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Systematic Review of the Study of Flood Risks using Remote Sensing

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***Abstract:** Floods are one of the most devastating natural disasters that cause various losses by having an excess of rainfall in a short period of time, they cause a high flow in rivers, subsequently damaging crops and infrastructure. They also cause sedimentation of reservoirs and therefore limit the ability of existing dams to control floods. In other words, the purpose of assessing the risk of a flood is to identify the areas of a plan that are at risk of flooding based on the factors that are relevant to the risks of flooding. Therefore, it is important to create a flood map that is easy to read and quickly accessible. Maps provide a stronger and more direct impression of the spatial distribution of flood risk, like diagrams and verbal descriptions. On the other hand, the repeated taking of satellite images in periods of time of a few days makes it possible to know the evolution of the floods, helping the authorities to access the affected population, as well as to define safety areas. The current work aims to systematically evaluate the study of flood risk through remote sensing. A qualitative analysis was carried out through which 80 articles indexed between 2017 and 2021 were reviewed, distributed as follows: 49 articles are from Scopus, 10 from Ebsco and 21 from ScienceDirect; It is concluded that geographic information system together with remote sensing technology are the key tools for flood monitoring, as it is a very cost-effective way to reliably deliver the required data over a large area, as well as record data under extreme conditions to overcome the limitations of ground stations*

***Keywords:** Flood map, Flood risk, GIS, Remote Sensing*

I. INTRODUCTION

Disaster risk has a significant impact on the well-being of any nation [1], as is the case in East Africa in the mid-21st century; flood disasters killed around 500 lives according to the March 2018 record [2]; In India, due to the frequent occurrence of droughts, more than 70% of its geographical area is exposed to the risk of flooding [3] or it also occurs due to the orography of the environment, as in Silesia Czech Republic, in terms of steep slopes and high percentage of soil types with low infiltration intensity [4]. The impact of floods affects the socioeconomic life of people, with the most vulnerable and poorest populations being the most affected [5]. The degree of importance of vegetation in watersheds provides a wide range of benefits; and its degradation would increase the rate of air pollution, erosive effects, and flooding, as well as threatening public health and social well-being [6]. Optimal water use occurs when there is proper resource planning, including more precise knowledge of morphometric parameters and runoff to accommodate flood conservation and management [7]. Engineering and project management are making enormous efforts to prevent and / or mitigate floods through design, construction and maintenance [8], however, in recent years, new technologies have become necessary to restore confidence and the comfort of the users; one of them is remote sensing [9]. In recent years, satellite remote sensing technology is playing an important role in flood monitoring, loss assessment and risk assessment [10]; basically, remote sensing devices, space vehicles or air, provide indirect precipitation measurements that require appropriate recovery algorithms, including passive or active sensors and ground-based weather radars [11] [12]. In a recent article, Cázares et al. performed a comparison of semi-distributed hydrological models between HEC-HMS and tRIBS (Integrated Real-time Watershed Simulator) to capture a simulation analysis that serves as strategies in flood mitigation; Despite the good results, the authors recommended the use of remote sensing products to overcome the drawbacks or limitations of data availability [13]. Teng and his collaborators also investigated the limitations of the TVD (Teng-Vazze-Duta) model compared to remote sensing extensions and observed that the proposed weighting scheme of the first model depends on the availability, precision and cost of processing the maps. remote sensing water tank [14]. GIS and remote sensing techniques are tools that facilitate the development of spatial models in areas susceptible to flash floods; its integration has individualized susceptibility investigations in machine learning models [15] such as: logistic regression, artificial neural network, bayes ingenius, neuro-fuzzy interference system, support vector machine; and parametric and non-parametric models [16]. There are more than 1700 operational satellites deployed on Earth and equipped with integrated and dynamic sensors to monitor the effects of disasters such as floods or landslides [17]. Rambabu's research and his collaborators generated thematic maps on drainage networks, slopes, geomorphology, land cover / land use and groundwater prospect maps; having as data resources of the Indian satellite platform IRS P6 in data LISS-II and LISS-IV [18].

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Abdelkarim et al. assessed the flood hazard for the city of Tabuk, merging the use of remote sensing (SR), GIS and hydrological models (HEC-HMS and HEC-RAS); using Landsat remote sensing technology in the extraction of multispectral resolution images of 1.84 m [19]. Wang et al. presented an airborne remote sensing method, as a measure against the disadvantage of satellite photography in the occurrence of rain and cloud obstruction, although it is not comparable to professional remote sensing, the development of computer vision algorithms and image processing to a mosaic orthoimaging is achieved for rapid flood disaster mapping [20]. The objective of this review is to select types of scientific research on the study of flood risks using novel remote sensing technology; in the analysis of machine learning models, geospatial data, interference from survey techniques, in the implementation of flood management measures.

II. METHODOLOGY

For the development of this review, recognized databases such as ScienceDirect, Scopus and Ebsco were included. The procedure consisted of a bibliographic search using the following keywords: flood risk and remote sensing, flooding and remote sensing, study of flood risk and remote sensing, risk and remote sensing, remote sensing, as shown in Figure 1, it also took into consideration articles published from 2017 to 2021, as shown in Table - I. To search for these articles, the sequence shown in Figure 2 was followed.

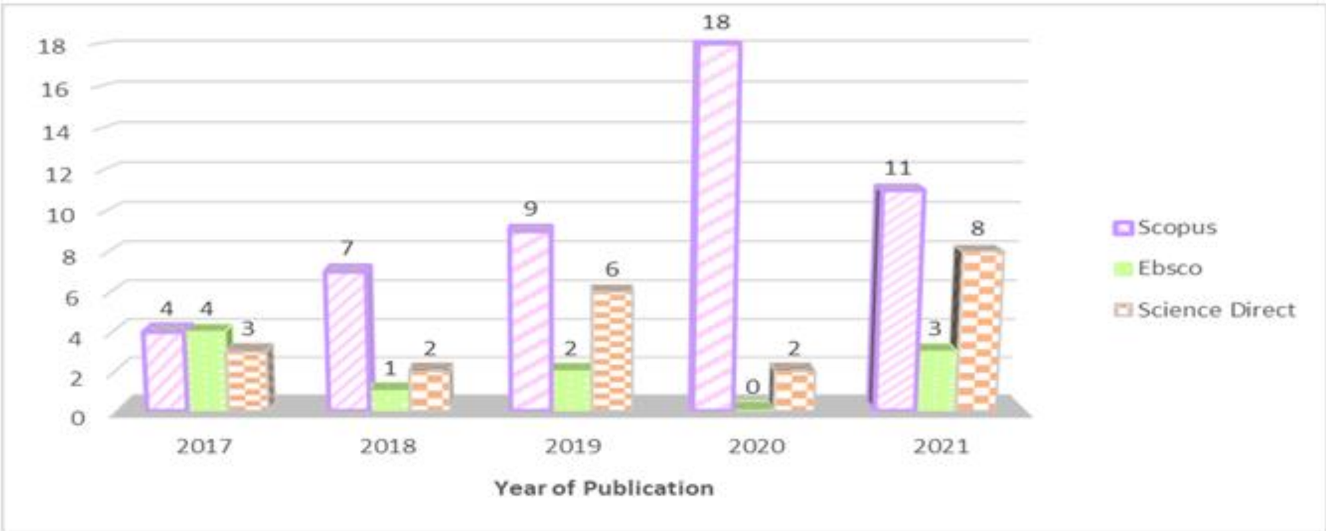

Fig. 1. Distribution of articles by year of search

Table- I: Search category of articles by keyword

Database	Keyword	Keyword using Boolean operators	Years of Search	Search Results	Subject Area Filters: Area	Subject Area Filters: Type of Document	Filter Results	Selected articles
Scopus	flood risk and Remote sensing	flood AND risk AND Remote sensing	2017-2021	1264	Engineering	Article/Review	104	8
	flood and remote sensing	flood AND remote AND sensing		6517			558	12
	study flood risk and Remote sensing	study AND flood AND risk AND remote AND sensing		785			66	3
	risk and Remote sensing	risk AND remote AND sensing		9569			747	26
Science Direct	flood and risk and Remote sensing			15483		Research articles/Review article	1082	14
	Remote sensing			250193			32290	7
EBSCO	Remote sensing	Remote sensing		254201	geographic information systems, artificial satellites	Academic Publications/ Professional Publications/ Journals	10010	2
	risk and Remote sensing	risk and Remote sensing		8491			807	8

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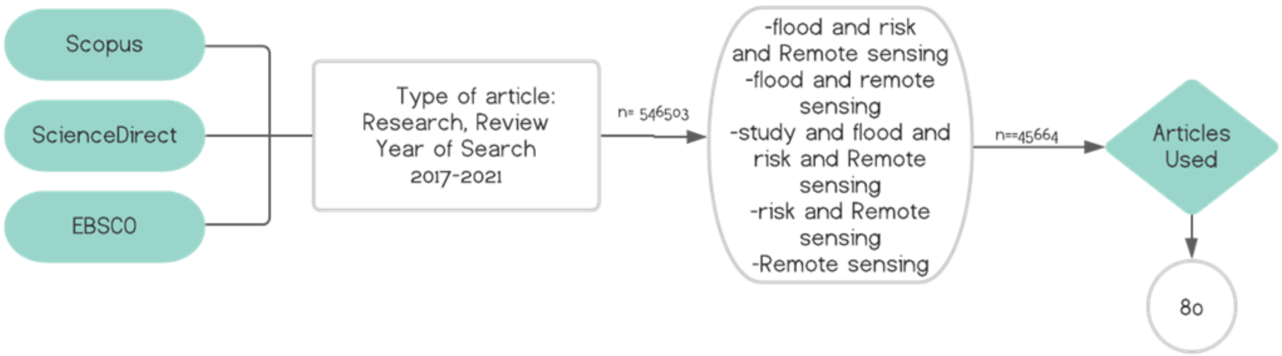

Fig. 2. Publication search and selection process

III. DEVELOPING

A. Remote sensing floods

Flood prediction models and advances in method applications have improved recommendations for reducing flood damage while reducing the risk of death. Historical data arising from empirical approaches are used to predict floods based on statistics, thanks to which technological advances have been achieved, especially in the areas of big data and machine learning [21]. The estimation of floods through satellite images (SI) is one of the analyzes that easily identifies the impact of natural disasters and natural water resources. Bodies of water (BW) have a very particular behavior towards the electromagnetic spectrum (ES) and can be visually enhanced by simple compositions of spectral indices (SI) [22]. Masses of water in liquid state (MWLS) tend to absorb energy, with a lower absorption in the visible bands (VB) and a slightly higher absorption in the short-wave infrared bands (SWIB) [23]. The reflection of the band is almost horizontal for liquid water. But when we find BW in solid state (BWSS), the visible bands reflect energy alarmingly and decrease when combined with SWIB [24]. This simple behavior will be what will set the standards for compositional analysis when working with BW [25]. MWLSs along any satellite band (SB) show dark tones due to energy absorption, while BWSS show bright tones due to energy reflection [26]. Acting with SB and, understanding the behavior of water throughout the ES, it is possible to work and analyze aspects such as the location of wetlands in the territory, quantify falls and movements of BW, evaluate surfaces affected by floods, or visualize irrigated areas in agricultural contexts [27] [28]. Flood analysis, with the help of satellite data, can work strategically with the bands of work to quantify and identify areas and zones affected by floods [29]. Conventional optical techniques from satellites like Landsat and Sentinel clearly show affected areas [30]. In a case of flood analysis with conventional optics, the SWIB are fundamental in the composition of EI of the image to be analyzed [31]. The affected area can begin to be analyzed by experimenting with filters such as Sentinel's traditional false-color SI [32]. This is how BWs look amazing when they experiment with SWIB in SIs [33]. Chromatically marked territorial elements can be reclassified to generate vector boundaries and determine the area in question through GIS [34]. Only analyzes such as supervised reclassifications are needed to classify land uses, as well as to identify the time before and after floods [35]. Thus, you will observe a flooded area when using SB in your study [36].

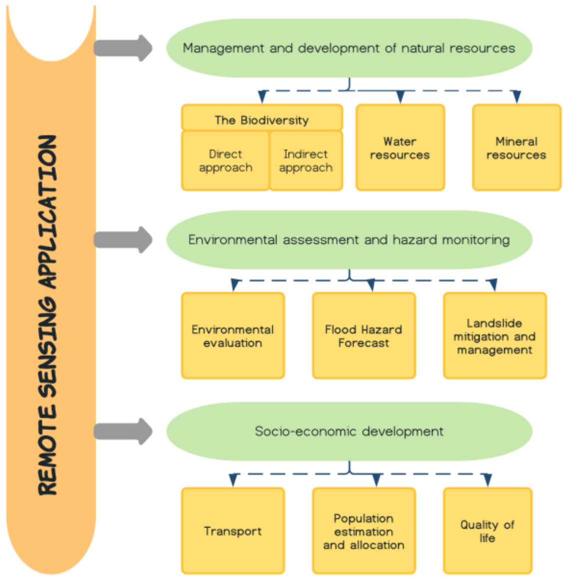

Fig. 3. Remote sensing applications

Source: [31]

In addition to SI compositions, it is also possible to distinguish BW and humid environments using indices such as the Normalized Differential Water Index (NDWI) [37]. The relationships between bands such as those proposed in the McFeeters method, the Gao method and the Xu method help to establish a standardized index to discriminate different territorial environments [38]. In these cases, it is necessary to use the SWIBs to compose the index according to the chosen method [39]. In these cases, it is necessary to use the SWIBs to compose the index according to the chosen method [40]. Under the NDWI index, a range of values between -1 and 1 is obtained, which can be used to interpret the areas with the presence of water in the territory.

B. Detection of flooded areas

Flood risk assessment focuses on flood management [41], and for an effective assessment to be developed, it is very important to have a flood scenario that incorporates the possible processes that arise during the event [42], and understanding these processes requires topographic, edaphological and meteorological data, as shown in the following image [43].

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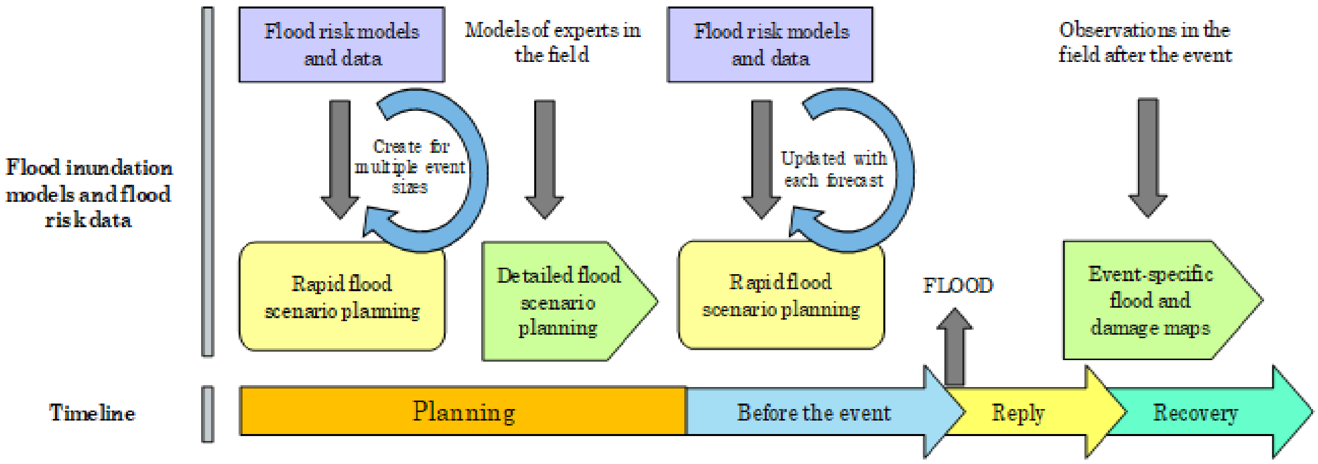

Fig. 4. Chronology of the chronology of a flood event

Flood delineation is currently based on hydrological and hydraulic modeling, remote sensing and field data collection [44]. Despite the benefits of these tools, they also have specific limitations, which may be related to the local context or be intrinsic [45]. Satellite information is commonly used as a tool to map areas affected by water. Therefore, it must be integrated with other types of information, forming a GIS [46]. The most frequently addressed applications with these tools are: flood risk analysis, flood mapping and monitoring, vegetation study in wetlands, flow modeling in rivers and streams, flood monitoring in urban areas, post-flood damage assessment, flood risk analysis, flood risk assessment, flood monitoring and mapping, and post-flood damage assessment [47]. The presence of water on the surface can be detected by active and passive sensors, since liquid water has the property of absorbing radiation in the mid-infrared range of the ES, so the reflectivity in this section is close to zero [48]. On the opposite, the amount of energy reflected in the visible regions of the near infrared can have a greater variability. This variability depends on the optical properties of the suspended particles, the water surface and the reflectivity of the submerged soil [49]. When conducting a floodplain survey, the first objective is to quantify the affected area. Bearing this in mind, it is necessary to make a map of the study area, classifying them by classes, whether they are flooded or non-flooded pixels [50]. Furthermore, depending on the extension of the research area, the properties of the classes, the required precision, the availability of images and the mapping will be carried out from high or low RE images [51].

Rapid response to floods is essential to limit damage and prevent unnecessary loss of life, which requires rapid monitoring of floods, in particular by mapping flood-prone areas [52]. Traditional ground survey in the field is often time consuming, expensive and impossible for inaccessible areas without air support. High-frequency, wide-range satellites are useful for monitoring flood dynamics for damage assessment and immediate response to emergencies [53]. Early flood mapping applications involved combinations and uses of visible spectral bands, such as VHRA (Very High-Resolution Advanced Radiometer) and VHRR (Very High-Resolution Radiometer) with a resolution of 1 km Vegetation Index of Normalized Difference (VIND).). With Landsat and MODIS, infrared spectral bands were created and temporal and spatial resolution were increased, resulting in better flood monitoring capabilities [54]. MODIS and VHRAR are used for large-scale mapping and often provide global daily coverage, but due to their low spatial resolution, accuracy is limited. Planet, Sentinel2, and Landsat, however, provide small-scale, reliable, spatially resolved images that are suitable for dynamic analysis and monitoring of some surface processes. However, optical sensors that are obstructed by clouds often have high coverage during floods caused by heavy rains [55]. Weather satellites use very high-resolution radiometric sensors (VHRAR) to generate natural dynamic transmission (NDT) images and collect remote sensing data from the National Oceanic and Atmospheric Administration (NOAA). By orienting the probe lines, they become perpendicular to the satellite's orbit because they provide a new low-cost NOAA remote sensing solution. In more detail, this approach focuses on the ability to sample a signal that has been processed and modulated in software, thanks to recent advances in software defined radio (SDR) [56]. This satellite provides adequate information to monitor flooded areas, generate alarms, estimate damage and manage excess water [57]. The determination of the extent of the flood from satellite images is based on synthetic aperture radar (SAR) or multispectral images (MI) [58]. The MI sensor is limited to clear conditions, while SAR images are plagued with noise such as speckle. Using a combination of SAR and MI data exceeds the limits of such sensors, which test the sensitivity of flood mapping performance to different combinations. The acquisition spectra of MI and SAR serve to transform the measurement band [59]. SAR providing high resolution images in all types of weather, with day and night resolution has proven useful for mapping one flood to another in real time. The SAR contains potential for adequate monitoring based on flood information. It also offers an optimal opportunity to understand flood risk and its rapid response to the proliferation of SAR satellites with very good temporal and spatial resolution [60]. However, traditional algorithms for flood extraction using SAR often require manual parameter adjustments or data annotations, posing challenges for rapid automatic mapping of large and complex flood scenarios. To solve this problem, a segmentation algorithm is proposed for near real-time automatic flood mapping over large areas and for all weather conditions by integrating SAR images [61].

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A time series of images allows you to track the duration of a flooded area, which can generate a warning before the event occurs. High resolution images are useful for accurately delineating flood zones and risk mapping [62] [63]. The analysis of the history of floods allows delimiting the alluvial plains based on different scenarios and, for this, it is necessary to keep a record of the areas that are usually affected by floods [64]. Therefore, this analysis can be performed for entire administrative units and individual lots [65]. The main mechanism involved in identifying flooded areas from radar data is the drastic variation in surface roughness [66]. In other words, a body of water with a slightly smooth surface, when it emits microwaves by radar acting in an oblique direction, is specifically reflected away from the antenna [67] [68]. The main difficulties encountered in delimiting ACAs arise when aquatic vegetation or wind alter the roughness of flooded canopies [69]. However, in some ecosystems, water and surface vegetation naturally interact with each other [70].

C. Post - flood effects

In natural systems, the main consequence of floods is the creation of hypoxic conditions and, therefore, a decrease in net photosynthesis and stomatal conductance [71]. Furthermore, a few days after the event, physiological changes begin to manifest through remote sensing, causing alterations in soil nutrients and ecological diversity [72].

The SRs allow evaluating changes in the phenology of different crops and in the aerial net primary productivity (ANPP). It is common to analyze the phenological state or primary yield of the vegetation using spectral indices (SI) that are directly related to the photosynthetic activity of the tree canopies. If a flood causes permanent damage to vegetation, this damage will be manifested itself in the reduction of INE even after the water has been removed [73].

Proper agricultural planning is important due to the periodic onset of weather conditions, droughts, and floods. Access to remote sensing data has been made more accurate through the collection of remote sensing data. Survey-based data collection has become more accurate, making it easier to distinguish between vegetation and land use.

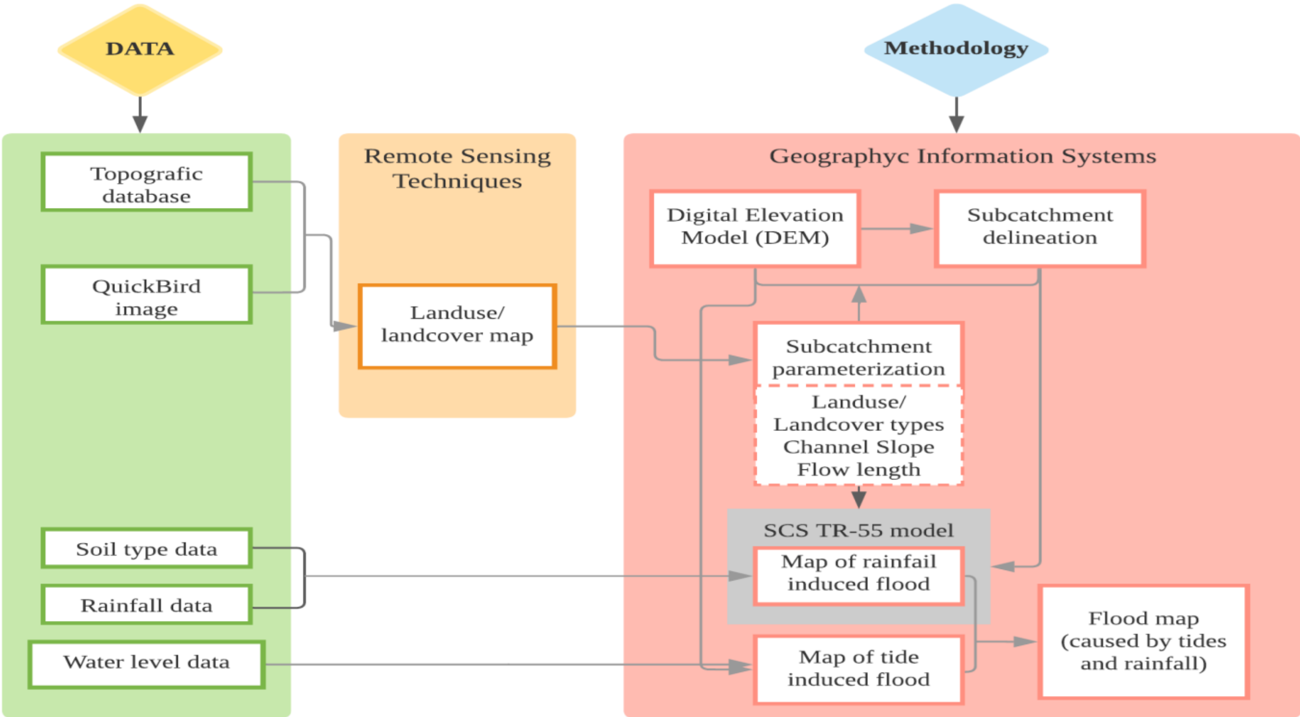

Fig. 5. Flood risk methodology of the case of District 8, Ho Chi Minh City, Vietnam.

Source: [74].

This means that farmers must have prior knowledge of the crop conditions and expected yields in their particular area so that appropriate financial and agricultural decisions can be made with the help of the VIND [74]. The authors [75] focus on detecting flood damage in agriculture. This damage is directly dependent on the effect they have on the crop and therefore accurate predictions must be made to produce more accurate results. In addition to assessing the damage caused by floods to crops, it is important to mention the concept of time series, which is used to analyze data and ensure that climate change over time is essentially the same. For different aspects when evaluating losses due to floods, the author [76] refers to the use of remote sensing data, the availability of which makes the estimation of flood damage based on more precise photographs, thus showing a panorama of the flooded area.

Crop morphology regulates the exchange of energy, carbon and water in agricultural systems. In other words, it is an important component of empirical process-based crop modeling to simulate soil biogeochemical cycles and also to estimate total primary and net yields, as well as to predict crop yields [77]. Extreme weather conditions are a major cause of crop yield loss, which studies have inferred that poor weather conditions during the August to November rainy season lead to low crop yields. Therefore, the measurement of crop flooding and the impact of waterlogging was of great practical value [78].

Advances in morphological pairing modeling generate a possible monitor media of the morphological progress of plants through remote sensing, with a priori(preview) information on transition dates and base forms. Consequently, the assumption of geometric proportions that support the models, as well as the challenge of specifying morphological criteria, have made it difficult to apply geometric coincidences in geometric studies [79]. The presence of water can be cyclical or constant. It can even be a determining factor in the origin of soil types in a region. This recurring presence confers its own characteristics, on one hand, to the geomorphology and, on the other, to the existing vegetation. This is typical in deltas and wetlands where satellite information from active and passive sensors [80].

IV. CONCLUSION

The occurrence of floods is a severe and catastrophic event that can occur anywhere. For this reason, controlling the impact of floods is essential, as it is done by mapping flood hazards and risks. However, to analyze and predict the spatial distribution of future flood management, it is considered necessary to refer to flood-prone areas. Various investigations have estimated that the frequency of flooding will increase in the future. Therefore, it is possible to efficiently choose an accurate risk assessment of the site through flood mitigation measures, including non-structural and structural measures. Flood risk is a combination of risk and vulnerability, considered a mathematical expectation, since they determine the probability of flooding for risk mapping. On the other hand, hydraulic models can create uncertainty because they require comprehensive hydrological data. Therefore, GIS-based models and the use of RS data can be considered as a complementary approach to flood modeling. Recent improvements in the efficiency of GIS and remote sensing technology have started a revolution in hydrology, especially in flood management, which can meet all the demands, forecasting, preparedness, prevention and assessment of flood damage, where it occurs. Technologies have proven to be very useful tools in monitoring ecosystems at different spatial and temporal scales.

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