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Original Article

Flood Disaster Management Using MIT App Inventor - A Case Study in South India

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Abstract - *All around the world, floods bring discomfort and death. Floods occur more frequently and with greater intensity due to socioeconomic advancements and changing weather. Flood management can be more effective by increasing the risk awareness among the vulnerable communities. Case studies that employ recent flood management strategies, including capacity building, community readiness, flood risk assessment, and flood early warning systems, were studied in detail. The 2018 flood caused extensive damage in Kerala, a state in Southern India, especially in the Chalakudy river basin. The flood management techniques through a variety of nonstructural measures were reviewed, and a capacity-building Android application was developed to help vulnerable communities in the Chalakudy basin. The MIT App Inventor platform was used to develop the mobile application. The application provides the user with flood-related information, which comprises flood forecasts by the Central Water Commission (CWC), dam water level updates by Kerala State Disaster Management Authority (KSDMA), emergency shelter locations, the areas that have been inundated, and certain precautions that the user should take. In addition, the system enables the user to place an emergency call to the disaster management team. The app can be modified and developed for other regions worldwide by adjusting regional parameters. The study assists in the flood mitigation process by educating the vulnerable community and making them more Flood resilient.*

Keywords - *App development, Capacity building, Early warning system, Emergency evacuation, Flood risk management.*

1. Introduction

Flooding is a natural phenomenon caused by an increase in river water levels, which submerge normally dry areas [1]. Over 5,000 people are killed by floods every year, making it one of the deadliest natural disasters in the world. The growing frequency of heavy precipitation, changes in upstream land use, and the rise in population are the main causes of floods [2]. Damages due to floods include destruction of private property and public health facilities as well [3]. Following the Sendai Framework 2015-2030 [4], all the member states must concentrate their efforts on four key areas: (1) comprehending the various aspects of disaster risk; (2) improving leadership to control disaster risk; (3) investing in resilience (4) increasing readiness for efficient response and (5) "Building Back Better" in terms of recuperation, restoration, and reconstruction. Flood risk management mainly includes an understanding and management of existing flood control structures and actions undertaken for the holistic analysis and reduction of flood risk [5]. Tariq et al. [6] grouped the flood management practices under four categories: flood abatement, alleviation, control, and relief. Reforestation, soil conservation, groundwater recharging, and such other practices come under flood abatement measures.

On the other hand, construction of flood walls, dykes, flow diversion techniques and so on are categorised as control measures. Flood alleviation is implemented through rescue operations such as evacuation, building public awareness, land use adaptation, and flood proofing. Flood insurance, compensation, and relief efforts are recommended as recovery measures [6]. Raising flood risk awareness is the fundamental step to be taken in the flood risk management process. This will help in planning mitigation activities and increase disaster preparedness, which would in turn lessen the impact of the flood disaster. Apart from that, prior information and warnings on floods always help reduce damage and death rates from floods [7].

The Sendai Framework Global Target A seeks to significantly lower global disaster mortality by 2030, making natural hazard deaths the main focus for directing policies on disaster risk reduction [4]. Flood risk management can be done using structural and nonstructural methods. The United

Nations says that nonstructural measures use information and practice to decrease the impact of disasters, mainly through policies and laws, increasing public awareness, and capacity building [8].

Flood warning systems are crucial in reducing the impact of floods, particularly for homes in high-risk locations that have already experienced flooding [9, 10]. Activities like informing family members about safety strategies and early leaving from the areas with elevated risks are necessary actions for lowering the effects of flooding [10]. Despite the Sendai framework emphasising the significance of disaster preparedness and capacity building, there is a noticeable gap in addressing the capacity needs at local and subnational levels [11]. The efficacy of disaster management is increased by integrating geospatial technology with mobile applications. This will facilitate the rapid dissemination of the information to a large audience [12]. The Chalakudy river basin in Kerala, a southern Indian state, has been experiencing continuous monsoon floods since the deadlier 2018 Kerala flood [13]. According to flood routing studies by Rema and Gopi [14], a significant number of local bodies within the basin are extremely vulnerable to flooding, with an inundation depth of about 20 meters. During the flood event, 1.247 million people were displaced, 474 people died, and about 20,000 homes were damaged [15]. The main goals of this paper are to review various flood management techniques through various nonstructural measures such as flood risk assessment, community preparedness, capacity development and Flood early warning system and develop an Android application with a view to strengthening the capacity of the vulnerable community in the Chalakudy area in the state of Kerala in India.

The following section narrates various flood management processes adopted across the world, including methodologies adopted for flood risk assessment, capacity building, community preparedness, and early warning systems. In addition, the methodology adopted for the development of a capacity-building app using MIT App Inventor and the app structure were also discussed through a case study.

2. Flood Management Processes - A Background Study

2.1. Flood Risk Assessment

Flood management aims to lower vulnerability and flood risk. As per UNISDR [16], risk is the probability of adverse impacts or losses, which stems from serious interactions between natural or manmade hazards and vulnerable situations. Flood risk can be examined using the four primary elements of the risk equation: exposure, capacity, vulnerability, and hazard. The intensity, volume, timing, and phase of precipitation, as well as the pre-existing characteristics of rivers and drainage basins, all affect the magnitude of floods [16]. Exposure refers to the degree to which the individuals, property and infrastructure are prone to the flood danger. The probability and magnitude of the Flood are assessed by hazard analysis [17]. Capacity is the collection of strengths and resources available in a society to manage and lower the risk of disasters and thus improve its resilience [4]. The extent to which a system is vulnerable to negative consequences is known as its vulnerability. Nonetheless, flood risk can be quantified in terms of the harm that floods cause to people, businesses, and the environment [18].

Bhere and Reddy [17] assessed the flood risk by focusing on building and infrastructural conditions, medical factors, damages to road networks, land cover, socio-economic and terrain factors. These variables are categorised under hazard, exposure and vulnerability components. Hazard analysis is carried out by mapping the flood inundation using a hydraulic modelling method, the simulation of which provides flow water profiles, flood depth and velocities. The inundation maps are generated for 50, 100 and 200 years, and the one obtained for 50 years is taken as the high hazard area. Topographic vulnerability is computed by employing the Analytical Hierarchy Process (AHP). A comprehensive vulnerability of socio-economic variables and topography is calculated by assigning equal weights to each of the variables. Flood exposure analysis includes the study of land use patterns, plinth height of buildings and road density.

Achu et al. [19] determined flood risk by analysing flood hazard and vulnerability factors. The authors developed a weighted combined machine learning technique that integrates five machine learning methods. The AHP technique was used in the study to determine the exposure to flood risk by taking into account several demographic and physical factors.

Tran et al. [20] developed a machine learning model to generate flood susceptibility maps and assess the flood damage in Vietnam. The model was optimized by five algorithms and evaluated by five statistical indices. According to the authors, a good training data set covering every scenario is ideal for machine learning models. The scientists pointed out that employing higher-resolution satellite pictures can yield more accurate results. Additionally, by combining machine learning models with hydraulic or hydrodynamic models, the quality of the flood map can be enhanced since flood depth and speed can be taken into account.

Kelly et al. [21] used an index-based approach for mapping flood risk in Australia by considering flood hazard, flood exposure, and vulnerability indices. Precipitation. Soil moisture and distance to the river were the three hazard indicators in the study. According to the scientists, there is a positive correlation between population density and flood exposure. Population density, Critical Infrastructure (CI) density, and land use type were the three exposure elements considered. The data was standardised using Fuzzy Logic techniques. The final risk index map was then validated with a Receiver Operating Characteristic test.

Kumar and Ramakar [22] studied the flood risk of the Kosi River Basin in Bihar. The authors employed GIS and the Analytical Hierarchy Process (AHP) to determine the risk level. Risk was calculated by integrating hazard and vulnerability factors. Geomorphic, hydrologic, and socio-economic investigations were carried out to create various thematic layers. The research area was classified into several zones with varying degrees of risk. The paper suggests that integrating AHP and GIS techniques is an effective tool for flood risk mapping and decision-making processes.

2.2. Community Preparedness and Capacity Building

Capacity building is the process by which individuals, organisations, and society as a whole strengthen their skills and resources to adapt in a fast-changing world [23]. Bringing individuals together within the same community to confront a common disaster risk and work toward collective emergency preparedness is known as community-based disaster preparedness [24]. Residents are particularly important since they are normally the first to react to emergencies and have every chance to save lives [25]. Every level of the organization works to create a system for disaster response before it happens as part of the preparedness actions. Lack of preparedness leads to disastrous consequences. The best approach to disaster management has been identified as preparing a community to prevent and lessen calamities [26]. Providing training and educating the communities for relief and rescue efforts assists them in times of catastrophe. Community-based disaster mitigation is a highly appreciated and effective strategy in both economically developed and underdeveloped nations [27].

Hendra & Kismartini [28] conducted a study in Songkar Village to assess the involvement of the civilians in disaster mitigation by a Village Disaster Preparedness Team. They examined the variables that assist and hinder the efforts of society to prevent flooding. Interviews, publications, and news from the mass media are the sources of the primary and secondary information used. Age and education are the primary motivational factors, but livelihood is the greatest hindrance.

Priyanti et al. [29] performed a qualitative analysis to investigate the perceptions among the community of its readiness to deal with a flood calamity. The information regarding the perception of the community of disaster readiness was gathered using a semi-structured interviewing technique. The interview mainly concentrated on the mobilization of human resources, disaster response plan, early warning system, policy and regulations, and skills and mindset. When it comes to flood emergency management, shelter becomes an essential component. Evacuation is advised for those at risk of flooding or other disasters. One of the elements influencing community readiness is the availability of shelter.

Yordanov et al. [30] explained how capacity-building efforts were carried out to increase educational ability and support disaster management through the use of GIS in the African nation. The training aimed to improve the knowledge and abilities of faculty, staff, local government representatives, and organizations that deal with disaster management. Because they are the most susceptible group during any hazard, the course also focused on the residents of the area. The primary goal of the program was to provide the students and the community with a theoretical and practical understanding of Geographic Information Systems (GIS), Spatial Data Infrastructure (SDI), and Volunteered Geographic Information (VGI). Finding the students most qualified to create disaster maps using open GIS platforms and remote sensing methods was the overall goal of the scheme. Only free, open-source GIS data and applications were intended for use in the course. Mobile mapping, open web-centred delivery, and services were also the focus of the course.

A capacity-building initiative was implemented in disaster-affected regions of Sri Lanka. About six thousand residents in vulnerable areas received training. Numerous topics about disaster risk reduction were covered in the program, including awareness-raising, management of water resources, community-based preparedness and response, psychosocial factors, first aid, and disaster exercises [31].

Yakubu et al. [32] studied the possible risks and hazards, with a view to developing residents for risk detection, readiness, and strengths and weaknesses for calamity prevention efforts in Nigeria. Using structured questionnaire survey methodologies, quantitative data were gathered. Experts were interviewed in semi-structured interviews to look into the community and household disaster training records, the mode of occurrence of flood events, resilient measures available in the society, evacuation plans, previous disaster data, and the information availability through raising awareness. The graves of the forefathers and ancestral residences of those impacted by the flood calamity were identified as major barriers to the evacuation plan. According to the survey, the community prefers to get flood disaster information via radio.

Margarena et al. [33] conducted research to build a resilient community by improving the readiness of vulnerable societies. Women and children have been listed as vulnerable communities in this study. Focus Group Discussions utilizing participatory mapping analysis with

GIS technology are the primary method of gathering data. The study says that to improve the readiness of the vulnerable community, government agencies and institutions must act quickly to offer resources, training, and assistance.

According to Xu et al. [34], knowledge alone is insufficient to overcome readiness, and training programs do not always result in people embracing preparedness. In the study, 32 people were interviewed, including seven city leaders and 25 members of the community. The interview guide inquired about preparation-related issues and the challenges faced by the community. Community readiness is hindered by chronic pressures, irregular trust, and a lack of community involvement.

2.3. Flood Early Warning System (FEWS)

An early warning system is defined as the facility to provide effective information at the right time, which allows the vulnerable community to take action to lessen the risk and prepare for an efficient response [35]. An early warning system should have the following components: risk knowledge, identification, monitoring, analysis, forecasting, warning dissemination and communication, and preparedness and response capabilities [2]. Emergency plans, including the details of temporary shelter locations, flood forecasts, and warnings, are essential components of an early warning system [7].

Hung Ngoc et al. [36] developed a system comprising a monitoring centre, a notification system, and an early flood warning station that runs on solar power. Both precipitation and water level sensors are installed at the flood warning station. Flood alert levels were set using the circuit board buttons or an SMS message sent from the user's mobile device [36]. In a project conducted by Diogo de Souza et al. [37], an Android application was used to gather information from potential users. It is then sent to the database for storage and further notification of registered users regarding flood events. The authors created a mobile device application for the warning system with the goal of rapidly and easily sending out text messages to individuals with real-time information and flood alerts.

Lack of funding and human resources, challenges with risk assessment and data collection, restrictions on how information can be disseminated to vulnerable groups, and an inadequate understanding of the society are some of the challenges in the operation of the Flood Early Warning System [38]. People can be made aware of the hazards in their area and the actions they can take to lessen their effects by participating in education and preparedness programs. To promote and clarify mobilization, officials and the public must have two-way communication channels. Local emergency response offices must have appropriate coordination systems for pre-disaster activity [39].

Potential victims need to act promptly for human, social, and financial damages to be effectively mitigated. Affected communities often lack access to necessities like safe shelters to respond to the warnings, efficient forms of transportation, logistical support such as life jackets, ropes, boats, helmets, stretchers, and knowledge of safe means of evacuation [40]. Residents, government specialists, officials, and private stakeholders are the primary initiators of early warning at the pre-flood stage [10].

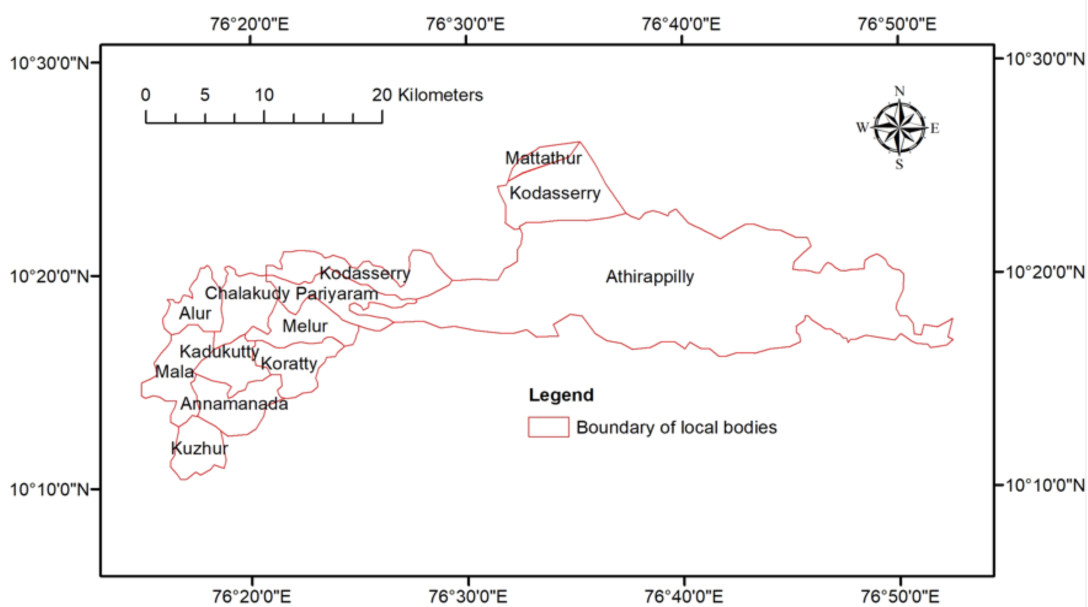

Fig. 1 Local bodies present in the study area

Source: website of the chief electoral officer, Government of Kerala

3. Case Study - Capacity Development App Building in MIT App Inventor

3.1. Study Area

The study focused on 12 administrative local boundaries in the Chalakudy area in the state of Kerala, lying within 10°10′–10°26′ North latitude and 76°13′–76°53′ East longitude (Figure 1). The Chalakudy river originates from Anamalai Hills in the Western Ghats and empties into the Periyar river in Puthenvelikara village of Ernakulam District. The boundary of the river basin was digitized manually from a study conducted by Nameer and Raghavan [41]. The local body boundaries were delineated from the map published on the state government website [42].

3.2. A Background Study on MIT App Inventor

Android Studio and MIT App Inventor are the two user-friendly options available for application development. This study uses MIT App Inventor to develop the mobile application system, which helps educate the user on flood-related information. MIT App Inventor is an open-sourced, browser-based app designer developed by Google in 2010, and presently managed by the Massachusetts Institute of Technology (MIT) [43]. About 30 million apps are created by more than a million unique monthly visitors from 195 countries around the globe [44]. To start the design process, the user first needs to visit the MIT App Inventor website [45]. After the login procedure, the user will be directed to the application design platform. All app-related information is saved in a cloud database; no hardware or infrastructure is required to store and manage the data. It can be connected to any AI device or standalone emulator by scanning the barcode generated by the system. To view the live updates of the app development on an Android phone, one should download the MIT AI2 Mobile Application from the Google Play Store.

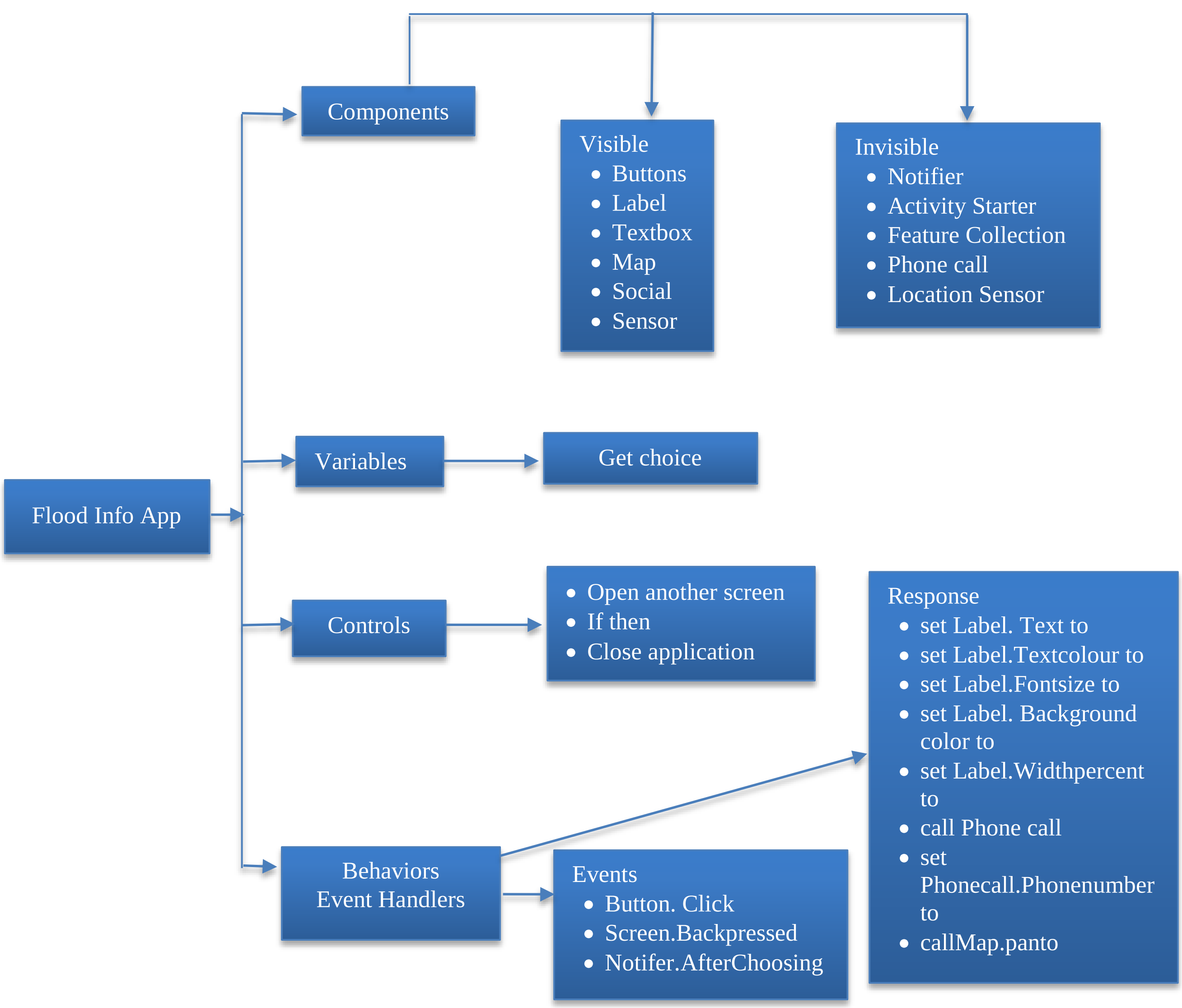

Fig. 2 Internal architecture of Flood Info app

MIT App Inventor has a graphical user interface with 3 main parts: (a) a 'Designer', (b) 'Blocks Editor', and (c) an 'AI companion' to test the app in real time [46]. The components in the App Inventor reduce the complications in handling the interactions in app development and help the developer think about the project.

The programming language is block-based instead of code-based. There are two types of blocks: built-in blocks (such as Booleans, strings, mathematical operators, and so on) and component blocks, which adjust the visual and behaviour aspects [47]. It has certain containers to hold values called Variables [48].

The blocks represent what the user needs to do in the application. To make it occur in the actual world, these blocks will be added to event handlers. Depending on the set of activities the user needs to take, blocks can be added or deleted from the event handlers [49]. The response of an app to the events is defined by Behaviour. To program the behaviour of the application, control blocks are highly essential. About 17 control blocks are available in MIT App Inventor [50].

Ramasamy and Gafar [51] designed a Flood monitoring system and navigation application to address infrastructural and environmental challenges. The MIT App Inventor platform was used to develop the application. The application assists the user in navigating through the routes safely from flooding.

Mustafa and Saparudin [52] integrated a number of cutting-edge technologies, such as Google Sheets, MIT App Inventor, IOT platforms, and app script, to create an alert system for water level monitoring. MIT App Inventor offers a number of modules for location sensors, emergency calling, message sending, and other features that allow people with limited programming knowledge to create apps more quickly [53].

3.3. Methodology

The process of developing an app on the MIT platform can be broadly divided into five steps, as discussed in section 3.2: Configuration of the environment by creating a Google account, incorporating sensors, buttons, labels, and other components in the designer view of App Inventor platform, adding blocks and event handlers based on behavioural aspects, testing the app with an emulator, and finally downloading and sharing the Android Package Kit (APK) file for installation on an Android phone.

Figure 2 depicts the internal architecture of the Flood Info application, outlining its various components, event handlers, variables, and control blocks. Various modules in the application will be discussed in the following section.

4. Various Segments in the Capacity Building Application

The features and possibilities of MIT App Inventor were analysed, and an initial level capacity building platform in the form of a mobile application, 'Flood Info', was developed. The app displays the following Flood related information – (i) Flood inundation details of the study area (ii) Flood emergency camp locations in the study area (iii) caution tips (iv) Flood Forecast by Central Water Commission (CWC) and (v) Daily dam water level-based alerts by Kerala State Disaster Management Authority (KSDMA). In addition, an emergency call provision is also provided for the user.

4.1. Home Page of 'Flood Info' App

The home page of the Flood Info App is designed in a user-friendly manner. The buttons on the screen show the flood information available in the app. The designer view has 6 button components, two activity starters, and a text box component (Figure 3). The buttons are labelled as Flood Inundated area, emergency shelters, emergency call, Caution tips, flood forecast, dam water level, and alert. The purpose of activity starters is to guide the user to the respective webpages, which display the flood forecast by the Central Water Commission (CWC) [54] and dam water level-based alerts by KSDMA [55]. The users are guided by the comment in the grey text box on the screen. Figure 4 shows the block-based programming script used in the home screen.

4.2. Flood Inundation Data and Emergency Shelter Locations

The flood inundation map (1 in 100-year return probability) of the Chalakudy region in Thrissur district of Kerala, published by the Risk Lab of KSDMA, is used as a reference for inundation details for the study [56]. The flood inundation map is georeferenced by setting the datum as World Geodetic System (WGS) 1984 in GIS software. The flood polygons are digitized from the inundation map and saved as a shapefile in. geojson format. It is then imported into the feature collection module under the Map component in the MIT App Inventor design platform.

The data regarding emergency shelters is always significant as far as the flood response and resilience are concerned. The location details of flood shelter camps for the 2018 Kerala floods were obtained from the Government of Kerala. The details of government institutions, public buildings, schools, churches, and auditoriums, which were used as flood camps during the 2018 flood, were identified and included in the data. In a similar situation in the future, this may help the affected community stay prepared. The location data of the flood camps were imported into the ArcGIS platform and saved as an Esri shapefile. It was then converted to GeoJSON format and added to the feature collection component in the designer platform.

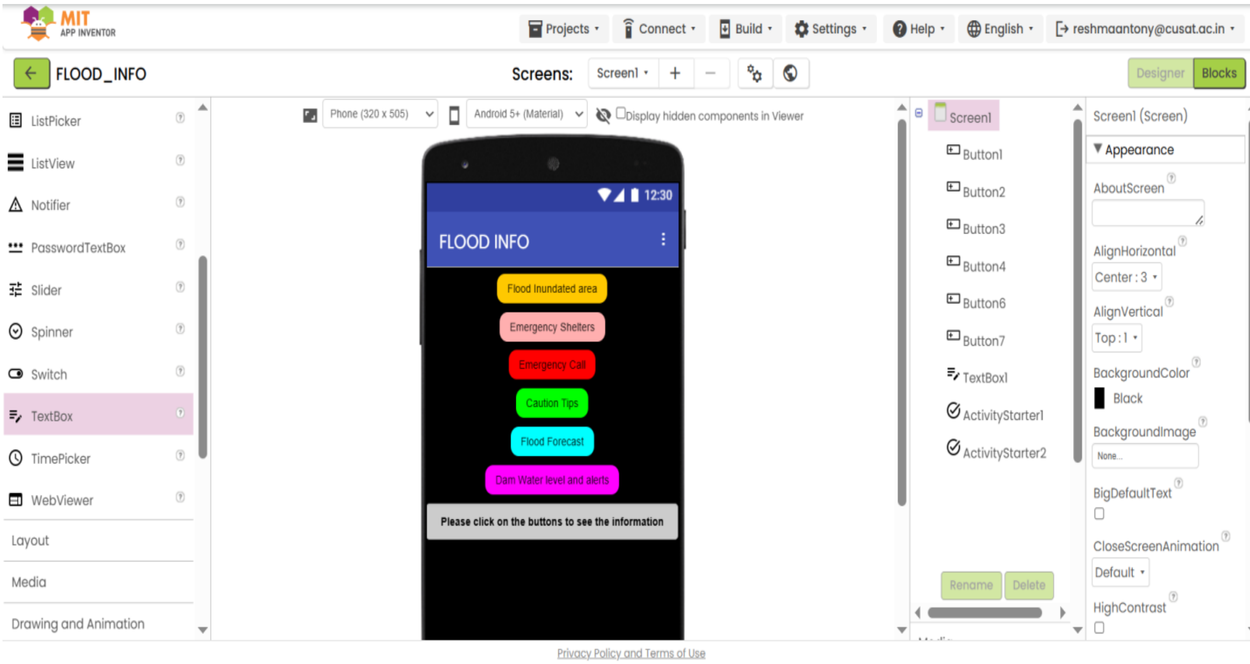

Fig. 3 MIT app inventor designer view of screen 1 of the flood info app

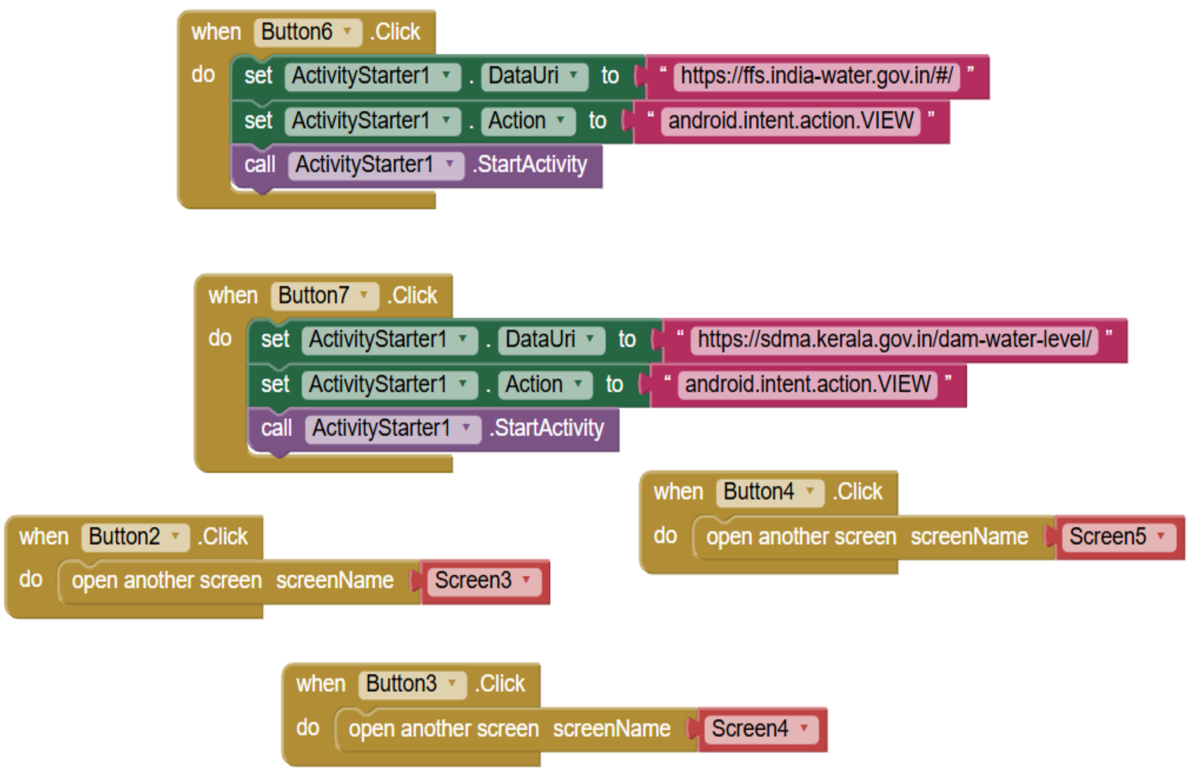

Fig. 4 The block-based programming script used in the home screen of the flood info app

This information in the application helps a registered user to stay prepared and evacuate to the shelter camps without waiting for repeated warning messages from the officials. The designer also provided a location sensor, which helps the user locate their area. The text box guides the user to get information on the nearest shelter camps. A control built into the block helps the user return to the home screen when the back button is pressed. Figure 5 shows the app screen, which displays evacuation shelter and flood inundation details, and Figure 6 displays the block used for getting the user's current location.

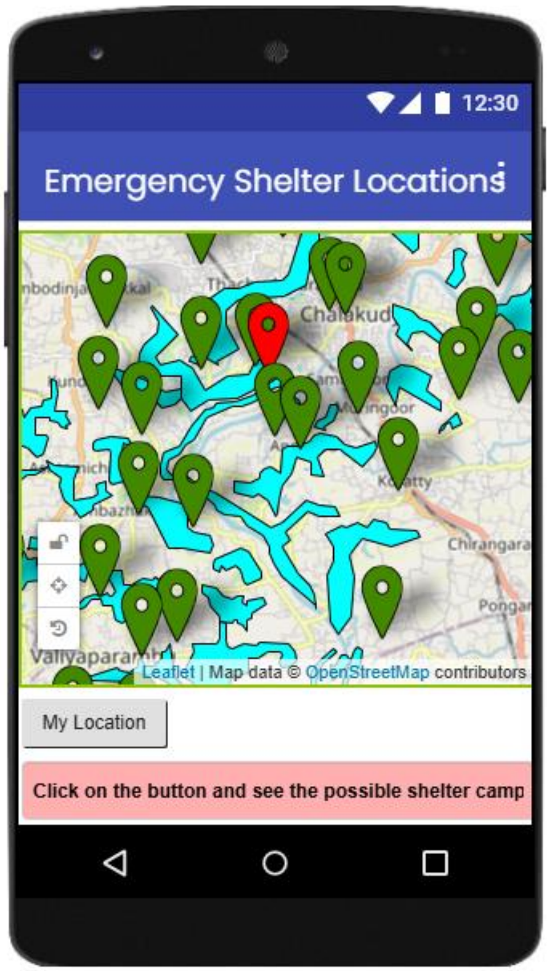

Fig. 5 Flood info app screen displaying evacuation shelter and flood inundation details

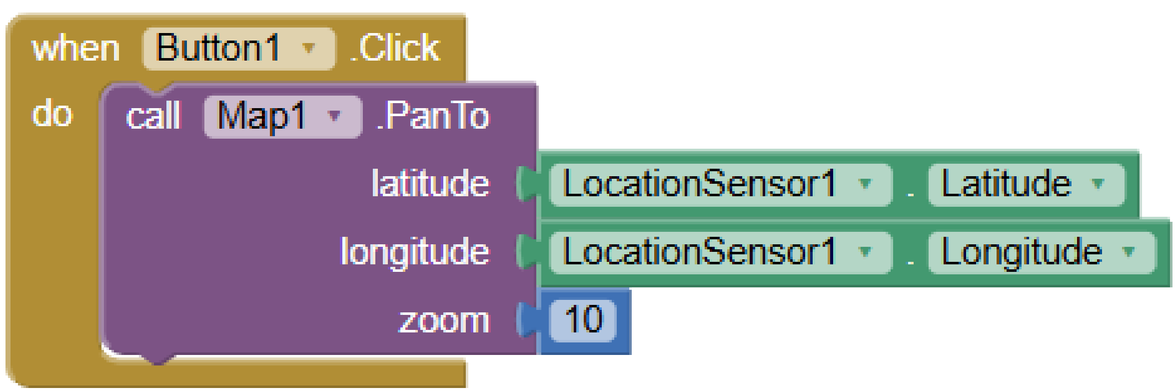

Fig. 6 Blocks used for sensing the location of the user

4.3. Emergency Call Provision

Emergency contact numbers are highly useful, especially during a disaster. The users can report the issues and request assistance from the disaster management team at any time. In the app, users are given the facility to call the police and disaster volunteers for support in case of an emergency. Additionally, they have the provision to type and call the Required contact numbers of friends and relatives. This is performed by adding three *phone call* modules under the *social* component, three button components, and a text box component to the designer platform. Figure 7 shows the emergency call screen, and Figure 8 displays the block and event handlers used for emergency calling.

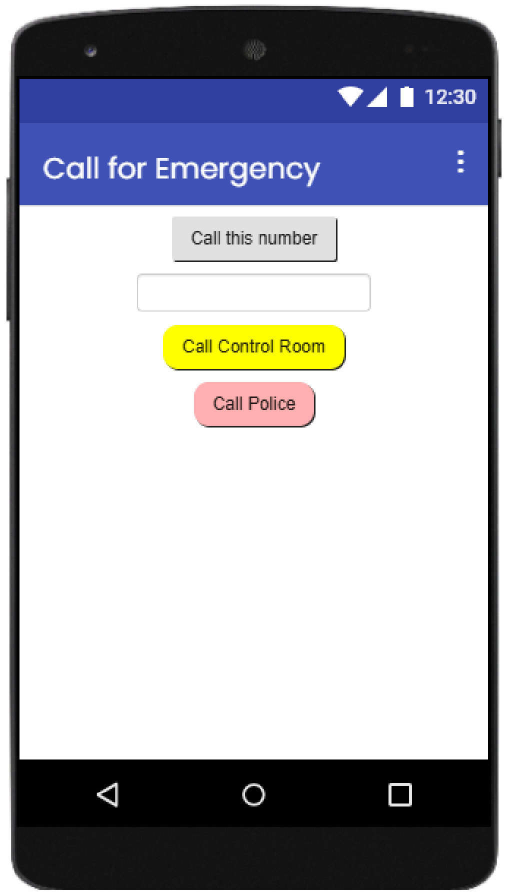

Fig. 7 Emergency call screen

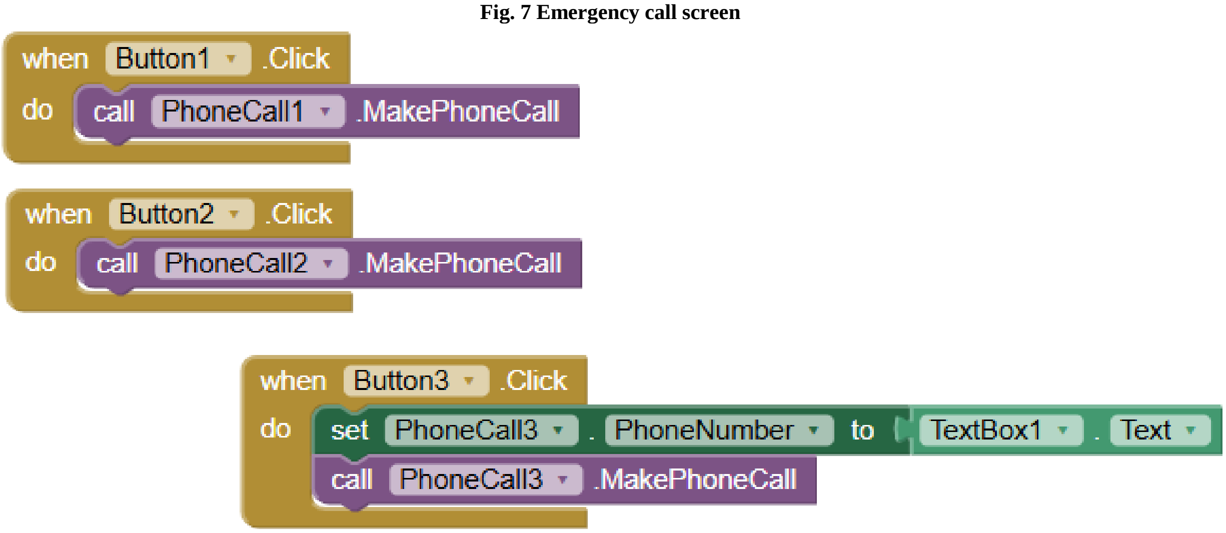

Fig. 8 Block arrangement for enabling emergency calling

4.4. Caution Tips

Caution Tips is a public educational page that helps to increase public awareness regarding disaster exercises and preparedness before, during, and after a flood. It helps to mitigate the flood disaster to a greater level and supports the vulnerable community in preparing for, surviving, preventing, recovering, and building back better from the disaster. It includes certain advice such as the items to be kept in the emergency kit, first aid kit, dos and don'ts during and after the Flood, advice before and during evacuation, and so on [57]. Figure 9 shows the mobile app view of the caution tips page. The block arrangement for displaying caution tips is shown in Figure 10.

4.5. Publishing of MIT app

The methodology to develop an app at a regional scale, shown in Figures 3 to 10, is simple and user-friendly. Every app published might include a version code and a version name. The purpose is to verify whether the app is upgraded or downgraded. After the final testing of the app using the AI companion app, an Android .apk file can be downloaded and used by an Android phone user. The app can also be published in the App Inventor gallery and made available in the Google Play Store [58].

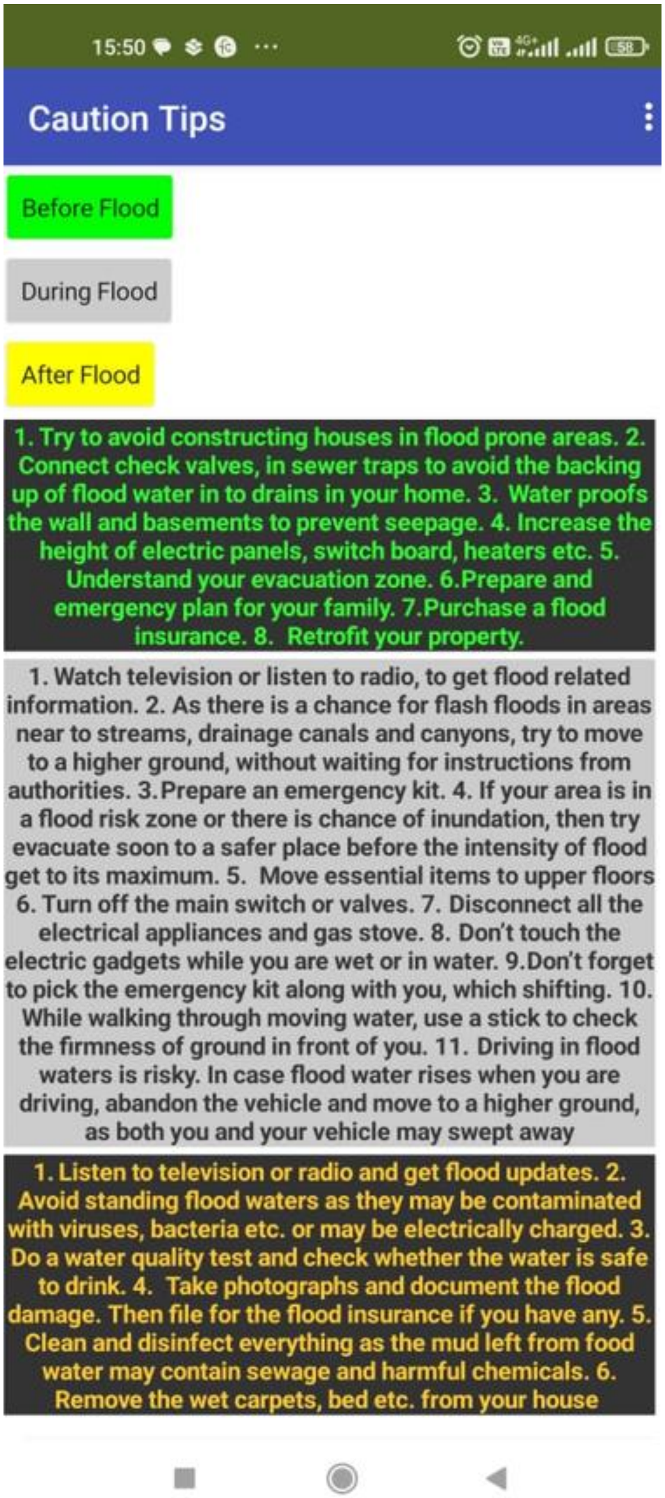

Fig. 9 Caution tips viewed in the mobile app

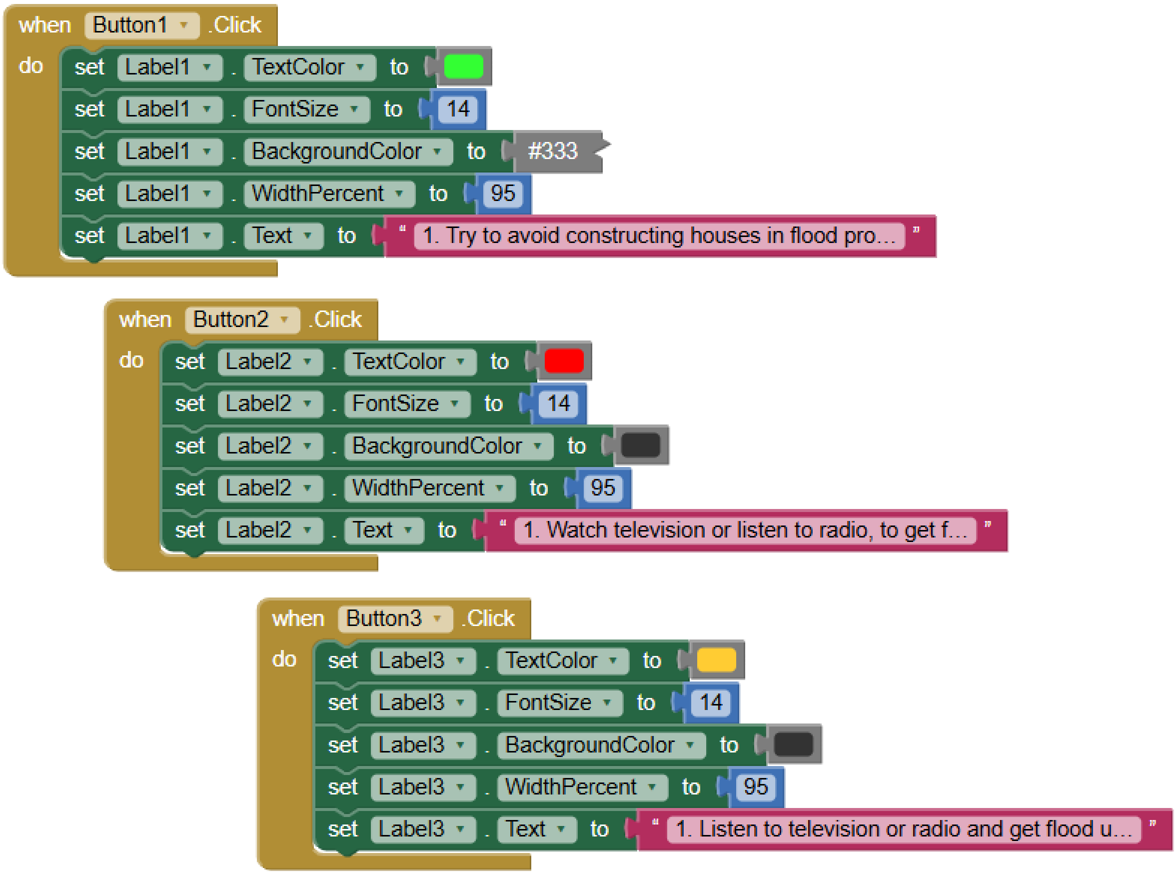

Fig. 10 Block arrangement for displaying a caution tip

4.6. Effectiveness of Flood Info App - User Feedback

Residents of the study area were asked for their opinions on the flood info app in order to assess its effectiveness. Users were asked to give feedback and offer suggestions for enhancements. According to the feedback results, users find the app information very helpful. Some recommended adding user reporting modules and bilingual support features to the application.

5. Discussion

The paper discusses various nonstructural flood management strategies, including flood risk assessment, community preparedness, capacity building, and flood early warning systems. The review indicates that researchers employ advanced technologies, such as hydrologic and hydraulic models, machine learning techniques, geospatial technology, and multicriteria analysis, to assess flood risk [17, 19, 20-22]. In contrast, solution-based approaches in flood risk studies are less prevalent in the literature. Effective flood risk mitigation requires the development of comprehensive mitigation plans. The flood risk app developed in this study educates vulnerable communities about flood-related information and outlines activities to be undertaken before, during, and after a flood event. The app enhances community capacity and promotes disaster readiness. However, the MIT App Inventor has limitations, including potential performance issues when handling large datasets. Integrating data from diverse sources poses a significant challenge in app development [59]. Additionally, real-time data collaboration requires a stable internet connection, which may limit accessibility for users in developing regions. The lack of user reporting features in the developed application is another drawback.

6. Conclusion

The risk of flooding is unavoidable. However, it is manageable, and mitigation is possible with structural and nonstructural strategies. Flood response strategies have decreased property loss or damage, injuries, and fatalities. The methodologies adopted in various nations for flood disaster management through nonstructural measures are discussed in detail. The review shows that risk mapping and early warnings are essential techniques for minimizing property damage and mortality.

The study comprehends the benefits of improving community preparedness and capacity for effective flood management. Educating local people about relief and rescue operations helps them manage disasters excellently. The methodology for developing a flood information application using MIT App Inventor is discussed through a case study in the Chalakudy river basin, in South India. The application helps in building the capacity of the vulnerable community in the Chalakudy area. The app consists of flood-related information, including flood-inundated regions in the study area, emergency shelter locations, Flood forecasts by CWC, dam water levels, alerts by KSDMA, and basic precautions to be taken before, during, and after the Flood. Apart from this, the app also provides an emergency call facility for the user during a disaster. Similar apps can be developed at the regional level to help the community by varying regional parameters. The outcome of this paper supports the efforts of the emergency management team and planning committees to mitigate the flood disaster by raising flood risk awareness among the vulnerable community.

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