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WEBFRIS: a web-based flood information system for enhanced resilience through risk awareness

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Abstract: A synchronous rise in flood-affected regions, human and economic damages bring the necessity of disseminating the flood risk information more than before. For efficient flood risk management, it is crucial to give due consideration to information flow for various aspects of flood disasters to the ground level. Unfortunately, while there have been several such approaches to present the flood-related information on the hazard components, the equally essential part of flood risk, which primarily addresses the socio-economic vulnerability, is not yet available. Under such circumstances, a 'web-based' tool is identified as a viable option as it can simplify the visualization of complex hazards, vulnerabilities, and risk databases for various end-users. To accomplish this, a first of its kind 'web-based flood risk information system', WEBFRIS, is developed by using freely available web-tools. The web-information system is demonstrated for the severely flood-prone Jagatsinghpur district in eastern India at the finest scale of the village level. The web-interface is designed, keeping in mind the technical needs of various bodies engaged in disaster mitigation and easiness of understanding for a non-technical audience. The unique representation of the information system enhances its flexibility and modularity, allowing users to gain prior knowledge of the regions affected to different degrees of flood hazard, vulnerability, and flood risk.

Key words: Flood hazard; flood risk management; socio-economic vulnerability; village level; WEBFRIS

1. INTRODUCTION

Several regions in the globe are projected to experience elevated risks from riverine flooding attributable to concomitant climate change and alterations in socioeconomic dynamics (Ntajal et al., 2017). These impacts pose a significant challenge to find solutions in comprehensively quantifying flood risk, which may facilitate in building flood mitigation infrastructures, improved land use/urban planning, and assist in the prioritization of emergency response strategies (Apel et al., 2009; Vorogushyn et al., 2018). Flood risk management (FRM), a non-structural measure, is identified as a potential solution for preventing damages from floods (Hartmann and Driessen, 2017). With the emergence of numerous sophisticated flood models and algorithms, the difficulties associated with data handling and computational efforts, though not leading to an end, is declining substantially (Dottori et al., 2016). However, in the long-run, for FRM to be a success story, it is crucial to give an equal footing to the information flow on various aspects of flood disaster to the ground level. The knowledge on regions affected by different levels of flood hazard, vulnerability, and risk is vital not only for citizens but also to various government agencies, disaster managerial teams, and policy makers (Martens et al, 2009; Wehn et al., 2015).

To date, considerable research has centered on inventing different ways by which the awareness on flood risk can be enhanced. Most of the studies have focused of the methods in representing flood hazards (Meyer et al., 2012) in these flood maps, with a limited attention towards flood risk. As Kjellgren et al. (2013) highlight, simply preparing flood maps is not going to solve the purpose of bringing attitudinal or behavioral changes among the public. It is necessary to bring a suitable, simple to understand, interactive and flexible way to disseminate the information effectively. In such cases, the conventional flood maps are not qualified enough to depict a complete picture of the flood risk issues.

Under such situations, a ‘web-based’ system that holds the power to simplify the representation of complex flood-related information for a non-GIS audience could overcome the barrier. In the present study, an easy-to-use web-based flood information system is proposed in order to promote shared knowledge of various flood related information among water professionals, policymakers, disaster management bodies, and general public. This paper presents an innovative Web-based Flood-Risk Information System (WEBFRIS) at a very fine scale of village level for the severely flood-prone Jagatsinghpur district (Orissa, India), accomplished through a unified flood risk mapping framework (Mohanty et al., 2019, 2020). The unique representation of the information system enhances its flexibility and modularity, allowing users to gain prior knowledge of regions affected by different degrees of flood hazard, vulnerability, and risk.

2. DESCRIPTION OF STUDY AREA

Jagatsinghpur district covers an area of 1760 sq. km and is located in the deltaic reaches (19°.58' to 20°.23'N latitude and 86°.3' to 86°.45' E longitude) of the lower Mahanadi basin in Odisha (India). It has eight blocks and around 1300 villages in it. The occurrence of floods almost every monsoon season is a usual story, which has resulted in the status of a severely flood-prone region by media reports and several past studies (Samal, 2011; Mohanty et al., 2020). The causes of floods are attributed to the geographical location and socio-economic hierarchy. River Mahanadi and its tributaries, namely, Paika, Chitrapola, and Nuna, and River Devi and its tributaries, namely, Serua and Kathjori, overflow from their usual volume due to heavy rainfall in the upper reaches, resulting in inundation in the adjoining flood-plains. Also, the severe tide impacts encountered at the river mouth and coastal reaches add to the menace of flood in the coastal villages. Talking about the societal hierarchy, a large population residing in Jagatsinghpur is dependent on agriculture and other allied activities as their primary source of income. As a result of which, whenever a flood occurs, they face a considerable set-back due to the agricultural loss and temporary unemployment. Few studies highlight the psychological behavior of place attachment, which also aggravates the vulnerability (Mishra and Mishra, 2010). Since recently, keeping in view the susceptibility of this region to frequent floods, the district administration has been taking drastic steps proper on flood management in terms of structural measures and strategic evacuations.

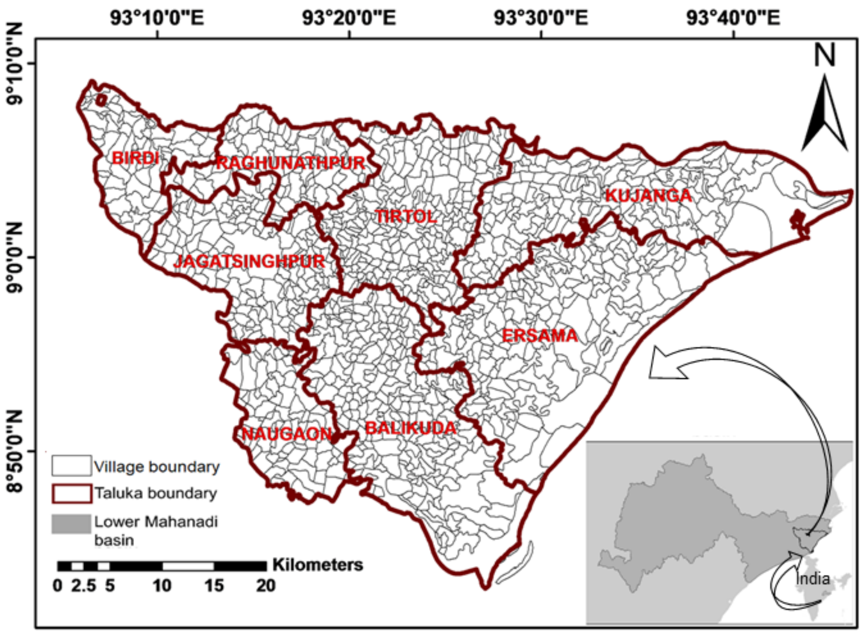

Figure 1. Description of study area: Jagatsinghpur district in the Lower Mahanadi Basin, Odisha (India)

3. MATERIALS AND METHODS

The conceptual framework of WEBFRIS is illustrated in Figure 2. Further details are provided in the following subsections.

3.1 Quantification of flood risk ($\mathcal{R}$)

The quantification of flood risk ($\mathcal{R}$) proceeds by evaluating the two components, flood hazard ($\mathcal{H}$) and socio-economic vulnerability ($\mathcal{V}$). To quantify $\mathcal{H}$, a detailed 1D-2D coupled MIKE FLOOD modelling framework is adopted through a flexible mesh approach that is derived from LiDAR DEM (2 m × 2 m grid size). The boundary conditions to this model setup are provided in the form of a 100-yr return period and 24-hr time series of design discharge, design storm-tide elevation and regionalized design rainfall. The design discharge is evaluated at the starting point of the river network in the flood model domain by fitting the Generalized Extreme Value (GEV) model to the daily time series of observed discharge (duration: 1970-2011). On the other hand, the design storm-tide is calculated as the sum of design astronomical tide and design surge. The design astronomical tide is determined by fitting a GEV to the long-term tide time series (duration: 1900-2100). The surge is calculated as the difference between the astronomical tide elevation and observed tide elevation for the coincident period. The design surge is determined by fitting a General Pareto distribution (GPD) to this time-series. The other important input, i.e. rainfall, is provided as regionalized design rainfall time-series, which is derived through a non-linear optimization-based framework. The rainfall pattern developed through this approach is capable of addressing the flood causing potential through the incorporation of design temporal pattern in the time-series (Sherly et al., 2015; Mohanty et al., 2018). The other relevant static data such as land-use, land cover, built-up area, etc., are provided as gridded inputs over the model domain.

The flood hazard from the model simulations is quantified in terms of the tuple of depth and velocity *'(d,f)'* as per the classes followed by Mani et al. (2014). On the other hand, socio-economic vulnerability is determined at the finest administrative scale (village level) by considering a set of 21 relevant socio-economic indicators in a multivariate data analysis framework involving principal component analysis (PCA), followed by a data envelopment analysis (DEA). Instead of the conventional flood risk definition given as a product of hazard and vulnerability, a new approach in the form of "*Risk Classifier*" (Mohanty et al., 2020) is followed. This innovative representation consists of a 5×5 choropleth, which portrays different degrees of risk from the individual and compound contribution of hazard and vulnerability components. This flood risk is quantified for a standard 100-yr return period for two scenarios: (i) Scenario-I: 1970-2011 and (ii) Scenario-II: 1970-2001. The entire flood-related information is embedded into the web database. The technical details of the web-based information system are provided in the subsequent sections.

3.2 Technical details of WEBFRIS

The web-system is composed of two modules: (i) Front end that consists of the open-source Google map database as the base map layer and web layout (written in HTML) and (ii) Back end that has the storage database of flood-related information (written in PHP My Admin) and representation of data feed (programmed in JSON language). The proposed framework is illustrated in Figure 3. The integration of the two parts aims to create a powerful and easy-to-use tool that allows users to visualize flood-related information tailored to their requirements.

3.2.1 Preparation of the layout of web platform in Hypertext Markup Language (HTML)

Hypertext Markup Language (HTML) is the standard markup language for creating web pages

(Berners-Lee and Connolly, 1995). With the convergence of Cascading Style Sheets (CSS) and JavaScript, it is capable to form World Wide Web browsers. In this web-based platform, we intended to provide a user-friendly interface. The various map layers, such as topographical features (e.g., district boundaries, taluka boundaries, and village boundaries) and flood-related options (e.g., flood risk, flood hazard, and socio-economic vulnerability) were put on the left side of the interface. This makes it easy for the user to select any required option, which will direct to displaying a particular map in the space provided for the flood maps.

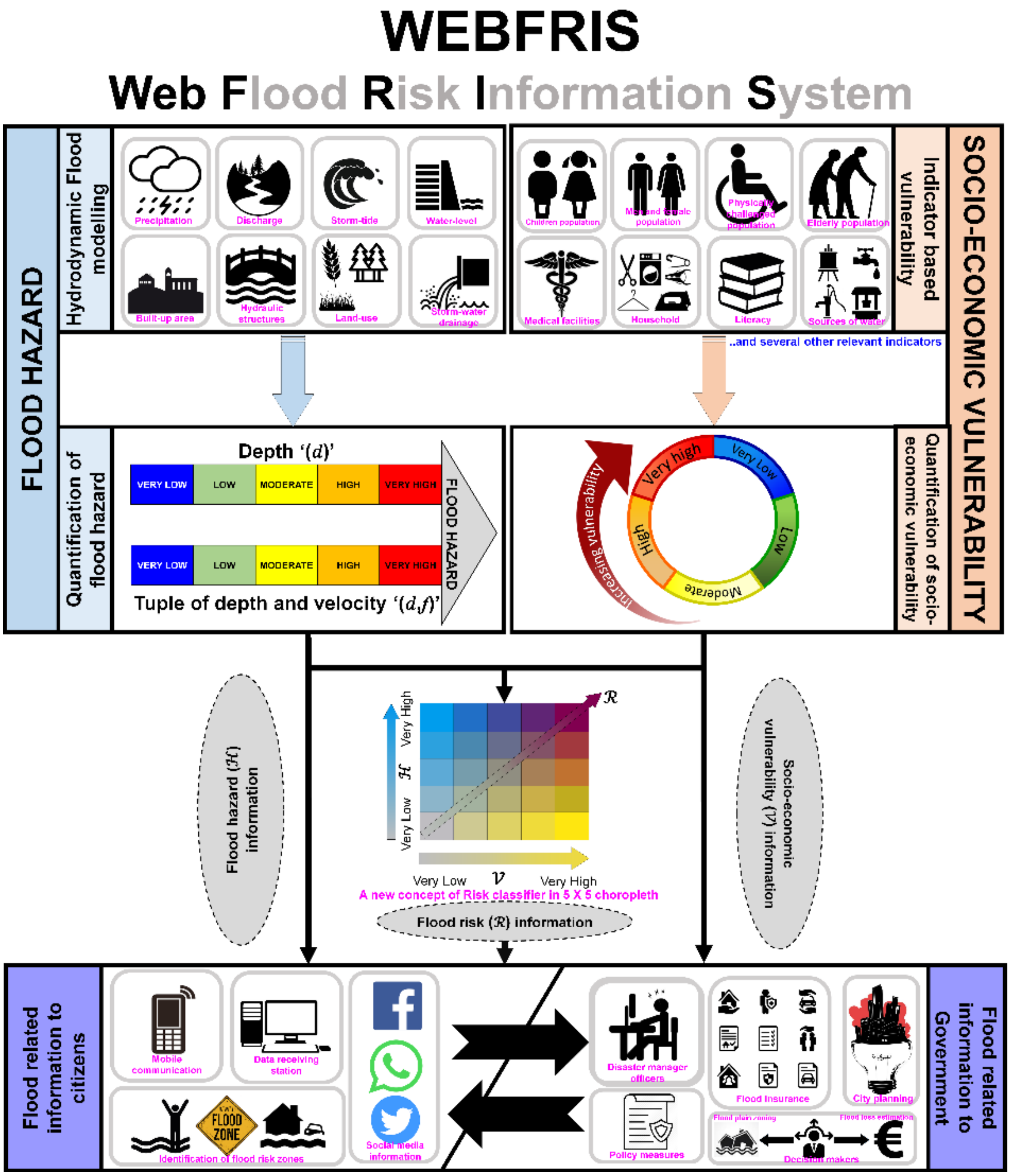

Figure 2. Design architecture of the proposed Web-based Flood-Risk Information System (WEBFRIS)

3.2.2 Creation of data base in php My Admin

PHP my Admin has grown into one of the most preferred MySQL administration tools for web hosting services. Numerous tasks such as creation, modification, or deletion of databases execution of SQL statements, and managing users and permissions can be performed with PHP my Admin. In the present study, the excel database containing the various administrative boundaries points at a very fine resolution spaced 150 m apart, and village point specific flood-related information on risk, hazard, and vulnerability are imported and stored in the format as illustrated in Figure 4 (a and b).

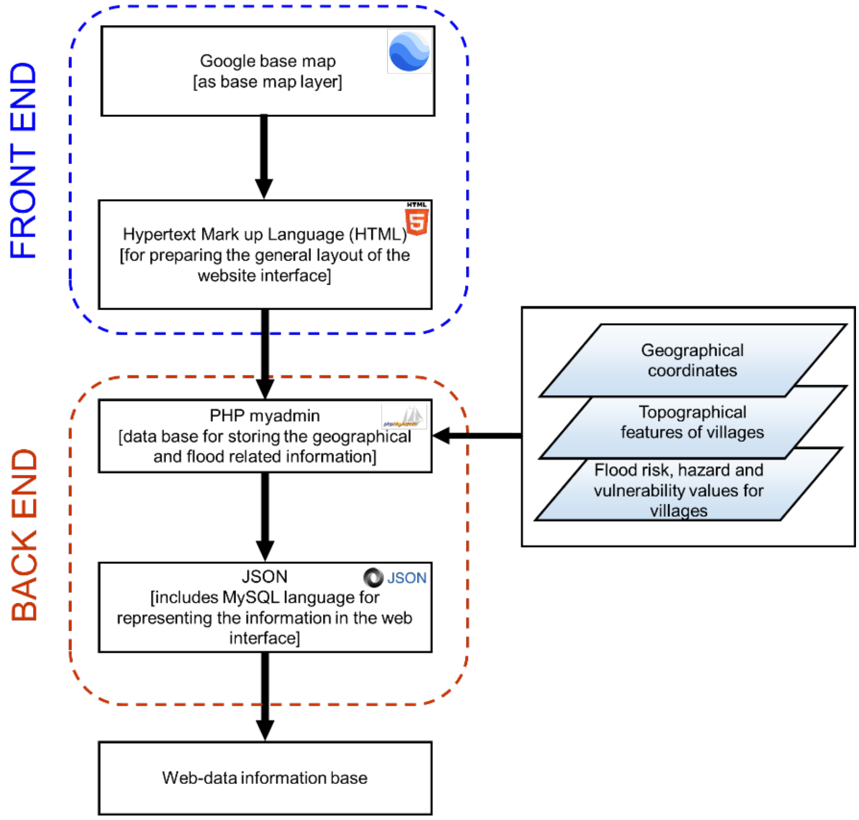

Figure 3. Proposed framework of WEBFRIS

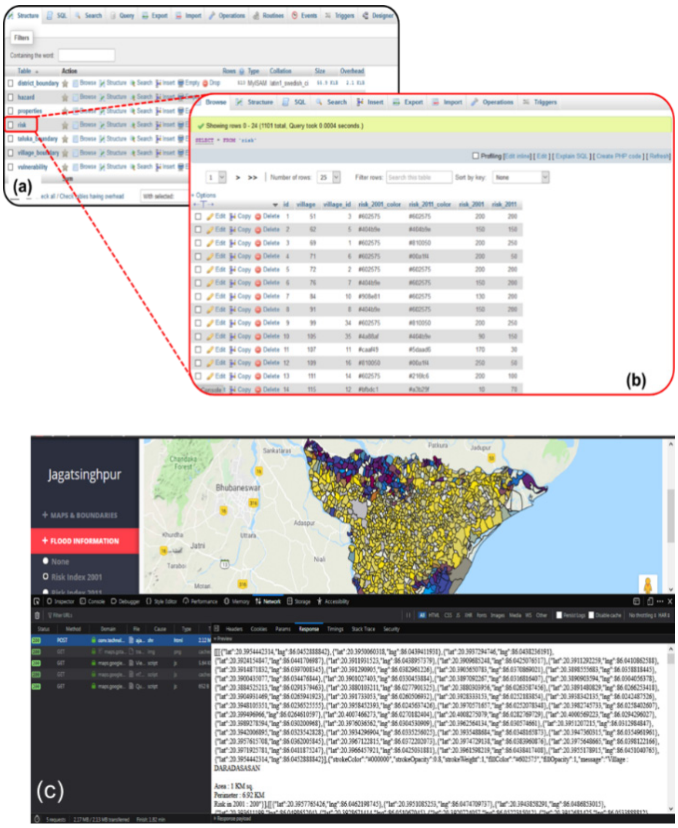

Figure 4. Database embedded in php My Admin for (a) the complete flood-related data and (b) flood risk related data, and (c) Implementation of village boundary in JSON

3.2.3 Graphical user interface using JSON language

JavaScript Object Notation (JSON) is an open-standard file format, which utilizes the human-readable text to communicate data objects. It is considered as the universal data format and widely used in asynchronous browser-server communication. The various flood-related information along with the static topographic information is encrypted over Google map. A representative format while implementing the village boundaries is provided in Figure 4 (c).

4. RESULTS AND DISCUSSIONS

4.1 Decadal changes in villages facing different degrees of $\mathcal{R}$

Firstly, we analyse the decadal changes in flood risk in Scenarios I and II. These two scenarios are characterized by the majority of the villages coming under $\mathcal{H}$-dominated and $\mathcal{V}$-dominated flood-risk, respectively. At the same time, we observe a noticeable rise in the number of villages (in the NE and SW regions) affected with high and very high flood risk, respectively, contributed equally from $\mathcal{H}$ and $\mathcal{V}$. Most of the area was dominated by high and very high $\mathcal{V}$, with few areas on the coast and lower Mahanadi River stretches facing high and very high $\mathcal{H}$. As illustrated in Figure 5, the number of villages facing very low and low $\mathcal{H}$ declined in Scenario-I. The ones facing a very high $\mathcal{H}$ rose to as high as 419 numbers, which is nearly 130% more than seen in Scenario-II. At the same time, the number of villages suffering from higher degrees of $\mathcal{V}$ declined in the latter scenario.

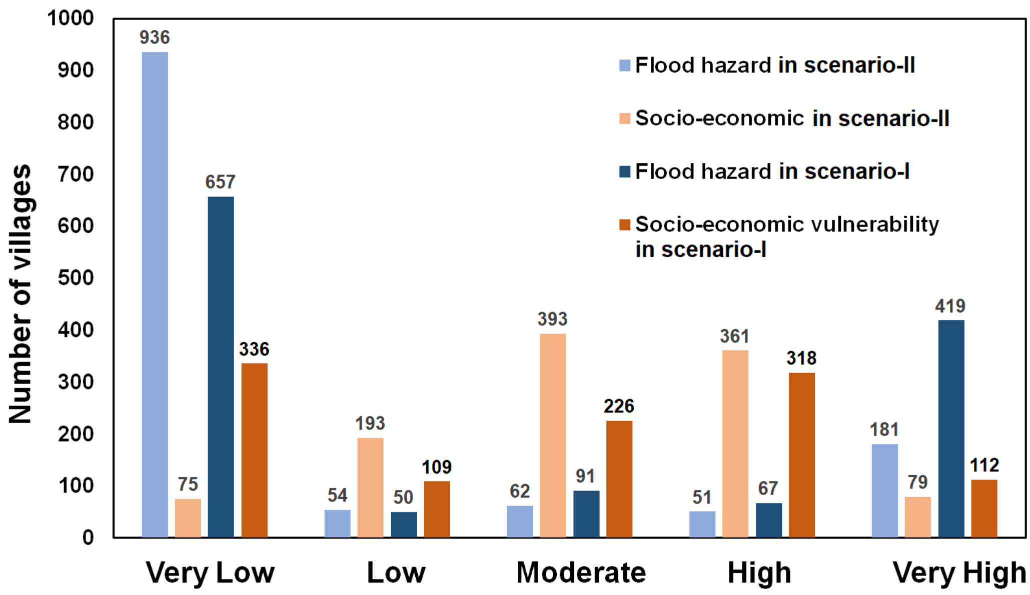

Figure 5. Number of villages facing different degrees of $\mathcal{H}$ and $\mathcal{V}$ in Scenario-I and II

In the next step, we visualize the number of villages facing $\mathcal{R}$, which is contributed by either $\mathcal{H}$ or $\mathcal{V}$ or both. An interesting observation is the prominent rise in villages (in the North East and South West regions) affected with high and very high flood risk in Scenario-I, contributed equally from $\mathcal{H}$ and $\mathcal{V}$. In Scenario-I, more villages were seen to experience $\mathcal{H}$ driven risk than in Scenario-II, where more villages faced $\mathcal{V}$ driven risk. Similarly, the risk contributed from the equal contributions of $\mathcal{H}$ and $\mathcal{V}$ has increased to almost two-fold from the past scenario. These observations are illustrated in Figure 6.

4.2 WEBFRIS: Web based flood risk information system

The user-friendly and simple layout of the web information system supports swift access to flood-related information. The huge stack of information embedded in the database aims to promptly provide information on the damage inflicted upon the dwellers along with potential future damage scenarios. By clicking on any village on the Google map layer, the user can notice a pop-up that displays various geographical (e.g., location, area, perimeter, etc.) and flood-related information (e.g., flood hazard, vulnerability, and risk values for both scenarios). Figure 7 illustrates a few screenshots of WEBFRIS for Scenarios I and II. With the unique manifestation of flood-risk, it is now much easier to enhance the existing FRM by giving due weightage either to hazard, vulnerability, or both. Also, it also draws the attention of disaster managerial groups and government organizations for prioritizing flood management actions. Over areas facing severe hazards in the upstream and coastal stretches, more attention should be exercised on improving flood plain zoning and constructing flood control structures. On the other hand, policy and upliftment schemes can be enforced over the vulnerability-dominated areas.

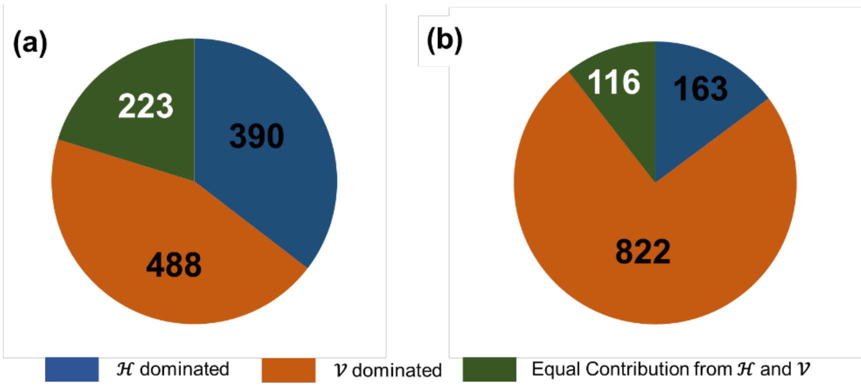

Figure 6. Number of villages facing different degrees of $\mathcal{R}$ contributed from either $\mathcal{H}$ or $\mathcal{V}$ alone and both in (a) Scenario-I (1970-2011) and (b) Scenario-II (1970-2001)

5. CONCLUSIONS

This study introduces one of its kind, a freely accessible 'web-based' flood risk information system for Jagatsinghpur district, a severely flood-prone region in India. The two primary components of flood risk, hazard and vulnerability were mapped over the region at the finest administrative scale of village level. The web platform through its user-friendliness and modularity provides easy accessibility of flood related information to citizens and other bodies involved in flood management schemes. The huge stack of information embedded in the web platform aims to promptly gain information on the damage inflicted upon the dwellers along with potential future damage scenarios. We hope to integrate this flood information system with the recently launched Jagatsinghpur Geoportal (http://www.gisodisha.nic.in/District/jagatsinghpur/) by the National Informatics Centre. This much-needed initiative is a commendable effort for the district, which has helped the disaster management authorities to visualize the geographical details in a spatial platform. The long term benefits by merging WEBFRIS with the Jagatsinghpur Geoportal will provide a structured approach to plummet the ambiguous economic expenditure on Flood Risk Management measures and provide substantial benefits to a broad community group on suitable adaptation and flood combating strategies.

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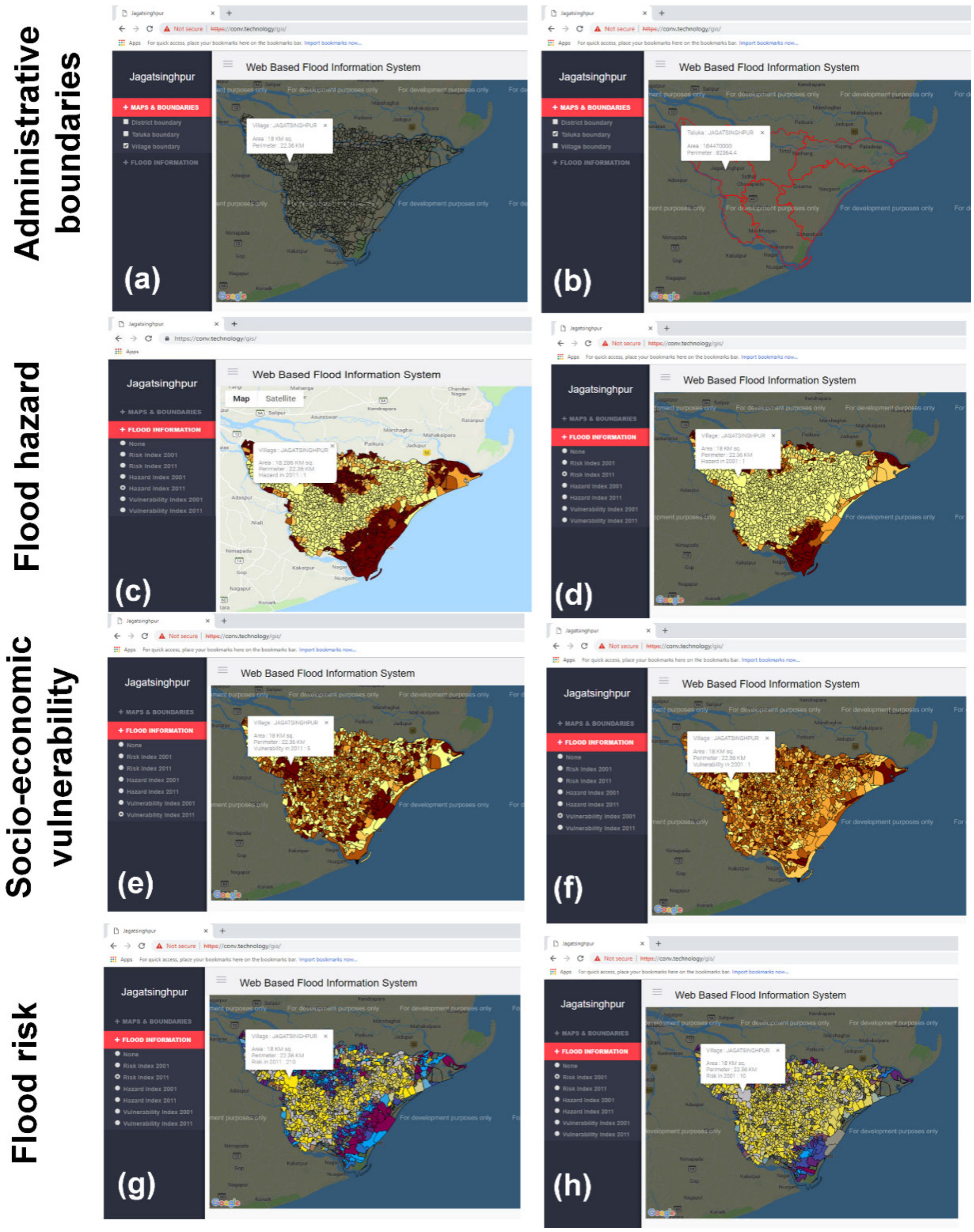

Figure 7. Screenshots of WEBFRIS: Administrative boundaries: (a) Villages (b) Taluka; Flood related information at the village level: Flood hazard maps for (c) Scenario-I (1970-2011) and (d) Scenario-II (1970-2001); Socio-economic vulnerability maps for (e) Scenario-I and (f) Scenario-II; Flood risk maps for (g) Scenario-I and (h) Scenario-II

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