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Flood risk analysis in areas surrounding the Burgay River in the city of Biblián

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[1] Juan Pablo Idrovo Ortiz https://orcid.org/0009-0003-1903-6804
Master's Degree in Construction with a Major in Sustainable Construction Administration, Catholic University of Cuenca, Cuenca, Ecuador.
juan.idrovo.03@est.ucacue.edu.ec

[2] Jose Abelardo Paucar Camacho http://orcid.org/0000-0003-2722-1850
Master's Degree in Construction with a major in Sustainable Construction Management, Catholic University of Cuenca, Cuenca
jose.paucarcamacho@ucacue.edu.ec

[3] Inain Gaibor Velasco https://orcid.org/0000-0002-4295-1969
Master's Degree in Construction with a major in Sustainable Construction Management, Catholic University of Cuenca, Cuenca; Disaster Risk Engineering, Bolívar State University, Guaranda, Ecuador.
numa.gaibor@ueb.edu.ec

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Palabras claves: Amenaza, Áreas vulnerables, Elementos expuestos, Riesgo de inundación.

Resumen

Introducción. Dadas las recurrentes inundaciones durante la temporada de lluvias, este estudio se enfoca en modelar el riesgo de inundación en las áreas adyacentes al río Burgay, ubicado en la zona urbana del cantón Biblián de la provincia del Cañar, Ecuador. **Objetivo.** Identificar el riesgo de inundaciones causada por la crecida del río Burgay en el cantón Biblián a través de la aplicación del método hidrológico – hidráulico para evaluar la amenaza, el uso de un GIS la zonificación de elementos expuestos a inundaciones para establecer estrategias para la reducción de riesgos. **Metodología.** Se emplea una metodología descriptiva-correlacional para detallar el fenómeno y evaluar las interrelaciones entre variables relevantes para este riesgo. **Resultados.** Los resultados destacan una distribución significativa de áreas expuestas a diferentes niveles de amenaza de inundación en las proximidades del río Burgay. Se identifican extensiones considerables con niveles preocupantes de riesgo, principalmente áreas de alta y media amenaza, abarcando un porcentaje considerable del territorio evaluado. Aspectos fundamentales de la infraestructura, como las edificaciones, la red de agua potable, el sistema de alcantarillado y las vías urbanas, muestran una notable exposición a estos niveles de riesgo, especialmente en las categorías de alta y media amenaza. **Conclusión.** La conclusión principal resalta la urgencia de implementar medidas preventivas y estrategias de gestión del riesgo en estas áreas vulnerables y expuestas. Estas acciones se tornan imperativas para mitigar los posibles impactos de futuras inundaciones, preservando la funcionalidad de la infraestructura crítica y garantizando la seguridad de la comunidad en el cantón Biblián de la provincia del Cañar, Ecuador. **Área de estudio general:** Ingeniería. **Área de estudio específica:** Construcción sustentable

Keywords: Exposed elements Flood risk Hazard, Vulnerable areas

Abstract

Introduction. Given the recurrent flooding during the rainy season, this study focuses on modeling the flood risk in the areas adjacent to the Burgay river, located in the urban area of Biblián canton in the province of Cañar, Ecuador. objective. Identify the risk of flooding caused by the flooding of the Burgay river in the Biblián canton through the application of the hydrological-hydraulic method to evaluate the threat, the use of a GIS and the zoning of elements

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exposed to flooding to establish strategies for risk reduction . Methodology. A descriptive-correlational methodology is used to detail the phenomenon and evaluate the interrelationships between variables relevant to this risk. Results. The results highlight a significant distribution of areas exposed to different levels of flood hazards in the vicinity of the Burgay River. Considerable extensions with worrying levels of risk are identified, mainly areas of high and medium threat, covering a considerable percentage of the evaluated territory. Fundamental aspects of the infrastructure, such as buildings, the drinking water network, the sewage system and urban roads, show a notable exposure to these risk levels, especially in the high and medium hazard categories. Conclusion. The main conclusion highlights the urgency of implementing preventive measures and risk management strategies in these vulnerable and exposed areas. These actions become imperative to mitigate the possible impacts of future floods, preserving the functionality of critical infrastructure and guaranteeing the safety of the community in the Biblián canton of the province of Cañar, Ecuador. General area of study: Engineering. Specific Area of Study: Sustainable Construction

Introduction

The frequency of natural disasters, especially floods, has come to the fore as one of the main concerns worldwide. The United Nations Office for Disaster Risk Reduction, or UNRRD, reported that the frequency of this type of incident has increased significantly in recent decades. In particular, there is a notable increase in the number of floods, which went from 1,389 cases between 1980 and 1999 to an average of 3,254 cases between 2000 and 2019 alone. This worrying trend suggests a significant growth of 234% in less than 20 years. The same organization also highlights that approximately 44% of all natural disasters worldwide have a hydrological origin, that is, caused by floods or damage inherent to rainfall (UNRRD, 2019).

In the context of Ecuador, floods are not considered unique or infrequent events; on the contrary, as a result of the nation's specific climatic and geographic attributes, there is a recurrent incidence of unfavorable hydrological phenomena throughout the year (Vallecilla et al., 2022). The Secretariat for Risk Management (SGR) provides records that offer a clear illustration of this situation. These records indicate that, during the month of February 2023 alone, there were 132 documented flood episodes, including: 7 cases of avalanches, 42 incidents of structural collapse, 6 hail events, 11 scour events, 1 thunderstorm event, and 16 gale events. The dataset effectively illustrates the considerable hydrological hazards that Ecuador faces on a regular basis (SGR, 2023).

An example of the aforementioned phenomenon is the Biblián canton, located in the Cañar province in Ecuador, which is currently facing significant challenges arising from the intense rainfall it experiences during the winter period. The region is affected by these intense rains, which has caused many hazards and calamities related to flooding. The canton has been suffering from the consequences of these strong storms for several years. A notable event occurred in April 2022, when the Burgay River overflowed, causing considerable destruction to the Biblián sports complex, the Livestock Fair and 27 residential properties (Primicias, 2022).

The need to address the material damage and economic losses caused by these disasters drives the search for viable solutions aimed at mitigating the risks and minimizing their impact on the community, since the overflow of the river, in addition to causing physical and economic damage, poses a significant risk to safety, the interruption of essential services, the displacement of homes and exposure to hazards that have significant impacts on the well-being of people residing in the impacted areas (Prefectura del Cañar, 2022).

Given the problem described above, the following research question is raised: How is it possible to carry out a detailed modeling of the flood risk in the areas adjacent to the Burgay River, located in the city of Biblián, in order to warn local authorities about the possibility of future disasters? To answer this question, it can be said that a viable and effective strategy for reducing the risk of disasters caused by floods would be to integrate a systematic analysis of the risk areas most susceptible to disasters to integrate them into local and national development management and planning procedures (Román, 2021).

One strategy for conducting these analyses involves using digital modeling technology to gather hydraulic and hydrologic information to determine hazard zones and identify exposed elements. This combination of approaches facilitates the identification of spatial patterns, supports decisions by allowing simultaneous analysis of large amounts of data, and provides answers to questions related to location, causality, and methodology.

Based on the above considerations, the present study establishes as a general objective the identification of the elevated risk of flooding caused by the increase in the flow of the Burgay River in the Biblián Canton, using a digital modeling approach that incorporates hydraulic and hydrological data specific to the region. This purpose is aligned with the hypothesis that, by carrying out an exhaustive characterization of the river's hydrodynamics and hydrological behavior, supported by the application of various technological tools such as SAGA, IBER and GIS, it will be possible to effectively and

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accurately discern the level of risk associated with flooding caused by the Burgay River in the urban environment of Biblián.

The achievement of the objective of this research allows the collection and analysis of numerical and spatial data that provide an accurate view of the probability of flooding and its impact on the region. The research also focuses on identifying elements and areas exposed to flooding, which helps to develop specific recommendations and strategies to mitigate the effects of disasters. These recommendations can be considered by local authorities and other relevant entities for decision-making and the implementation of preventive and mitigation measures.

The importance of this research lies primarily in the population of Biblián, as this study allows for a scientific and data-based assessment of flood risk, the identification of the most vulnerable and exposed areas, and the design of effective prevention and mitigation strategies. In addition, it provides crucial information on the underlying factors that contribute to flooding, which will promote more resilient urban planning and adequate risk management.

The results obtained will have a direct impact on local decision-making, resource allocation and the implementation of public policies aimed at protecting the population and reducing the social, economic and environmental impacts of floods. Furthermore, this research contributes to scientific knowledge in the field of risk management and resilience to natural disasters, providing lessons and good practices that can be shared and used in other similar contexts, thus promoting the safety and well-being of communities affected by floods.

The dependent variable of this research is the flood areas, which can be conceived as the excessive accumulation of water in normally dry places, since the overflow of rivers, lakes, canals or the accumulation of water in flat areas occurs when water levels exceed the capacity of the soil to absorb water or the capacity of the current drainage system (Tariq et al., 2022). Similarly, the independent variable in this study is the hydraulic and hydrological characteristics of the area, which can be defined as the attributes and conditions related to the hydraulic behavior of a body of water and the hydrological dynamics of the surrounding region. These variables include, among other aspects, the topography of the terrain, the flow rate, precipitation rates, soil retention capacity, and the specific geography of the study area (Sequeira, 2021). The theoretical framework that characterizes the study variables through the contributions of different authors is presented below.

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Hydrological modeling and hydraulic characteristics

Hydrological modeling is a crucial tool that uses mathematical and computational models to accurately simulate the behavior of water in a watershed. This tool allows predictive simulations to be performed in various situations by using a complete collection of hydrological data, including precipitation, evapotranspiration, infiltration, and runoff. Obtaining high-quality results depends largely on the accuracy of the hydrological data and the mathematical model used, so it is essential to collect information in a rigorous and accurate manner to ensure reliable results. Hydrological modeling has the flexibility to be distributed or clustered, depending on the scale and complexity of the study, in addition to its wide range of applications, from water resources planning to flood management and environmental impact assessment, highlighting its vital role in decision-making for water resources management and the prevention of water-related natural disasters (Camargo, 2021).

For hydrological modelling to be effective, it is necessary to go through a model adjustment process that involves the application of different approaches, tools or numerical techniques to correct the parameters. The purpose of this adjustment is to ensure that the simulated results match the real data that may include modifications in flow measurements, water levels and other relevant hydrological factors. The objective of calibration is to determine the most effective combination of parameters that allows the model to faithfully replicate the hydrological patterns observed in the research area. This procedure may involve the use of optimization algorithms, which help to identify the optimal combination of parameters that minimizes the disparities between the simulated results and the observed data (Dutta and Sarma, 2020).

The concept of “hydraulic characteristic” refers to a branch of physics that deals with the study and application of the properties and behavior of fluids, especially liquids, in motion or at rest. This discipline covers concepts such as pressure, velocity, flow rate, and force applied to fluids, and is applied in various areas of engineering, as it is used to design and analyze systems that involve the transfer of energy through fluids. This may include the design of water supply networks, dams, canals, flood modeling, among others (Pooni et al., 2022).

In this research, the hydraulic characteristic used is flow, which is essential for hydrological modeling in order to predict areas susceptible to flooding. Flow is the measurement of the volume of water or any other fluid that passes through a given location within a given period of time. Volumetric flow is a quantitative measure of the speed at which a fluid flows and is usually indicated in measurements such as cubic meters per second (m^3/second), liters per second (l/s) or gallons per minute (gpm) depending on the unit system chosen (Avila, 2015).

Geographic Information System (GIS)

Before discussing the most pertinent conceptualizations of Geographic Information Systems (GIS), it is imperative to begin with a thorough examination of the beginnings of geomatics (often referred to as geoinformatics). Recent advances in Information and Communication Technologies (ICT) have brought about a significant transformation in several scientific domains. These advancements have facilitated the creation of applications that possess the capacity to effectively handle substantial amounts of data, including geographic information (Annamalai et al., 2022).

The domain of geomatics encompasses the acquisition, examination, and utilization of descriptive data and spatial information pertaining to georeferenced entities. The field of geomatics encompasses a wide range of applications in various fields that rely heavily on spatial data. These domains include, but are not limited to, environmental research, urban development, transportation, land use and tenure. The scope of research covers various topics, including integration of spatial databases and information systems, digital image manipulation, software development, decision support, web-based utilization of geographic information technologies, geographic information management, environmental modeling, remote control of devices, cartography, and utilization of the global positioning system or GPS (Song and Wu, 2021).

GIS technology facilitates the detection of spatial patterns and improves decision-making processes by simultaneously analyzing extensive data sets. In addition, this platform provides resolution to queries related to geographic positioning, causal relationships, and research methodologies. Furthermore, these systems allow the acquisition of thematic maps based on the specific needs and preferences of clients. The data provided is considered accurate and may be subject to change as deemed appropriate. GIS is a comprehensive combination of hardware, software, and geographic data that has been developed to effectively acquire, retain, alter, examine, and present geographic information in its various forms, with the overall goal of addressing complex problems (Alarcón and Ordoñez, 2019).

Similarly, GIS functions as a storage system for spatial data that is linked to the visual elements of a digital map by a shared identifier. The practice of referencing objects can be used to identify the attributes of an object. Alternatively, it is feasible to determine the spatial coordinates of an object within the cartographic framework by using a database (Caceres et al., 2018).

A GIS has the ability to address a wide range of queries, which may vary in terms of their degree of complexity. The aforementioned tasks encompass a diverse range of activities. These activities include examining the attributes of a particular region, assessing compliance with designated system requirements, comparing different spatial or temporal scenarios, identifying optimal routes between multiple locations, identifying spatial configurations, and building models based on simulated phenomena or actions. In contrast, the use of various software programs allows for the retrieval, transmission, conversion, overlay, manipulation, and visualization of geographic information (Chambilla, 2019).

Topography and land use

One of the most feasible methods currently available to review the topography and land use of a region is through the review of the institutional and legal documents that a company has. For the purposes of this research, in addition to a GIS analysis, two types will be reviewed: the cadastre and the development and territorial planning plan. Each of these is mentioned below.

Cadastre can be defined as a comprehensive database that encompasses physical, legal, and financial data pertaining to properties within a specific geographic area. The system described above is widely recognized as a real estate database that brings together essential attributes of properties and their occupants. Its main objective is to understand the property registry and provide information to government authorities. The urban cadastre is a specialized instrument used within urban environments, primarily intended for the purpose of collecting and distributing financial data related to the city's infrastructure. This information is subsequently used in administrative planning processes. The above is considered as a specialized inventory that encompasses geographic, geometric, legal, and physical-constructive data (Lucio, 2020).

As regards the second category mentioned above, Ecuador’s territorial planning process is regulated by two important laws: the Organic Law on Territorial Planning, Land Use and Management – LOOTUGS and the Organic Code of Decentralization of Territorial Organization Autonomy – COOTAD. The main objective in LOOTUGS is to defend the responsible and sustainable use of territorial resources, safeguard the natural-cultural heritage and effectively regulate activities within the territory. To achieve this, a broad framework of instruments is established that covers several levels, including supranational, national, regional, provincial, cantonal, rural, parish and special (LOTUGS, 2016; COOTAD, 2010).

In the area of supranational affairs, various plans are designed to promote Latin American integration and its strategic commitment on the international stage. At the national level, the formulation and approval of the National Territorial Strategy, Special Plans for Strategic National Projects and Sectoral Plans of the Executive with an impact on the territory take place. The Decentralized Autonomous Governments of various levels, including regional, provincial, cantonal, rural parish and special regime governments, have the power to approve Territorial Development and Planning Plans, as well as

Complementary Plans. The Special Regime of Galapagos has a well-defined strategy to promote sustainable development and effective territorial planning.

The COOTAD emphasizes the importance of collaboration between decentralized autonomous governments to articulate their territorial development plans with the National Development Plan and manage their competencies in a complementary manner. The code also describes the National Territorial Strategy as an additional tool to the National Development Plan. It emphasizes the need for coordination and harmonization between the central government and decentralized autonomous governments for effective territorial planning within their respective jurisdictions (COOTAD, 2010).

The coordination of national planning is facilitated by the National Decentralized System of Participatory Planning. This system includes various entities such as the National Planning Council, the Technical Secretariat of the System, the Planning Councils of the Decentralized Autonomous Governments, the Sectoral Councils of Public Policy of the Executive Branch, the National Equality Councils and social participation bodies such as Citizen Councils, Advisory Councils and other forms of participation.

Methodology

This study employs a descriptive-correlational research design that combines two distinct approaches. The descriptive design focuses on providing a detailed and comprehensive characterization of the current state of the study phenomenon, through the exhaustive collection of data from the area. Meanwhile, the correlational design focuses on measuring and evaluating the existing relationships between two or more relevant variables (Osada et al., 2021). In the context of this research, this design is implemented to delineate the areas susceptible to flooding in Biblián, specifically those near the Burgay River in the urban area. Topographic, hydrological and hydraulic data from the region were collected and integrated into a statistical analysis program. This integration allows examining the relationship between terrain characteristics and flood probability for a 50-year return time, establishing possible patterns of dependence.

The study adheres to a quantitative approach, as it involves the numerical treatment and analysis of the collected information using specialized programs such as SAGA, IBER and GIS. These tools are specifically used to perform hydrological and hydraulic modeling, as well as to identify hazard and flood areas. This quantitative approach enables precise and objective measurements by focusing on the analysis of numerical data, reducing subjective interpretation and significantly increasing the effectiveness, validity, reproducibility and predictive capacity of the results obtained (Cienfuegos et al., 2019).

This research is carried out in the Biblián canton, located in the Cañar province, with a territorial extension of 205.30 km². Within its hydrographic system, the Burgay River

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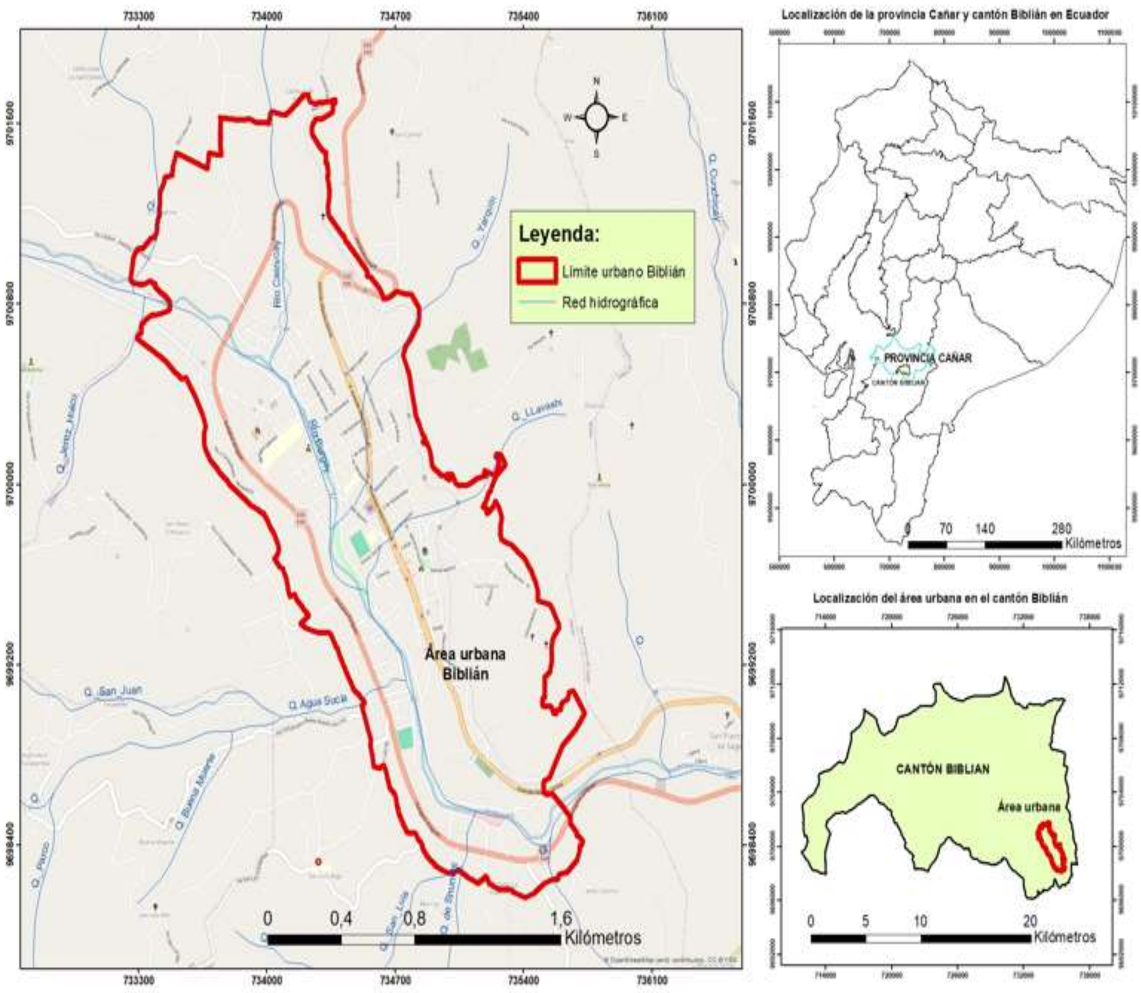
stands out, representing a vital source of productivity for the canton, since it provides significant humidity to the soil, making Biblián one of the most fertile points in southern Ecuador. The study sample focuses on the urban area of influence of the Burgay River, which covers an approximate length of 25 km. This selection is based on previous records of flooding that this sector has experienced during periods of intense rainfall. The total extension of the study area comprises approximately 55 km², including the areas adjacent to the river. Figure 1 shows the study area:

Figure 1

Location of the urban area of Biblián



In the evaluation and estimation of the threat, two types of modelling are implemented: hydrological modelling (flow calculation) and hydraulic modelling (flood depths and area). In addition, the zones and levels of flood threat are determined, and then the elements exposed to flooding are identified. Each of these procedures is detailed below:

Hydrological modelling

For this process, the expected flow that the Burgay River could register in the next 50 years is determined. Information from the study entitled "Design of a 20-meter span bridge over the Burgay River" (Clavijo, 2015) is used. The Rational method was used to calculate a flow of 128.69 cubic meters per second (m³/second) for a return period of 50 years, data that was used in the flood threat model.

Hydraulic modeling

To begin with, the Digital Elevation Model (DEM) is developed using satellite images with a spatial resolution of 12.5 meters obtained from the European Space Agency (ESA) satellite and using the SAS Planet software (ESA, 2022). This DEM is improved to achieve greater detail of the topography of the Burgay River through extrapolations using the GLOBAL MAPPER software (version 24). Then, the hydrological modeling data and the DEM of the Burgay River are used to carry out the flood hazard modeling in the IBER software version 3.3.1). The results are presented in raster images showing the height or depth of the water in meters (m) for a return period (TR) of 50 years for the area of influence of the Burgay River in the urban area of Biblián.

Determination of threat zones and identification of exposed elements

The threat zones are determined from the raster image (modeling in IBER) that indicates the flood height, using the ArcGIS software (version 10.3), the flood threat zones and levels are classified and established as described in Table 1 (Paucar, 2016). Regarding the identification of elements exposed to the threat of flooding, the threat map with a 50-year TR is correlated with the maps of infrastructure, buildings, drinking water networks, sewerage, urban roads and bridges, based on the data provided by the Cadastre Unit or Department of the Decentralized Autonomous Government - GAD of Biblián for the year 2023.

Table 1

Flood threat zones and levels with a 50-year TR in the Burgay River

Flood threat zones and levels	Criteria	Possible effects
High threat	Draft or water sheet height = equal to or greater than 1.00 m	High risk for people and possible serious damage to infrastructure.

Medium threat	Draft or water depth = From 0.41 to 0.99 m	Damage to homes, vehicles may lose grip, objects may be dragged which could affect the stability and mobility of people.

Table 1

Flood threat zones and levels with 50-year TR in the Burgay River (continued)

Flood threat zones and levels	Criteria	Possible effects
Low threat	Draft or water sheet height = 0.01 to 0.40 m	It would have minor impacts on human lives; there could be trips, falls or other minor causes.

*Note.*adopted from (Paucar, 2016)

Results and discussion

As can be seen in Table 2, the areas have been categorized into three levels according to the height of the flood: high (equal to or greater than 1.00 meters), medium (0.41 to 0.99 meters) and low (0.01 to 0.40 meters). When examining the hectares (ha) associated with each threat level, it becomes evident that the high threat area covers 12,459 hectares, which represents approximately 41.34% of the total. A total of 8,422 hectares, representing 27.94% of the study area, are classified as having a medium risk level. Finally, the region classified as low threat comprises 9,257 hectares, which represents 30.72% of the total area. These data are represented graphically in Figure 2.

The results of the study on the distribution of flood hazard zones around the Burgay River, in the urban area of Biblián, highlight a worrying situation in terms of potential risk. While it is important to recognize the notable increase in areas categorized as high and medium hazard, which constitute a significant portion of the overall study area, it is crucial to address this issue from a risk management perspective. These results emphasize the importance of taking immediate action to implement preventive and urban planning strategies that can reduce the potential negative effects of future floods in the identified vulnerable areas. This is crucial to ensure the safety and well-being of the local population.

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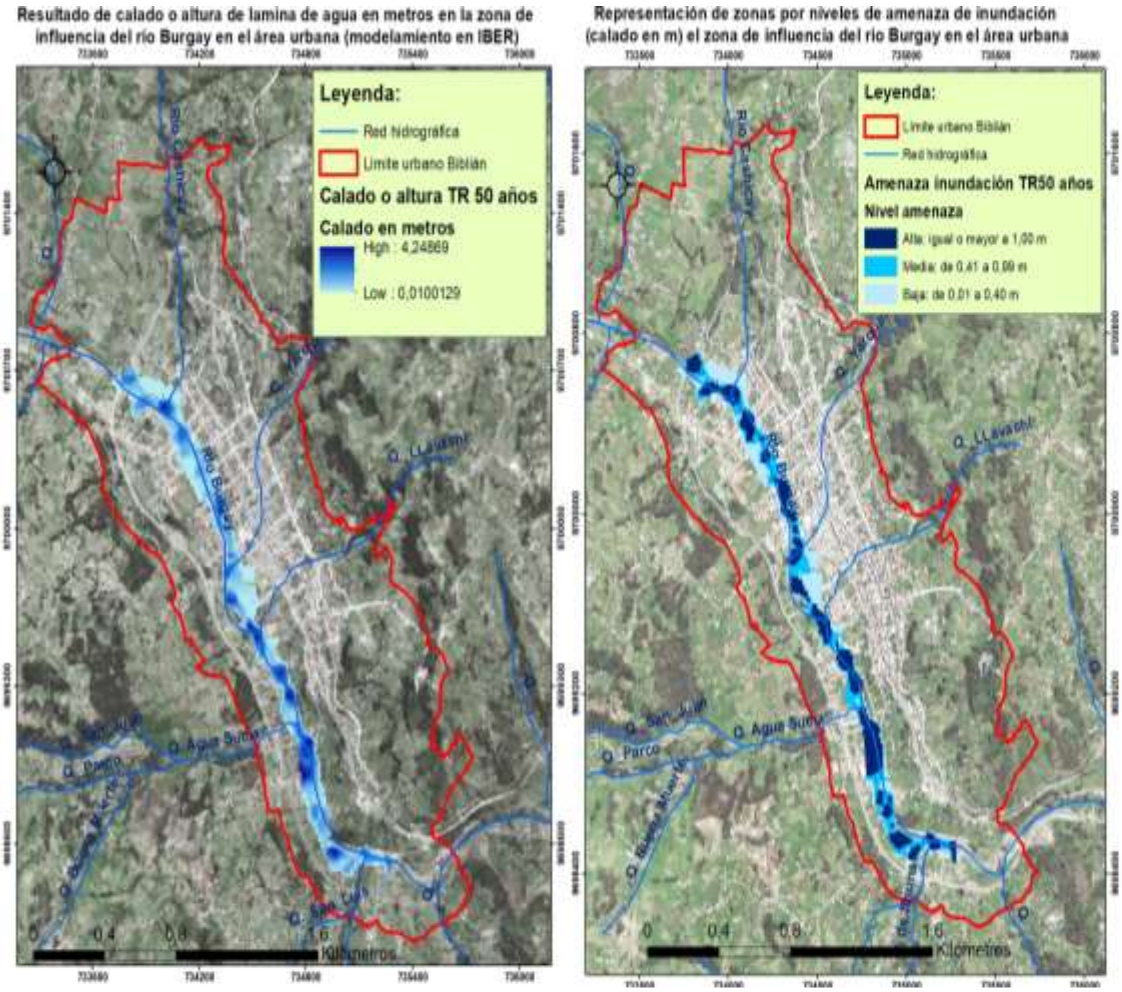
Table 2

Flood threat level in populated areas (ha) surrounding the Burgay River

Flood threat level	Area in ha	Percentage
Height: equal to or greater than 1.00 m	12,459	41.34
Average: 0.41 to 0.99 m	8,422	27.94
Low: 0.01 to 0.40 m	9,257	30.72
Total	30.14	100,00

Figure 2

Flood threat for TR 50 years of the urban area surrounding the Burgay River



Next, we proceed to the analysis of elements exposed to flooding threats in the Burgay River in the urban area of Biblián. As can be seen in Table 3, single-story buildings represent the largest number of constructions in all threat categories: high (23.31%), medium (33.08%) and low (43.61%), totaling 133 buildings. On the other hand, two-story buildings occupy the second position in terms of level of exposure to threats with a total of 98 threatened constructions with a distribution of: high (22.45%), medium (33.67%), and low (43.88%). In contrast, three-story buildings have a lower presence in the high threat category (11.11%), although they show a similar percentage between medium (44.44%) and low (44.44%), with a total of 9 buildings. These data reveal a trend where single-story buildings are more numerous and more evenly distributed across risk levels, while multi-story buildings show relatively similar exposure to different threat levels.

The distribution of buildings according to flood threat levels reveals a worrying situation regarding the exposure of structures to potential flooding. Despite the prevalence of single-storey buildings, their susceptibility to flooding of varying intensities across all risk categories is a cause for concern. Meanwhile, it is worth noting that there are fewer two- and three-storey buildings, but they face a more balanced range of threats. This emphasises the need for preventive measures and urban planning strategies tailored to each type of structure, taking into account their different exposure and vulnerability to different flood scenarios.

Table 3

Exhibition of buildings by flood threat level for TR 50 years on the Burgay River in the urban area of Biblián

Classification	High		Average		Low		Total	
	Number	%	Number	%	Number	%	Number	%
1 floor	31	23,31	44	33.08	58	43.61	133	100
2 floors	22	22.45	33	33.67	43	43.88	98	100
3 floors	1	11,11	4	44.44	4	44.44	9	100
Total	54	22.50	81	33.75	105	43.75	240	100

On the other hand, the level of exposure of essential infrastructure is determined. As can be seen in Table 4, the drinking water network shows a uniform distribution between its threat levels, with close percentages in the high (31.23%), medium (32.00%) and low (36.76%) levels, with a total length of 2,560.77 meters. On the other hand, the sewerage network exhibits a higher percentage of exposure in the high threat category (44.87%), followed by the medium (30.04%) and low (25.09%), with a total length of 3,636.67

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meters. Urban roads show a similar distribution, with a high percentage in the high threat level (43.83%), followed by the medium (30.61%) and low (25.56%), covering a total length of 8,195.15 meters. However, the exposure of bridges shows a peculiarity, where 4 of its 6 meters of total length is in the high threat category (66.67%), the remaining (2m) has a medium exposure (33.33%) with zero exposure in the low category.

These findings highlight the worrying exposure and vulnerability of critical infrastructure to varying degrees of flood risk. The drinking water network and the sewerage network face significant levels of risk, while the bridge infrastructure is of particular concern due to its exposure to high and medium hazards. This situation underlines the importance of protecting the area's vital infrastructure, particularly the bridge network, through a strategic approach and targeted measures to ensure its resilience to future flooding.

Table 4

Exposure of essential infrastructure by flood threat level for TR 50 years on the Burgay River in the Biblián urban area

Infrastructure exposed to flooding	**High**		**Average**		**Low**		**Total**	
	Length (m)	**%**	**Length (m)**	**%**	**Length (m)**	**%**	**Length (m)**	**%**
Drinking water network	799,829	31,23	819,513	32,00	941.43	36.76	2560.77	100
Sewerage network	1631.86	44.87	1092.31	30.04	912.50	25.09	3636.67	100
Urban roads	3591.55	43.83	2508.70	30.61	2094.90	25.56	8195.15	100
Bridges	4.00	66,67	2.00	33,33	0.00	0.00	6.00	100

Figure 2 below shows the elements exposed to flood threat for TR 50 years in the urban area surrounding the Burgay River.

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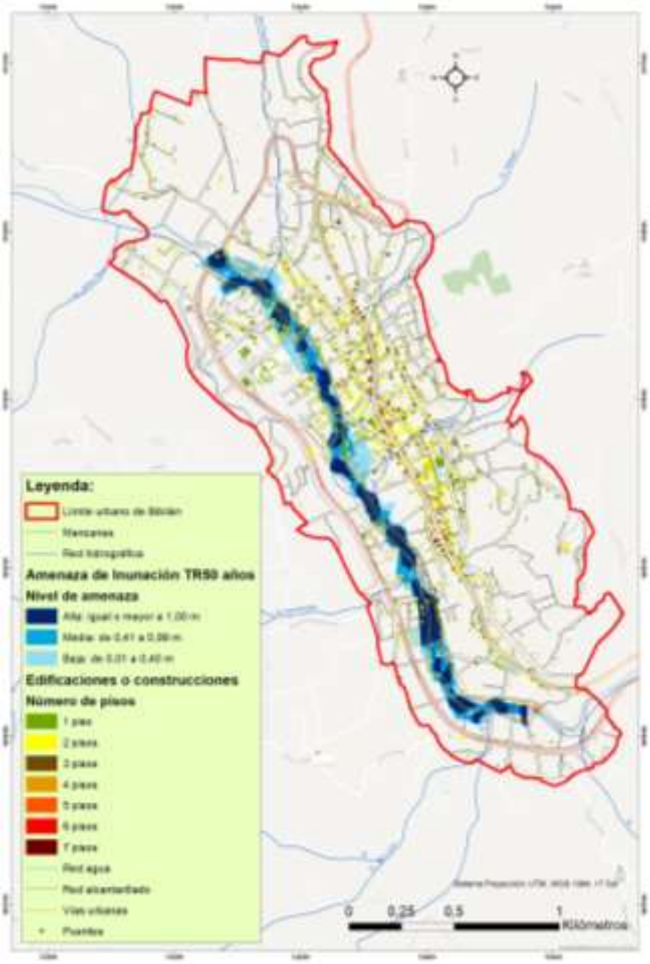
Figure 3

Elements exposed to flood threat for TR 50 years of the urban area surrounding the Burgay River



Conclusions

- The flood risk assessment in the Biblián urban area revealed a notable distribution of areas exposed to different levels of threat. The data collected indicate that there are significant areas at risk, with both high and medium threat levels covering a substantial portion of the assessed territory. This assessment highlights some crucial areas that need urgent attention and proactive measures to minimize the potential consequences of future flooding.
- The distribution of exposure to different threat levels among elements exposed to flooding, from essential infrastructure to buildings, is uneven. Important infrastructure such as drinking water networks, sewage systems and urban roads face significant levels of risk, particularly in the high and medium threat categories. It is crucial to establish specific measures to safeguard and adapt these

vital components, ensuring their continued operation and safety in the event of potential disasters.

- The results obtained offer the Decentralized Autonomous Government (GAD) of Biblián a solid basis for developing flood risk reduction strategies in the urban area. These findings provide useful information for designing preventive measures strategies and implementing effective risk management policies. In addition, the methodology used in this assessment offers a reliable and repeatable experience for other regions of the Cañar province and throughout Ecuador. It provides a well-organized and effective approach to assess and manage flood risks in different urban areas and territories. Feeling exposed in the field.

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Conflict of interest

There is no conflict of interest

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