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Flood Vulnerability Assessment: A Multiscale, Multitemporal and Multidisciplinary Approach

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Abstract: Recent catastrophic events related to floods in Colombia reveal again the situation of disaster as a development issue not solved in the country. It is necessary to analyze in more detail the areas under threat and their respective vulnerability to the different mechanisms can generate flooding events and make adjustments in the assessment of disaster risks for the appropriate decision-making at local, regional and national levels. This paper presents a research project in its first phase, whose main objective is to develop a methodology for vulnerability assessment from a multiscale, multitemporal and multidisciplinary perspectives, combining the use of indicators and a spatial information system to analyze exposure and vulnerability at regional and local level in specific areas. This methodological tool will also enable local and regional authorities to identify the most appropriate strategies to reduce vulnerability and adaptation options, and make better decisions in assessing disaster risk. The information generated in this study will contribute to public policy action structured to correct short- and medium-term situations of actual or potential vulnerability, which can also be used in other activities of territorial and environmental planning, developing technology transfer activities and training associated with the research project in the service of the authorities and communities. Results obtained of the vulnerability analysis for a Colombian study area will relate to the hazards obtained in a parallel project whose goal is to identify the best risk management strategies through the development of GIS (geographic information system)-based scenarios for different risk and vulnerability reduction options.

Key words: Floods, hazards, developing countries, GIS, disaster, indicators.

1. Introduction

Floods are the most frequent natural events in Colombia. They are known as “socio-natural” threats that have generated great damages in the country’s recent history by their high frequency, large territorial extensions involved, and the high amount of population affected.

Since the second semester of 2010, Colombia is going through a winter emergency caused by rains reaching “catastrophic” levels. According to United Nations OCHA (Office for the Coordination of Humanitarian Affairs) consolidated figures, there are 2,796,449 victims, 69 missing, 463 injured and 362 dead in the country, in addition to hundreds of thousands of families that have lost their goods, households, crops, and other means of livelihood [1]. This winter emergency has also severely affected multiple public infrastructures like schools, hospitals, and means of communication.

Floods are increasing but equally the socio-economic and environmental impacts on the local residents. The tragedy can be avoided or dramatically reduced through pre-, during- and post-disaster investments in preparedness activities and associated infrastructure, flood plain policy development, effective watershed land use planning, flood forecasting and warning systems, and response mechanisms.

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The development agendas of the country are urged of conscience projects in disaster risk management, from public, private, and mixed initiatives whose principal objectives are strengthening the decision making capacity, planning, and execution of tasks to prevent, mitigate, or reduce disaster risks, as well as to increase the quality of life of the population under human sustainable premises [2].

Colombia is a country which has a lot of knowledge to develop and strengthen especially at a regional and local level of:

- local realities and risk zones;
- causing agents of risk situations;
- evaluating and locating the minimum necessary resources to face any eventuality;
- community inclusion and participation in the diagnosis, analysis and decision making processes.

This is why the most important subject that brings us together today to work on this research is the vulnerability for risk mitigation and reduction.

It is a complex problem that requires the study of all the social and natural systems that affect a disaster modified environment from different multitemporal, multiscalar, and multidisciplinary perspectives.

2. Study Area

The study area is located between the departments of Bolivar, Sucre, and Magdalena, on the coordinates of 73.64°-75.24° W and 8.38°-9.64° N (Fig. 1).

It is a part of a larger region called La Mojana, with an exceptional natural, environmental, and cultural richness. Due to the confluence of the Magdalena and Cauca rivers (two of the main rivers in Colombia) and the low slopes, it presents a great deal of swamps or water bodies usually located in floodplains. This complex system of wetlands promotes the natural control of the flooding cycles and creates a vital habitat for wildlife, flora, and the communities which occupy the region [3].

This zone is unsustainable in its current condition of development due to impacts caused by the absence of planning, land use, and inappropriate use of natural resources. Floods are increasingly affecting the conditions of social and economic development of its communities and the different mitigation measures implemented until now have been characterized as sectoral, disjointed, and punctual. That is why it need to be contributed in the creation of a participatory

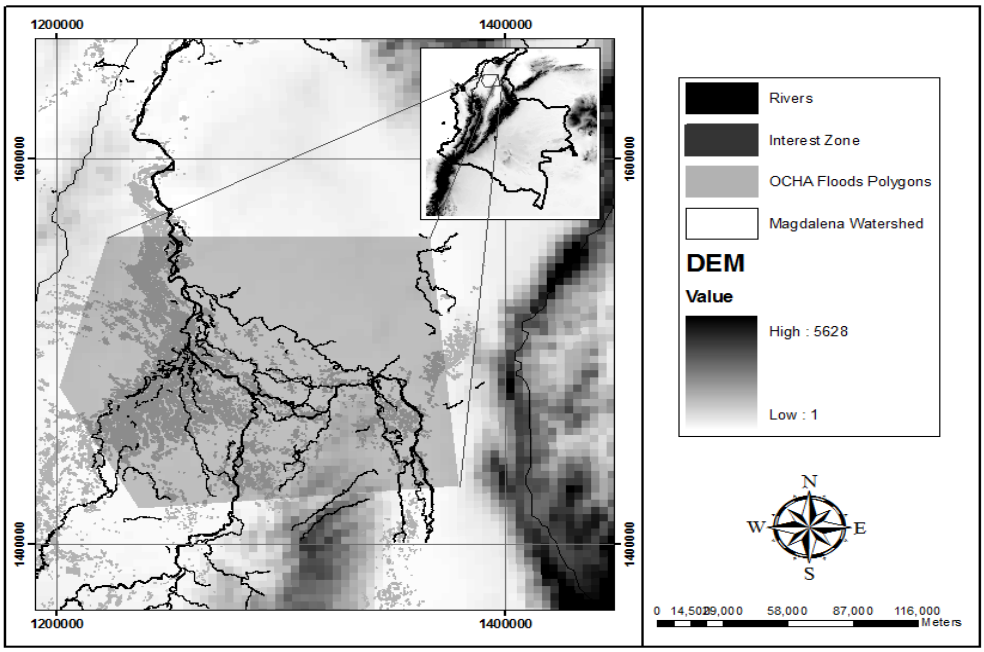

Fig. 1 Study area.

territorial development model, based on an appropriate flood risk assessment, to promote an adequate management and thus a sustainable development in the region [4].

3. Methodology

The methodological proposal is comprised within a conceptual framework that defines the problem of disasters as an unresolved problem of development, under the view that disasters are not a problem of nature but a problem of the relationship between the environment and the organization and structure of society. It is a real, viable cause-effect relationship to overcome and that includes all society and the development processes [5].

It is necessary to see this problem from two perspectives: A systemic approach that brings together processes and activities aimed at achieving a specific objective: assessing the vulnerability for an appropriate disaster risk management, this approach should allow local authorities to identify processes that can trigger a disaster event within its territorial context and decide how it is going to be controlled or reduced; And a management approach which helps to build concepts and criteria to guide risk management. This approach must be oriented to a better environment in its territory [6].

It will require the use of tools and means to know and evaluate the condition and dynamics of local level vulnerability. Because of this, the vulnerability flood assessment is complex and there is great uncertainty when taking decisions. These decisions are influenced by other factors that add complexity or affect the work, such as the absence or limitation of the quantity and reliability of data, the environmental dynamic and risk conditions, the definition of the study period, and the complexity of risk under changing development patterns in economic, social, environmental, and territorial terms.

3.1 Study Area Restriction and Data Processing

There exists a collection of information related to floods in the area: information gathered from historical studies and reports, technical information obtained by IDEAM (Institute for Hydrology, Meteorology and Environmental Studies), and mapping generated by IGAC (Geographic Institute Agustín Codazzi) and OCHA-Colombia.

It has been identified that the most affected populations and the registers of water level stations located at or near their jurisdiction and made a selection of dates belonging to the maximum events for the area (which for practical purposes had to be divided in two zones 1 and 2, since it is a large area) stations and dates of events maximum for zones 1 and 2 respectively are shown in Tables 1-4. The obtained flood polygons are shown in Fig. 2.

3.2 Field Level Verification

A travel route has been designed for field verification. It consists based on going through two circuits that seek to cover the largest number of municipalities and populated centers, with two essential characteristics: a large population and historical flood occurrence (Fig. 3). Circuits go as follows:

- Brazo de Loba and Brazo de Mompós on the Magdalena River;
- Brazo de la Mojana to El reposo, then Cauca River to the Brazo de Loba.

Table 1 Stations located in Zone 1.

Code	Station
2502737	Santa Ana
2502745	Plato
2502768	Magangué-Esperanza
2502794	Tacamocho
2901701	Tenerife
2903702	Calamar
2904707	San Pedrito

Table 2 Selected years for Zone 1.

Year	Month	Level obtained (cm)
1974	December	939
1984	November	979
1988	November	973
1999	November	853

Table 3 Stations located in Zone 2.

Code	Station
2320705	La Nobleza
2321706	La Gloria
2502702	El Banco
2502715	Guaranda
2502729	Sitio Nuevo
2502732	San Roque
2502733	Peñoncito
2502736	Armenia
2502741	Regidor
2502749	Las Aguadas
2502753	Barbosa
2502764	Tres Cruces
2502793	Coyongal

Table 4 Selected years for Zone 2.

Year	Month	Level obtained (cm)
1975	November	930
1999	November	979
2007	November	876

In these circuits, the geo-referenced information on maximum events, (levels attained, duration, cause, effect and other elements to fully describe the process of flooding) of floods in the areas is gathered. The benchmarks of the stations will be noted for grid of points of accuracy that can be combined with data from satellite images to create new flood polygons and associate them to flood return periods. In addition, this information can be used to correct the existing digital terrain models.

Other relevant information is obtained from local authorities and communities living in the area, as well as from the documents found in historical records, especially regarding potentially vulnerable elements (all those in the flood plains) and direct and indirect impacts (assessment of loss or damage) caused by the floods.

Finally, a classification of floods was performed to generate the final mapping of threats. Floods are classified according to their behavior, magnitude, and impact, using a qualitative classification proposed in Ref. [7]: ordinary flood, extraordinary flood and catastrophic flooding.

3.3 Vulnerability Assessment for Mitigation

Risk management is part of the shifting paradigm within the planning of sustainable development. It is essential to reduce vulnerabilities that have been increasing in recent years. The vulnerability assessment focuses the attention on floods in the

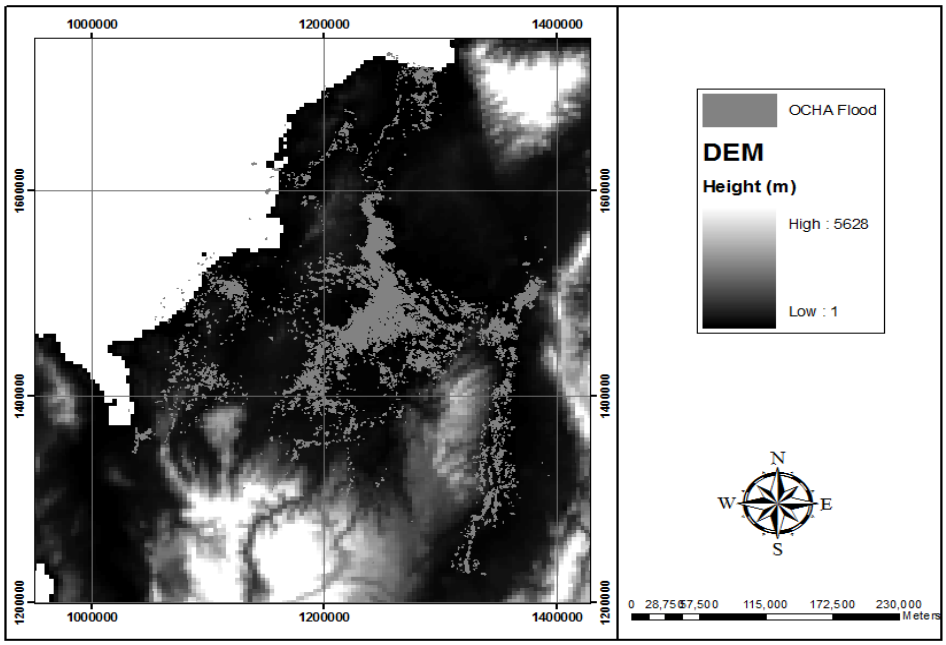

Fig. 2 Flooding polygons in the study area.

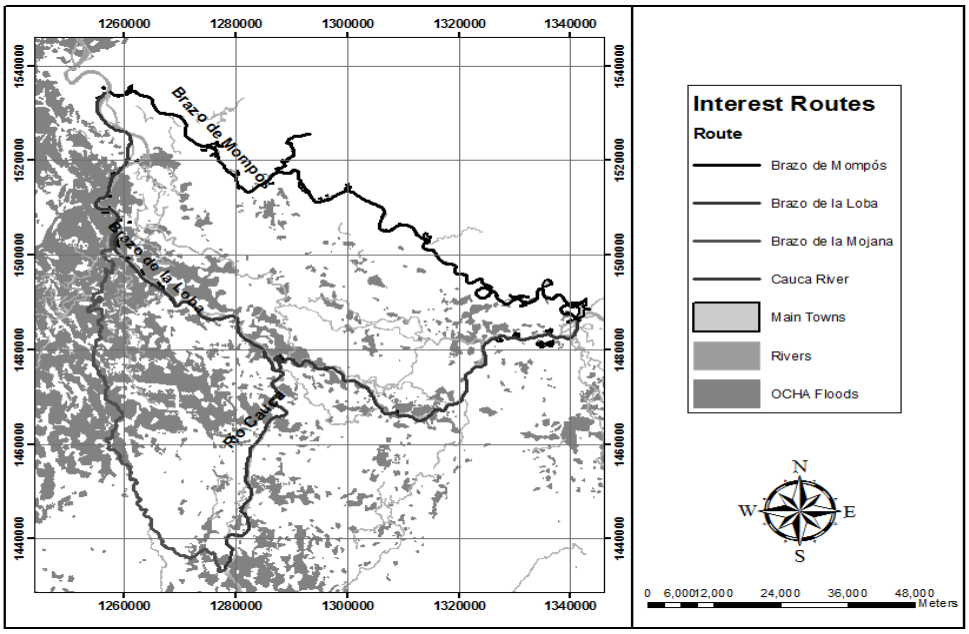

Fig. 3 Selected circuits.

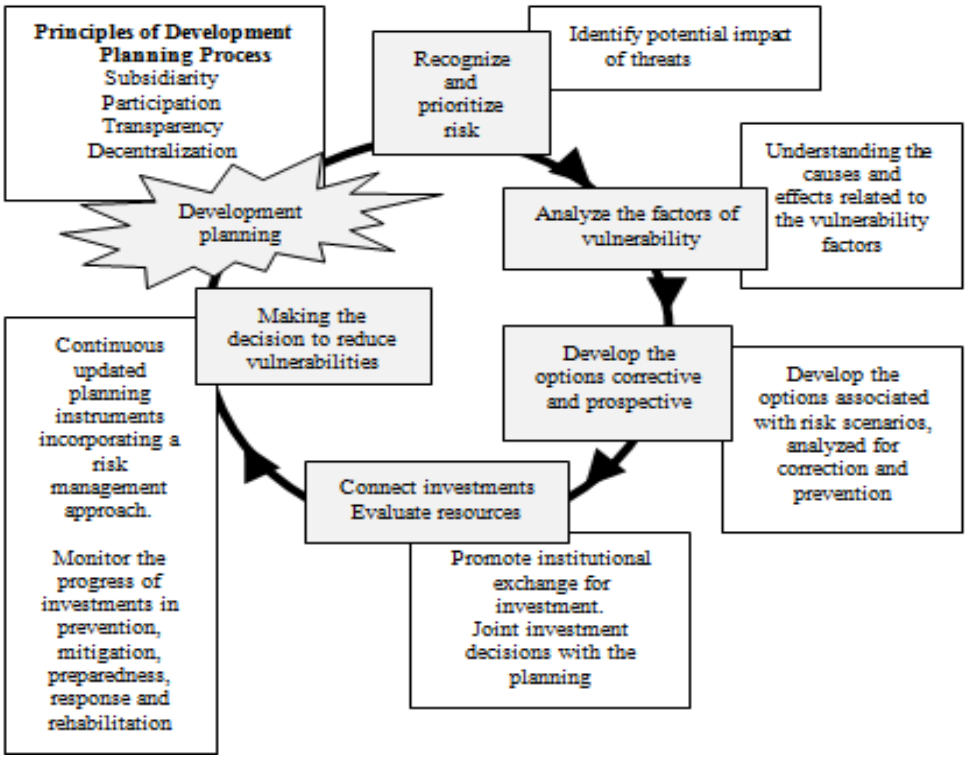

Fig. 4 Cycle to reduce vulnerabilities factors.

analysis and solution before and during the causes and effects generated, taking into account the reduction cycle premises of Fig. 4 [8].

The main purpose of this research is to find the right methodology to support the threat and vulnerability at the same scale (local and regional) for different return periods. To accomplish this search:

- Find different alternatives to standardize assessment of economic, social and environmental communities losses using quantitative and qualitative

methods [9];

- Form multidisciplinary teams to perform technical engineering exercises and local development planning. To assess those factors or conditions determined by physical, social, economic, and environmental factors that increase the impact susceptibility of communities to flooding;
- Build different scenarios of impact-adaptation;
- Build an indicator system related to the socio-natural conditions, to the institutional capacity and citizen participation.

4. Results

The work has allowed the establishment of a local strategic context that contemplates the relationship between the town, its organization, and its environment.Compare the nature, condition and dynamics of floods with the condition and structure of the operational base and its capacity to respond to them. It includes the analysis of environmental, financial, political, institutional, social conditions, and the identification of the actors who can affect or be affected by their decisions and/or activities [10].

It has also provided an organizational context including regulatory, administrative and technical elements.

It should be taken into consideration that it is necessary to do a systematic process which identifies the different components of vulnerability that seeks to cover all aspects: physicals, economical, social, institutional, political, technical, cultural, ideological, educational and ecological [11].

This identification must be done under mechanisms of citizen participation to ensure that all actors that have a large knowledge contribute from their different perspectives [12]. All this information, as well as the contained in the SISBEN (Beneficiary Identification System), regional annual statistics, quality life indicators, information from territorial and environmental plans, reports of environmental authorities and other sources supports the indicator system under construction.

The challenge facing the academic investigation is to build a future of communities more resilient to risk and foment the consciousness of the importance of risk reduction as an integral component of sustainable development [13].

5. Final Remarks

In this research project in its early stages until now has dominated the execution of the activities of collecting, analyzing and processing of primary and secondary information to determine its relevance before use. Primary information has been obtained by transects, meetings and interviews with local authorities and communities, collection of georeferenced information in the field and photographic records.

Secondary information was obtained from the review and evaluation of all information related to tools and management practices at national, regional or local such as: land use plans, development plans, accountability reports, plans action of force, operating plans and annual investment, environmental plans, risk management plans, disasters records, reports on the state of natural resources, statistical yearbooks, cadastral information, etc..

The achievement of the information has not been easy, and demands the establishment of schemes and mechanisms to ensure the availability, timeliness and quality of information, especially the official governmental information. Additionally, there are factors that add complexity or affect risk management such as the limitation on the amount and reliability of data which force to make assumptions, the dynamics of the environment and the complexity of the risk under changing patterns of development in economic, social, environmental and territorial.

Respect to cartographic information, its construction will be the result of an analysis of information in more detailed scales, because in the current scales (1:500,000, 1:100,000) it is not possible

define precisely threat and vulnerability components.

The risk management should be done locally using an appropriate resolution, considering more detailed scales (1:25,000 or greater) due to the implications in terms of human lives, quality of life and infrastructure. For this reason, a participatory geographic information system is intended to be other practical tool for assessing the threat and vulnerability in a larger and more updated scale.

The information generated in this study will contribute to public policy action structured to correct short- and medium-term situations of vulnerability, which can also be used in other activities like territorial and environmental planning especially.

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