often used for the recording of frost: the formation of ice crystals on surfaces (during field surveys) and meteorological measurements of air temperature [159]. As far as agriculture is concerned, frost can be described as a meteorological event when crops and other plants experience freezing injury due to occurrence of an air temperature less than 0 °C [151].

Meteorological measurements have high accuracy but have limited ability to describe the spatial heterogeneity of frost distribution [160]. Attempts to spatial interpolate air temperature measurements and frost often lead to unrepresentative spatial patterns, due to the low number and the irregular distribution of weather stations [161].

Nowadays, with the rapid technological and scientific development in Earth Observation (EO) technology, there is an upgraded potential in the study of the spatiotemporal distribution of frost. Especially in areas where temperature data are unavailable or expensive due to sparsity of meteorological stations or difficult access, remote sensing can be an important and valuable source of information [162]. Remote sensing data have been developed that provide ready to use products with information on night-time land surface temperature, through which frost can be recorded. The values of remotely sensed LST are determined from Planck’s Law using the emissivity of thermal infrared (TIR) bands. The quality of LST retrievals is affected by sensor characteristics, atmospheric conditions, variations in spectral emissivity, surface type heterogeneity, soil moisture, visualization geometry, and assumptions related to the split-window method [162].

A broadly used LST data source is the Moderate Resolution Imaging Spectrometer (MODIS) sensor, which has been providing information since 2000. The MODIS LST product (MOD11A1) has very high temporal resolution, with more than one revisit per day for some areas of the world, but its spatial resolution is course (1 km). The accuracy of the retrieved LST depends on the atmospheric and land surface conditions and is better than 1 °K in some cases [163].

An alternative source of night time LST is the Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) sensor. The accuracy of the ASTER LST product (AST-08–L.2) is calculated to be 0.3 °K and has a 90-m resolution for land areas, but its temporal resolution is lower, as its revisit time is at 16-day intervals [164].

A relatively recent thermal infrared sensor is the Landsat 8 Thermal Infrared Sensor (TIRS), with two adjacent thermal bands. Several approaches have been developed for the generation of LST from Landsat 8 data, such as the radiative transfer equation (RTE)-based method, the split-window (SW) algorithm and the single channel (SC) method. The highest estimated accuracy is accomplished with RTE, which is better than 1 °K [165].

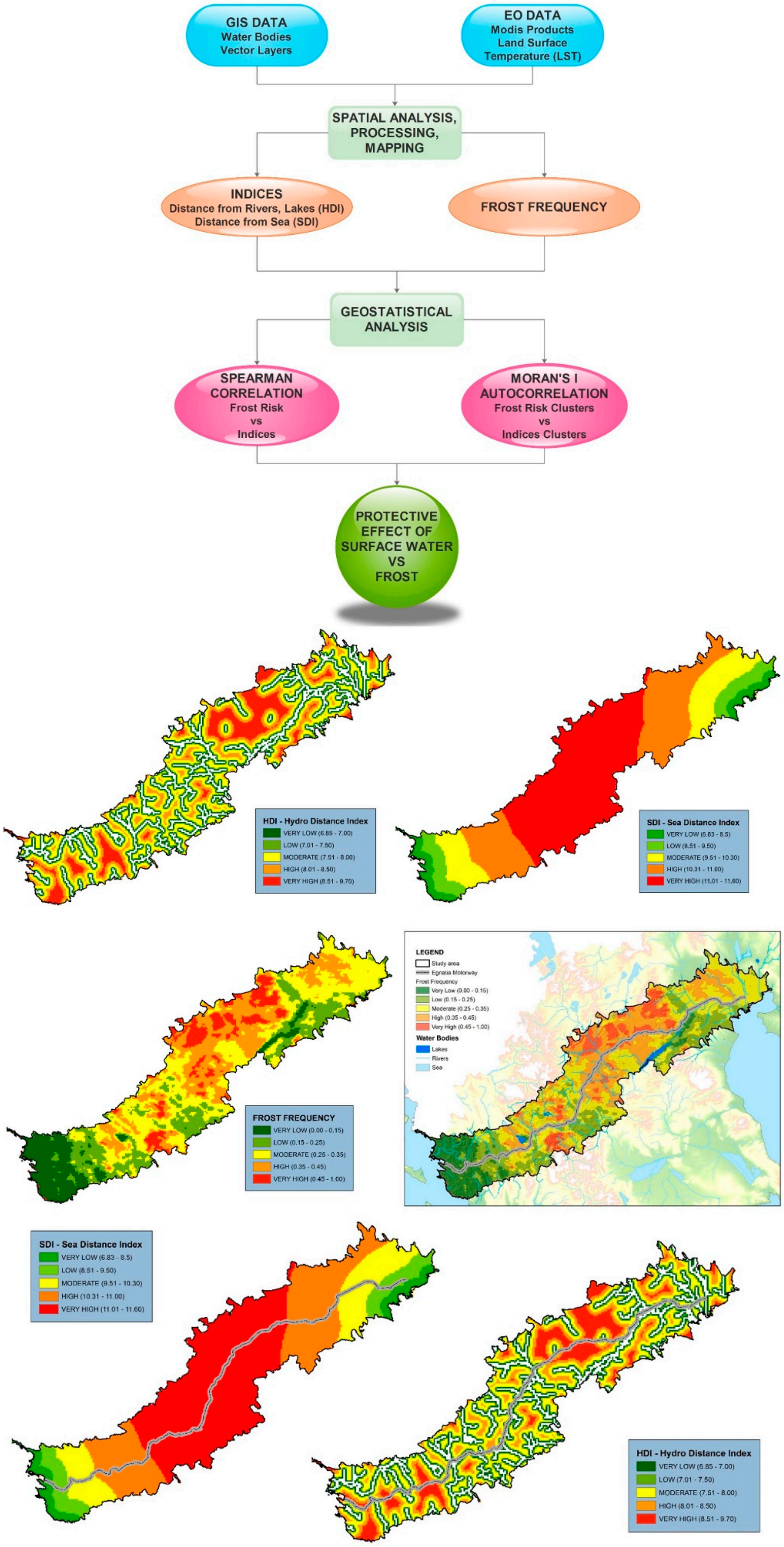

Figure 4. An example of integration of GIS and Earth Observation (EO) for frost monitoring [158].

Lastly, Sentinel-3 which has been developed by the European Space Agency and provides with LST data on a daily basis since 2017. The product SLSTR Level-2 LST product contains LST information with a spatial resolution of 1 km. The accuracy of the derived LST depends on atmosphere type and is estimated to be 0.8 °K for Polar Regions, 1.5 °K for mid-latitudes and 2 °K for equatorial latitudes [166].

In temperature fluctuation and frost monitoring studies, it is essential to have datasets with high spatial and temporal resolution. The limitations of the currently available EO data sets of either low temporal resolution, or low spatial resolution can be overcome by synthesizing high temporal resolution imagery with high spatial resolution imagery (Liu & Weng, 2012). The development of data fusion models such as Spatial and Temporal Adaptive Reflectance Fusion Model, has enabled the generation of ASTER-like daily land surface temperature with promising results [167–170].

2.5. Flood Monitoring

Natural disasters have significant impacts in many countries around the world, with a large number of deaths, damage to technical and infrastructure projects and population relocations. In addition, due to the significant impacts of climate change, these impacts are expected to increase in the coming years in many countries. Although technology and scientific knowledge have grown significantly today, natural disasters continue to have disastrous economic and environmental consequences, as well as many human casualties worldwide. The study and monitoring of these phenomena has been consistent in recent decades and has shown increasing trends [171]. In order to successfully monitor these phenomena and manage their impacts, it is very important to create hazard and risk maps for both the natural and the artificial environment [172,173].

Among the most dangerous and serious natural disasters, affecting more than 75 million people worldwide, are flood events [173]. In extreme flood events, it is important to quickly manage the magnitude of their impacts and land uses covered by water [174]. In this context, flood mapping and modeling are useful tools for monitoring, predicting, protecting, but also improving short and long term assistance to affected areas immediately after the event.

According to Lekkas [175], there are two types of floods, upstream and downstream. Upstream floods are observed in the higher parts of the drainage area and are generally the result of intense short-term rainfall in a small area. In contrast, downstream floods are caused by long-term storms that infiltrate the soil and cover a wide area. Most floods are the result of (i) the total amount and distribution of rainfall, (ii) the permeability of rock or soil, and (iii) the topography of an area. It has also been found that the distribution of land use, especially in small drainage basins, can significantly affect the size and frequency of floods. In addition, the risk of a flood in a watershed is determined by the following factors: land use, flood volume, intensity and frequency, elevation and duration of flood, season, weight of sediment deposited, and finally efficiency of monitoring, prediction, prevention, warning and emergency measures adaptation mechanisms [175].

New environmental challenges have put water resources monitoring and management at high academic and research interest. The local effects of climate change in recent decades, such as rising temperatures, decreasing rainfall (or increasing in other cases), desertification, etc., but also the occurrence of extreme phenomena such as storms, floods, landslides, and soil erosion threaten human life and infrastructure. The tendency to deal with this issue is rapidly increasing, due to the ever-increasing occurrence of such phenomena and the need for optimal monitoring and management, but also due to the technological boom that provides new tools and techniques. This constantly modifying and changing environmental regime has promoted the need for systematic research in related fields such as hydrology and/or hydraulics. Important goals of this endeavor are optimal methodological efficiency, comprehensive databases, and in particular state-of-the-art modeling developments, as well as understanding, monitoring and predicting an event or phenomenon of high importance nowadays. Modern geo-technologies (e.g., GIS and Remote Sensing) play a key role in this ongoing effort.

In the early 1980s, geographers argued that flood maps did not significantly influence people's perception of floods and at the same time did not provide sufficient research planning. According to the Canadian Flood Disaster Reduction Program, although awareness of the effects of floods has increased among—after mapping—groups, it is not due to maps [176,177]. In an effort to improve this weakness many methods have been tried. Among these is the use of Remote Sensing (RS), which is not a new idea. In 1980, proving the previous argument, a research paper proposed the application of remote sensing for disaster monitoring and warning through various processes, such as flood mapping and assessment [178].

During the next decade, the use of Remote Sensing and GIS in flood monitoring and research became well established. Both passive and active sensors were used and tested, as can be understood by the two following references. Hubert-Moy et al. [179] suggested that the spatial analysis of Landsat Thematic Mapper (TM) is compatible for the study of floods in small catchments. The study also supported the fact that satellite image processing and flow analysis can simulate flood conditions even several days after the event's peak, although the satellite's repeatability is low. On the other hand, the usefulness of synthetic aperture radar (SAR) data was examined in a 1996 study. This study was able to compare satellite data on river floods with photographic recordings (taken from a small aircraft) aiming to demonstrate the accuracy of the SAR technique [180].

In 21st century GIS, Remote Sensing and other modern technologies play an important role in flood monitoring, analysis and mapping, but also in hydrological and/or hydraulic modeling, firmly established. Many scientists aimed to develop new ideas based on the above tools and techniques. Free software packages have been developed and distributed, huge global digital databases have been created and a multitude of research projects have been carried out. The evolution and revolution of hydrological and hydraulic modeling, as well as flood monitoring, analysis, and mapping, with modern technologies are flourishing, constantly finding new applications, satisfying ever-increasing demands—needs and inviting more and more young scientists to work in this field. The use of remote sensing data for monitoring and investigating floods and related phenomena (e.g., coastal impacts from sea level rise due to climate change) has increased rapidly in recent years. Various monitoring and research applications were based on RS data like LIDAR (Light Detection and Ranging) [181], RADARSAT SAR [182], NEXRAD III [183], EUMETSAT, SENTINEL [184–186], COSMO-SkyMed SAR [187], optical and microwave data US DMSP/Quikscat, RADARSAT, LANDSAT-5/7 (TM, ETM+), EOS-AM TERRA/MODIS, SRTM DEM and ASTER [188–190]. The continuous evolution and improvement of remote sensing data (coverage range, spatial resolution, data frequency, etc.) is expected to continuously increase their use and efficiency.

Furthermore, several scientists have attempted to exploit, or propose new, hydrological, hydraulic and other models along with remote sensing and GIS data and techniques, in order to investigate and monitor several issues directly or indirectly related to surface runoff and flooding [189,191–195]. At this point it is worth mentioning the development of the HYDROTEL hydrological model [196], the application of the hydrological model SLURP [197,198], the SWAT model (Soil and Water Assessment Tool) [199–203] and its evolution SWAT2000 [204], the HEC-HMS/RAS models [183,186,205–211], the naturally distributed WEP-L hydrological model [212], the MIKE11 model [213], spatially distributed hydrological model LIS-Flood model [214]. An example of the variety of applications, which combines hydrological and other models (e.g., SLEUTH) with Remote Sensing and GIS, is the study of urban sprawl [215,216].

The evolution of geographic–spatial analysis methods, and in particular of GIS, has been the forerunner and essence of change to the approach of flooding from purely mathematical–theoretical models and in situ research into a functional approach through spatial analysis, spatial models, geostatistics and other related methods, e.g., logistic regression, frequency analysis, etc. [185,217–233]. The next figure (Figure 5) provides such a context [230].

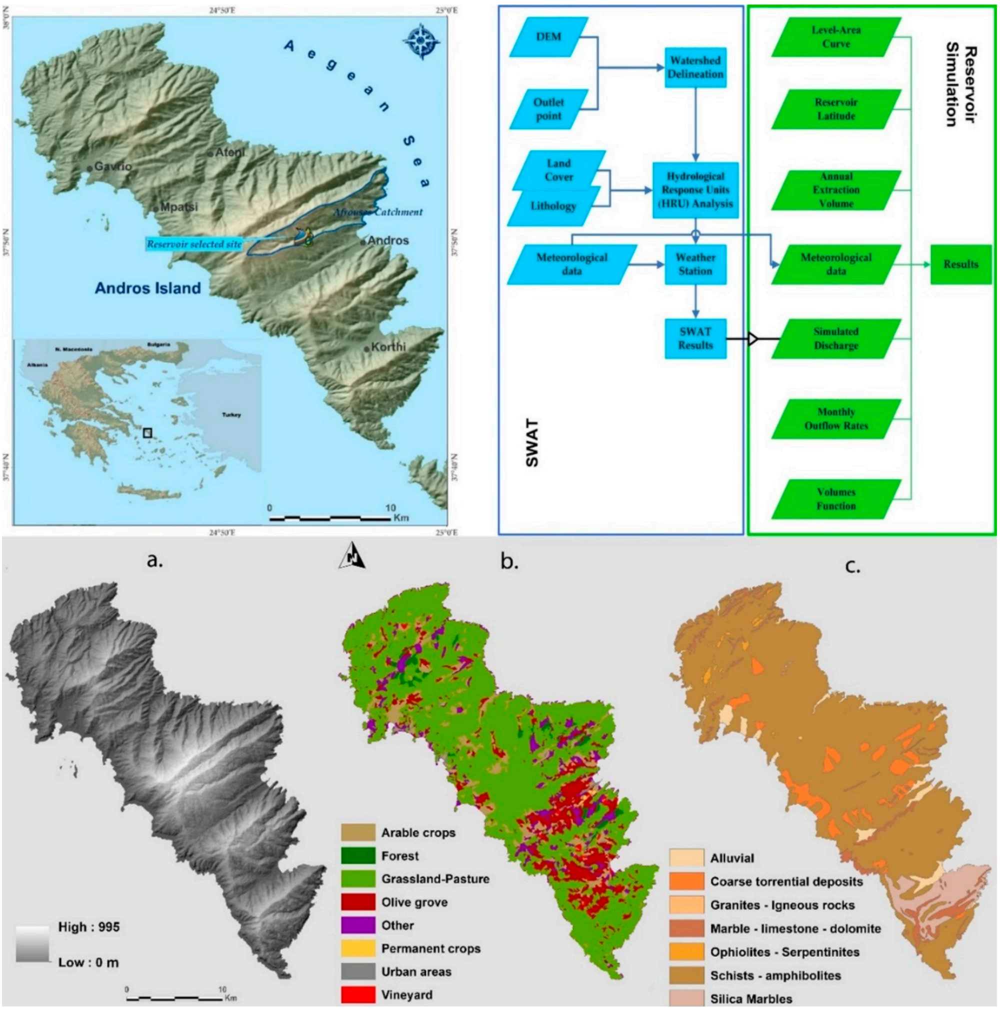

Figure 5. An example of GIS-based model for exploitation of floods via reservoirs ((**a**). DEM, (**b**). Land cover map, (**c**). Geology map) [230].

In general, the development of new technologies for rainfall–runoff modeling and flood monitoring, analysis, and forecasting, either in combination with GIS and Remote Sensing or autonomously, also involves the use of advanced methods such as Artificial Neural Networks (ANN), which are a highly evolving area of research [234,235], the application of fuzzy logic algorithms [236], SVM (Support Vector Machine) models [237].

The constant evolution of technology, as can be understood from the literature review, provides ever-more modern tools and techniques for the assessment and monitoring of natural disasters, and in particular floods. The development of new models (and the evolution of older ones), Geographic Information Systems, Remote Sensing, Applied Spatial Analysis, Geostatistics, etc., are some of the capabilities currently available to researchers, engineers, etc. to approach disastrous phenomena, such as floods. The need to apply these tools, to modernize existing methods, as well as to continually evolve and create new ones, is further enhanced by the effects of climate change and modern environmental, social, and economic requirements and needs.

2.6. Sea Level Rise Monitoring

According to the IPCC, (2018), global warming is likely to reach 1.5 °C between 2030 and 2052. Ablain et al. [238], explained in detail the importance of sea level rise, i.e., a measure of the increase in ocean volume, as a clear indicator of climate change and one of its main effects, by using data from European Space Agency (ESA) Earth Observation (EO) mission such as the ERS-1&2 and Envisat missions, the TOPEX/Poseidon, the Jason-1&2 and Geosat Follow-on (GFO) missions. Sea-level rise over the next century is expected to contribute significantly to physical changes along shorelines, enhancing coastal hazards particularly on low-gradient coastal zones, developing geodetic technologies and especially the Global Positioning System (GPS) [239,240]. Model-based projections of global mean sea level rise (relative to 1986–2005) suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5 °C of global warming [241].

Global warming is causing global mean sea level to rise mainly by the melting of glaciers and ice sheets resulting to the super induced addition of water into the ocean as well as by an increase of water body volume due to thermal expansion [242]. Relative sea level changes induced by variations for water in the oceans and land movements can be detected by tide gauges measurements, while EO satellite altimetry/gravimetry, as well as GPS satellites can be applied to measure absolute sea level changes at a global scale [243].

Tide gauges have been used since ancient times to record sea level variations but a well-developed network of tide gauges at almost 1000 locations around the globe, started to appear by the end of the nineteenth century. Moreover, the existence of altimeter satellites such as TOPEX/POSEIDO creates the opportunity for even better measures [244–246]. Human activities are estimated to have caused global mean sea level rise of about 21–24 cm since 1880 and even though there is a network of tide gauges provides valuable information about sea level changes from a few seconds to centuries [247–249], these observations suffer from several limitations, i.e., their geographic distribution which is poor in open oceans or the southern hemisphere, the availability of records which is not contemporary for all stations and the effect of vertical land movements which is the one of the main difficulties to interpret tide gauge measurements [244,250].

On the other hand, satellite altimetry together with SAR altimetry is described by Cipollini et al. [251] as one of the workhorses of open-ocean operational oceanography and global sea level monitoring, providing for more than 28 years valuable data sea level date with accuracies of the order of just a few cm even for the most remote areas of the oceans. Major support has been provided to the international scientific community by several space agencies such as the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and the Centre National d'Etudes Spatiales (CNES) in research and development of innovative techniques for coastal altimetry.

According to Ablain et al. [238] satellite altimetry data fit well with tide gauge measurements, however it is of great importance to be able to link the satellite altimeter measurements of sea level rise with the tide gauge measurements, by bridging the open-ocean measurements with those in close proximity to the coast in order to meet the scientific needs for better data resolution.

GIS has proved that when it is integrated with remote sensing data and tide gauge measurements, it has the potential to act as an important tool in monitoring the environmental and socio-economic effects of sea-level rise. GIS is increasingly used as a support tool in sea-level rise monitoring, as it allows homogenization and integration of all the available data into a geodatabase, in order to access information, perform spatial and geostatistical analysis and it has a strong potential to combine a broad range of complex variables and data in varying formats and to integrate physical, ecological, socioeconomic, and hazards information. Furthermore, owing to its numerous advantages such as editing and data automation, visualization, mapping and map-based tasks, spatial consultation, spatial analysis, and geostatistical analysis and its flexibility, GIS can be used in further planning applications and future scenarios. Over the years GIS has shown great potential in its application and problem-solving capabilities and a great number of researchers have applied GIS-based methodologies to study sea level rise globally and regionally.

3. Contribution of Earth Observation in Natural Disasters

In the era of climate change, disasters are a cause for concern in the research sector due to their devastating effects worldwide. Indeed, the incidence and frequency of natural disasters has significantly increased in the recent decades [252–254]. A variety of scientific approaches are employed to reduce the loss from disasters based on their characteristics.

Earth observation (EO) has progressively developed into a significant resource for disaster management, including the quantification, and detection of the spatiotemporal distribution and variability of many environmental hazards at different scales [254,255]. Especially the rapid growth in the EO sector over the last decades has made it easy to capture the impact of disaster on land, water, vegetation, and human health during many disaster events. Satellite-based EO is regarded now an established technology for mapping and monitoring spatial information about disasters at frequent intervals in all weathers at real time [256,257].

Satellite remote sensing is becoming gradually the preferred tool for disaster management, because it offers information over large areas at short time intervals. Furthermore, the information gathered from past and present conditions allows the identification of changes occurring in Earth's cover and helps to frame management and mitigation strategies [258]. The obtained EO datasets are the primary input data source for various geospatial analyses that allow retrieval, mapping, tracking, simulation, and representation of disaster-related events in a more effective and accurate manner in a short time without visiting the ground. EO exists scientific and technical strengths pose a broad range of new capabilities in assessing and monitoring several features of environmental variables [259]. Thus, remotely sensed forecasting-nowcasting, monitoring, and assessment of environmental hazards is becoming attractive, since these systems provide also consistently available data with high resolution covering large areas [260].

EO includes satellites with varying spatial and temporal resolution at both geostationary and polar orbit. Both orbit types consist two complementary sources of data which can provide the best choices for disaster management. Polar-orbiting satellites are placed at low altitude (<1000 km from Earth surface) provide data at high spatial resolution and low temporal resolution. On the other, the geo stationary satellites are placed at higher altitude (36,000 km from Earth surface) and acquire data at low spatial resolution with high temporal resolution (even in order of few minutes) [261–263]. Many satellite platforms carry more than one sensor onboard, which acquire spectral information starting from the visible, infrared, and thermal to the microwave region of the electromagnetic (EM) spectrum. Between others [252,264,265], have reviewed the use of different EO sensor types in various natural hazards. Depending on the interaction mechanism of the EM wave with atmospheric constituents and the surface features of the Earth, the sensors that operate in active and passive mode at different wavelengths are used to collect data on various geophysical phenomena. Monitoring of natural disasters over the decades reveals that EO measures natural disasters using primarily optical and microwave (MW) technologies [266,267].

Natural disasters predictions rely on the availability of suitable EO data products which could be collected by short- to long-term monitoring [268,269]. Continuous and frequent EO provides high spatio-temporal data that allows gathering information to study past and present phenomena. There are currently numerous EO data available for tracking natural hazards, including data on the buoys located on the ocean floor, station used for tracking the atmosphere, observations of aircraft and orbital satellites around the globe. Optical sensors have constantly improved both spatial and spectral resolution [253,263,270]. For example, optical sensors MODIS [271], ASTER [272,273], Hyperion [274], and OLI [263,275] have proven their advantage and usefulness for mapping hazards successfully but the use of such data is limited by weather conditions. On the other, microwave sensors overcome these limitations and are used where factors such as clouds impede optical observations. Some of such sensors for mapping disasters are radio direction and ranging (RADAR), radiometers, scatterometers, and radar altimeters [254].

Mitigation of natural disasters can be successful when detailed information about the expected frequency, characteristics and magnitude of natural hazard over any area are available [276]. There are three major phases of disaster management activities on which EO can potentially contribute to (1) the preparedness phase occurs long before the event with risk prediction and risk zone identification; (2) the prevention phase taken up just before or during the event, includes early warning/forecasting, monitoring, and preparation of contingency plans; and (3) the last phase is response and mitigation for damage assessment and relief management just after the event [277]. Information required during any of those phases of hazards' phenomena can be gathered from EO sensors over a large area by means of various sensors operating on board aircraft or satellites. Subsequently, this information can be processed in a GIS environment implementing appropriate geospatial analysis techniques, to deliver information useful in developing an effective disaster management plan for optimizing preparations and undertaking management options [256,263,278]. Disaster mitigation and preparedness can be successfully made possible using EO data and image manipulation techniques and offer input data as systematic observations to risk modelling [256,279]. The geospatial analysis of land surface condition integrated with various spatial and non-spatial data helps in efficient management and framing effective mitigation plans. The broad variety of data with different characteristics allows identification of surface and subsurface ground conditions and provides minute and rapid analysis. However, there are certain limitations with the use of EO in natural disasters. For example, EO does not provide information about the subsurface ground features beyond certain depths. EO data predictions also come often with some biasness, and ground truth observations for calibration and validation process are required to assess their predictions.

Particularity and Technical Characteristics of EO Satellites

The methods, techniques, and tools described in this work are modern contemporary and effective tools for research, management and monitoring of the environment and geo-environmental hazards in general, such as drought, floods, soil erosion, groundwater, frost, sea level rise, etc., as well as all the valuable natural resources. One of the most important features of these tools, which enhance their dynamics, is their evolutionary capabilities, which are based on the modern way in which these methods were developed and structured (modern software, data, techniques, etc.). Therefore, the ever-increasing scientific knowledge and technological progress will always be beneficial in the evolution of the methods presented.

Regarding satellite programs, there are two main types of earth observation imagery—Passive and Active imagery. Passive imagery includes panchromatic, multi-spectral, pan-sharpened, hyper-spectral, microwave radiometry and Active imagery includes Synthetic Aperture Radar (SAR), LIDAR, Radar Altimetry, GNSS-R and Radar Scatterometry. Low resolution images have a Ground Sample Distance larger than 300 m. Medium resolution is between 300 m and 30 m, high resolution from 30 to 5 m and very high resolution (VHR) below 5 m. In terms of duration there satellites with revisit time 1 h (e.g., COMS) but the Ground Sample Distance (GSD) is 500 m and there are satellites with revisit time 26 days but with the GSD being 2.5 m (e.g., SPOT-5). Furthermore, the number of bands differs between different types of satellites. Thus, there are satellites with 1, 2, and 3 bands (e.g., Himawari 8) and satellites with 21 bands (e.g., Sentinel 3 A/B). Thus, there is a variety of choices in terms of satellite sensors or platforms, GSD, which would be most suitable each time for an application or research investigation. The next table (Table 2) is providing the most famous EO satellites with their main characteristics (launch year, number of bands, spatial resolution, altitude, and revisit days).

Table 2. EO satellites and their main characteristics.

Satellite Name	Launch Year	No of Bands	Spatial Resolution (m)	Altitude (km)	Revisit Time (Days)
SPOT 1	1986	3	20	832	2–3
SPOT 2	1990	3	20	832	2–3
SPOT 3	1993	2	20	832	2–3
SPOT 4	1998	4	20	832	2–3
SPOT 5	2002	4	10	822	2–3
SPOT 6	2012	4	6	694	1
SPOT 7	2014	4	6	694	1
MODIS	1999	36	250–1000	705	1
Landsat 1	1972	4	80	917	18
Landsat 2	1975	4	80	917	18
Landsat 3	1978	4	80	917	18
Landsat 4	1982	6	80	705	16
Landsat 5	1984	6	30	705	16
Landsat 6	1993		30	705	16
Landsat 7	1999	6	30	705	16
Landsat 8	2013	9	30	705	4.5
Sentinel 1	2016	C	2	693	12
Sentinel 2	2015	13	10–60	290	5–10
Sentinel 3	2016	21	300	814	100 (min)
SeaSAT	1978	L	20		24
ENVISAT	2002	C	25–50		35
Radarsat-1	1995	C	20–30		24
Radarsat-2	2007	C	20–30		24
ALOS-1	2006	L	9–30		46
ALOS-2	2014	L	6–10		14
COSMO-SkyMED	2007	X	3–15		1–8
TerraSAR-X	2007	X	1–3		11

Nevertheless, a challenge that needs to be addressed in terms of satellite programs, actually is the time-consuming consolidation of downloads and data production. The latter, which requires the sending of new satellites and their integration into existing formations. At the same time, effort is required towards improving the spatial discretion of the receivers (and therefore the products) of these satellites, which in order to achieve this requires a new generation of sensors (transmitter and receiver) in satellite equipment. In addition, one of the possible future targets for environmental surveillance products would be to try to reduce the error they present, which, as mentioned, is already evolving in product documentation. Efforts to validate and improve this data are already being carried out by co-processing ground measurements from stations in several EU countries, with the aim of not only adjusting the error by comparing the measurements, but also assessing the specific weather and morphological conditions of each region.

4. Environmental Monitoring, Geospatial Data, and Spatial Data Infrastructures (SDIs)

Environmental monitoring processes are directly connected to the collection, store, management, and analysis of spatiotemporal data. The collection of several types of environmental data is based on the use of both smart devices and sensors [280] including also mobile and low-cost solutions [281]. Moreover, traditional monitoring instruments are combined with Unmanned Aerial Systems (UASs) towards the production of high resolution data in both temporal and spatial dimension [282,283]. Over the last decades, the expeditious development of Geographic Information Systems (GIS) tools contributed substantially to the effective management and analysis of geospatial data. However, modern approaches of geospatial data manipulation, in both national and multinational level, are based on the use of integrated Spatial Data Infrastructures (SDIs). In European level, the status of the national SDIs, as well as the influence of European INSPIRE Directive, are discussed in several studies [284–287]. At the same time, other studies describe the use of

SDIs in national level (e.g., in Poland) [288] or in specific domains based on environmental data collection (e.g., in marine spatial planning) [289].

The basic components of an SDI model can be grouped into three main categories, including users, technology, and products [290]. In this categorization, technology part contains additional subcomponents including access network, policy, standards, metadata, as well as processing tools, while the main products of SDIs are consisted of data and services [290]. Among the basic parts participated in the design and the implementation of contemporary SDIs, users have undoubtedly a significant role. The last decade, several studies highlight also the importance of incorporating volunteered geographic information (VGI) for environmental monitoring [291], of course with a respect on the derived data quality [292,293]. Simultaneously, a huge and open challenge is referred to the integration of VGI techniques into global GIS platforms [294].

One of the major and challenging issues in SDIs development is related to cartographic data harmonization [295], either in national or multinational level. Considering that environmental monitoring data are usually produced by several organizations (possibly with non-uniform standardization protocols) using different devices which may produce various file formats and/or data characterized by different ranges of spatiotemporal accuracy, this process of their integration is considered quite important. For example, incompatibilities in monitoring can be referred to different temporal and spatial scales [296]. Geospatial data harmonization can be achieved either considering common approaches in data standardization (i.e., implementing common directives such as EU INSPIRE Directive) or after implementing methods which examine geospatial data heterogeneity in terms of their nature and distribution [297].

As also mentioned above, SDIs provide both data and services to the potential users. Particularly, geospatial data services give the opportunity to distribute different types of geospatial data, including vector (e.g., ESRI® shapefiles) and raster (e.g., GeoTIFF) data, as well as (geo) databases (e.g., PostGIS databases) via World Wide Web (WWW). This information can be accessed through desktop GIS environments, simple web browsers, or other (spatial data) infrastructures, while geospatial data can be used in several standalone or web-based applications. The basis of geospatial data services is connected to the use of specific open protocols and standards, such as Web Map Services (WMS), Web Feature Services (WFS), Web Coverage Services (WCS), and Web Map Tile Services (WMTS). The aforementioned standards are developed and distributed by the Open Geospatial Consortium (OGC, https://www.ogc.org/, accessed date: 20 December 2020) in order to ensure the interoperability among the developed systems. In general, modern web mapping approaches utilize open source technologies, including open data, software, and tools [298,299], while online map services is a new cartographic cultures which requires the collaboration between cartography and GIS community and this of software developers [300]. Klein et al. [301] point out the need of open source platforms and widely available cloud-based environments in order to move forward to open scientific analysis of environmental data. Hence, prototype solutions, such as the application provided by Wiemann et al. [302] for water quality, could be adapted in several domains having either local, international, or global coverage. Towards this direction, recently Lacroix et al. [303] present also an open platform (MapX) which aims to support environmental monitoring process by provided authorized geospatial data in local, national, and global scale.

Finally, SDIs can serve as powerful Decision Support Systems (DSSs) with valuable applications in environmental monitoring processes for scientific and/or decision-making purposes. Concurrently, considering the variety of Internet of Things (IoT) devices, contemporary SDIs could also provide real time (or near real time) geospatial information [304] which can be used as an input in several (online or not) geo-processing analysis tools in a specific geographic context [305].

5. Discussion

The necessity for resourcefully managing with environmental monitoring has led numerous scientists to carry out studies on a variety of directions such as prediction and impact assessment, besides monitoring. The modern requirements for small budget applications and management tools are met by the continuously developing modern technology. Thus, advances in geoinformation technologies, such as in RS satellite technology, open spatial databases, and contemporary technologies in GIS, area likely to complement overpriced and time-consuming fieldwork, outdated techniques and enormously problematic data collecting methods.

In support to the above mentioned, this work presented an extensive literature review consisting of 304 references. From this total, 192 refer to applications involving GIS and 150 refer to applications involving RS. 226 refer to applications in specific study areas, 23 refer to applications worldwide and the rest do not relate to specific applications or specific areas. The next figure (Figure 6) presents these facts.

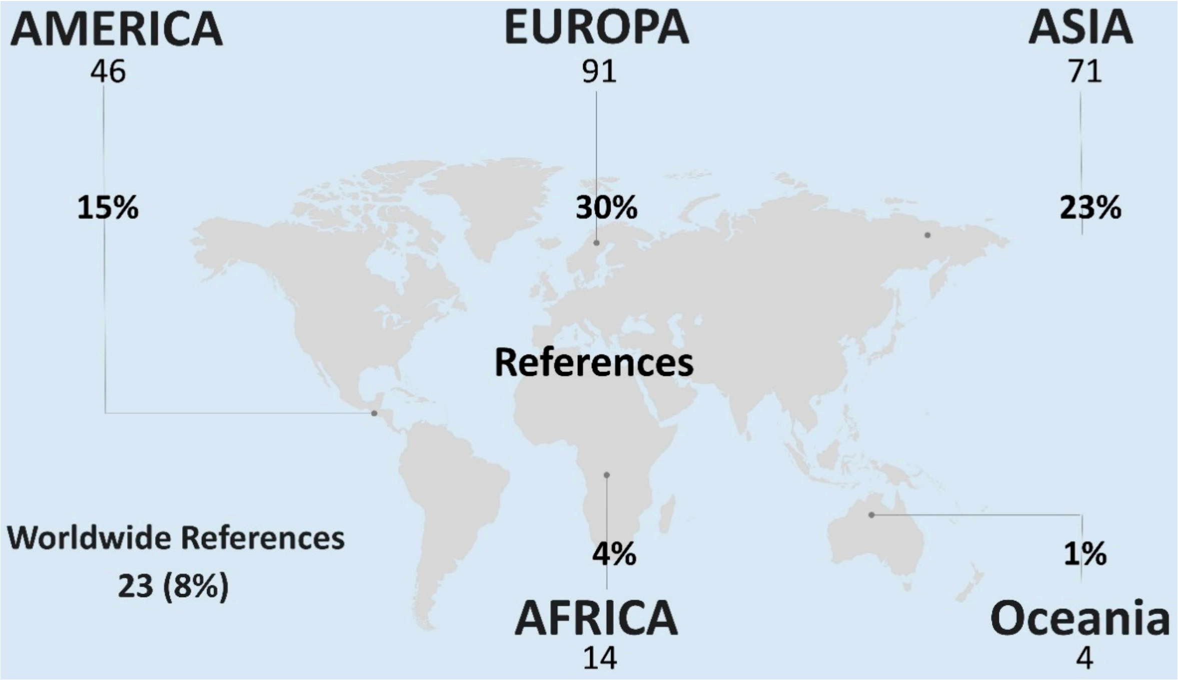

Figure 6. Spatiality of research areas in used references.

The above figure shows the spatiality of the used references in terms of continents. One of the goals of this work is to present applications from around the world. Thus, the provided reference list covers this goal. In parallel, these references are not from specific regions from each continent, but they are referred to a variety of countries within each continent. Thus, there are many countries that are been covered through the presented references, such as Australia, Brazil, Canada, China, France, Germany, Greece, India, Iran, Italy, UK, USA, etc. The next figure (Figure 7) presents these countries.

Figure 7. The referred countries of this work.

6. Conclusions

As has been made clear from the present review, continuous monitoring of the environment is subject to an interdisciplinary approach. It includes a number of procedures and actions that cover both the evolution of natural phenomena and their catastrophic effects mainly due to the problem of climate change. However, what is the deep meaning and at the same time the cause that challenges all these changes and the effects on the environment? Why is this explosion of scientific methods and technologies happening today in order for this monitoring to extend to protection measures?

It is concluded that mentioned methodologies, technologies, and tools attempt to provide extensive solutions for disaster detection, modelling and monitoring of the environment. Appropriate geospatial data and procedures together with other socioeconomic data can be used in order to evaluate the risks involved. Thus, these data can provide raw material towards the creation of management plans and mitigation policies. The comprehensive diversity of data with dissimilar features permits the monitoring of the environment to the fullest extent at the time, while trying to reduce uncertainties and limitations.

7. Current Challenges and Future Trends

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) reports that this is a very crucial decade in terms of future terms in geospatial technologies. The previous decades the digital data provided the basis for the decision making policy for the public and private sector. Nowadays, digital world is producing huge amount of data and especially geospatial data with such a speed, in which the main task is to reveal new ways of understanding and analyze of this data very fast.

Thus, new trends like big data, artificial intelligence with machine learning and deep learning techniques, new EO products, drones, smart cities, autonomous vehicles arise. All these must be managed in a sustainable way in order to maximize the profit that results from them. This will lead to improved monitoring by using for example better satellites, improved spatial and temporal resolution, better modeling/analysis (geostatistical analysis, time series analysis, and geospatial intelligence) in all phases (pre-, plus-, and post-catastrophic) and finally to better response/participation (speed improvement, mobile applications, crowd sourcing, etc.).

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