Socio-environmental effects of flash floods in Rio Pindo, Pastaza, Ecuador

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Abstract: Rivers are fundamental elements in populations and at the same time represent risks arising from extreme events. The objectives of this work were to identify the main environmental effects caused by the overflow of the Pindo Grande River in the Shell parish and to know the state of emergency preparedness of the population. A survey format was developed that collects socioeconomic information, housing, services and effects due to the river floods, which was applied to 135 people located in neighborhoods surrounding the river. It was determined that the majority of the population has not been trained for emergencies with flashlights being the most frequently reported item of equipment needed. The main impacts were on water and electricity supplies. It is concluded that the areas surrounding the river are exposed to risks due to flooding and the majority of the population has not been trained in emergency management.

Key words: flood; risk; rain; environment; population

1 Introduction

Water consumption within river basins is primarily intended to meet the needs of the population, thus exposing it to potential contamination risks. Floods are a common occurrence within these basins (Montoya and Rodríguez 2020). In Ecuador, Andean and Amazonian river systems are categorized as Andean streams (those above 3,200 meters above sea level), mountain rivers (those between 500 and 3,200 meters above sea level), and Amazonian rivers (those below 500 meters above sea level) (Encalada et al., 2019). Torrential flows are characteristic of small, mountainous basins. These flows consist of a mixture of water and sediments that move rapidly along the riverbed, and in recent decades these climatic events have been reported with increasing frequency, resulting in human and economic losses. (Aristizabal et al., (2020).

Shell is a strategic parish in the province of Pastaza, the second most populated, despite not being one of the oldest towns. The Mera Canton has a population of 11,861 inhabitants (National Institute of Statistics and Censuses, 2010). This area is characterized by frequent and intense rainfall (Abril et al., 2019). The largest population concentration is found in the Shell parish. Tourist, economic, and institutional activities take place here. In 2002, a dam was built on the Pindo Grande River in the Shell parish with the aim of increasing tourism and generating development opportunities. This dam was destroyed by flooding caused by excessive rainfall on December 30, 2016.

The objective of this study was to identify the state of preparedness of the population in the event of river flooding.

2 Materials and methods

This project was carried out in the Shell Parish in 2017 (Figure 1). Its temperature characteristics, according to the Rio Amazonas meteorological station database for a 30-year return period, are: a maximum temperature of 30.5°C, a minimum temperature of 12°C, and a minimum average temperature of 21°C. July is the coldest month and October the warmest. Abril et al. (2019) indicate that the average annual rainfall is 5,367 mm. Historically, the highest rainfall occurs in April, with an average of 570 mm, and the driest month is August, with an average of 335 mm. The maximum rainfall recorded in 24 hours was 244.6 mm, which occurred on the day of the river overflow event, reaching a flow rate of 226.9 m³/s, while its normal base flow rate is 6 m³/s.

For the development of this work, a survey was carried out in the neighborhoods near the location of the River, these being: Cuatro de octubre, Voz Andes, Copales, Mushualpa, Nuevo Amanecer, Pindo Mirador, Pueblo Nuevo, Sacha Runa, San Antonio, San José, San Luis and Shuaretza and Sicha Puma, in which a total of 135 surveys were applied, which consisted of 4 blocks, the first corresponding to the description of the respondent, the second with socioeconomic aspects, housing structure and provision of services, the third block environmental aspects and the last one preparedness for emergencies.
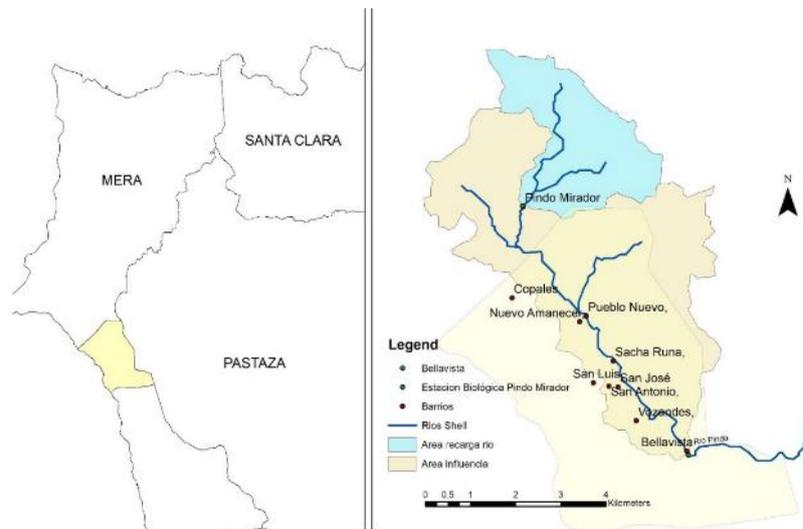

Figure 1. Location of the study area

The data were entered into an Excel spreadsheet and subsequently transferred to SPSS (IBM, 2013), where they were processed using frequency analysis. A multivariate multiple correspondence analysis with rotated components (Cuadras, 2014) was applied to the factors age, time since the most frequently reported disasters occurred, distance to the nearest point, and number of people residing in the household. The Kaiser-Meyer-Olkin coefficient was estimated, and an optimal scaling dimensionality reduction analysis was performed, yielding Cronbach's alpha coefficient applied to the disaster memory block (Hair et al., 1999). A bivariate analysis of variance was conducted to determine whether the variables age, sex, ethnic self-identification, length of residence, and level of education contributed to the variability of the responses. Prior to the analysis, data was categorized by age, considering ranges of less than 20 years, 1 to 30 years, 31 to 50 years, 50 to 70 years and more than 70 years, and for residence time less than 5 years, 5 to 10 years, 11 to 20 years, 21 to 30 years and more than 30 years.

3 Results

Figure 2 shows that the majority of respondents are female, with the largest group falling within the 16-30 and 31-50 age ranges. The majority of residence times range from 1 to 20 years, the predominant education levels are primary and secondary, and the main occupation of the respondents is agriculture.
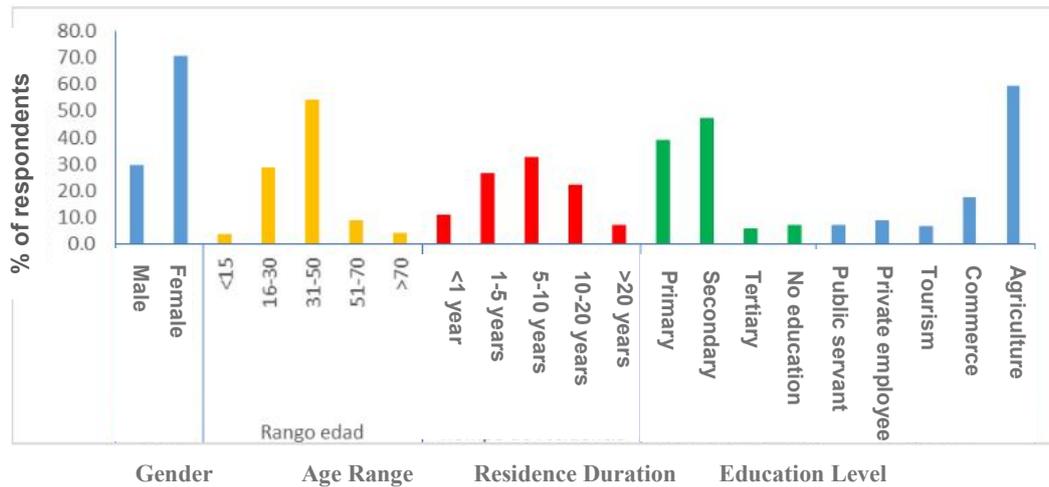

Figure 2. Respondent profile

Regarding housing characteristics (Figure 3), the majority of respondents reported owning their homes. The predominant construction materials were cement and wood, with a single-story structure. Most respondents had legally registered properties, and the existence of communal land was also noted. Thirty percent were unaware of the property's status.
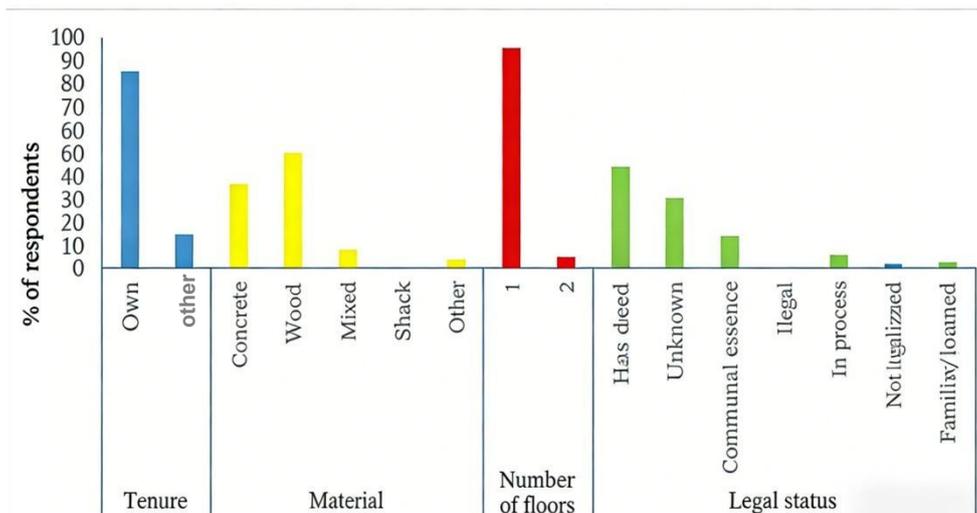

Figure 3. Housing characteristics

Regarding access to basic services (Figure 4), at least 80% of respondents reported having piped water and electricity; 37% had cell phones, and a smaller percentage had internet and landline telephone service. As for access roads to the surveyed areas, the majority of respondents reported that the roads were unpaved.
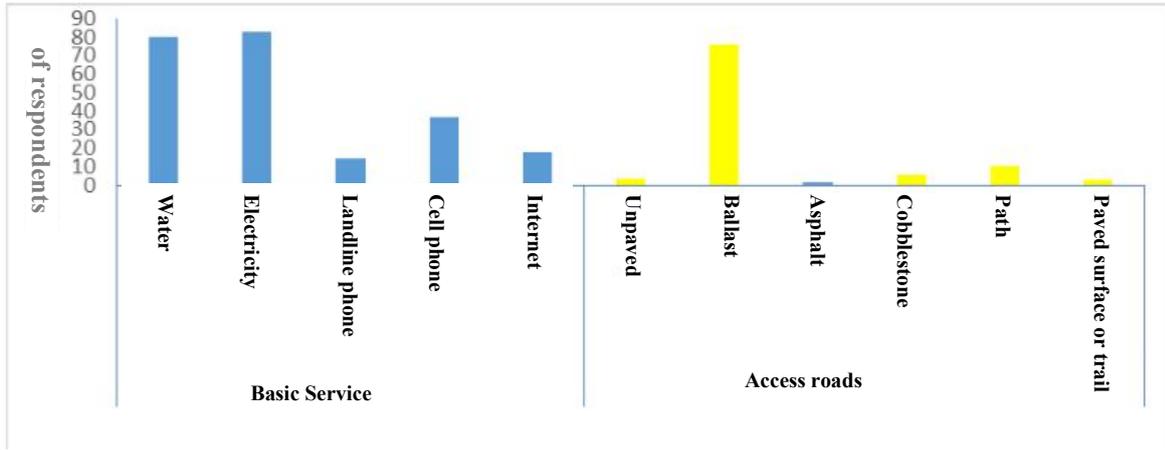
Figure 4. Basic services and access routes

In terms of sanitation (Figure 5), the majority of respondents use a well, followed by a toilet inside the home. Wastewater is mostly discharged into water bodies, public sewers, and rivers. Solid waste is disposed of by 75% of respondents using the collection truck, with collection occurring primarily once or twice a week.
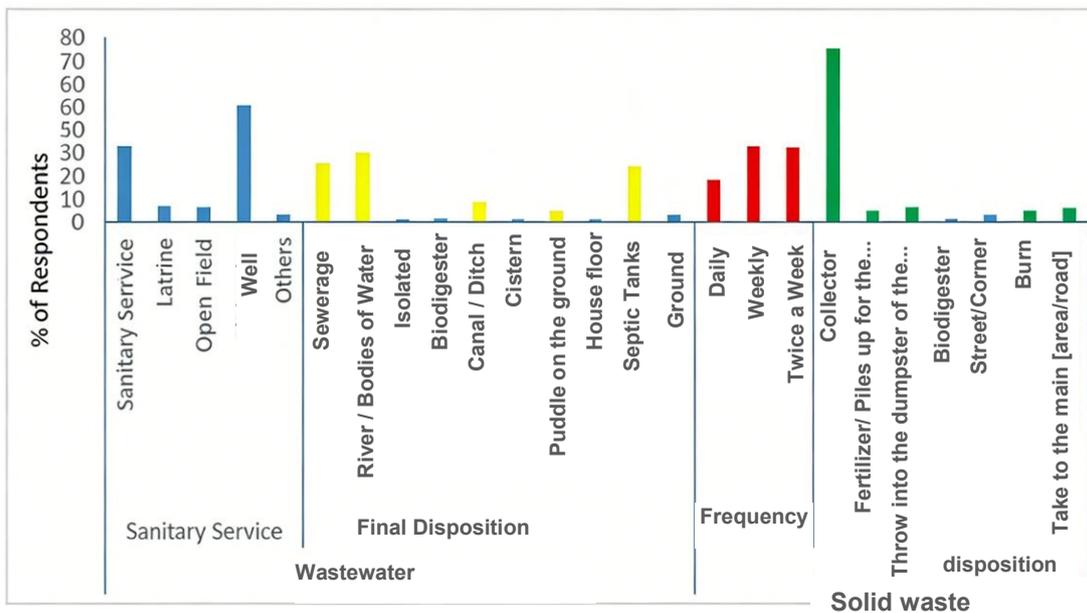

Figure 5. Sanitation Services

The main risk factors (Figure 6) are the presence of rivers and estuaries, and for 10% of respondents, the presence of flood-prone areas. Regarding the impact of the December 30, 2016 event, 65% reported disruptions to water service and 25% reported disruptions to electricity service. More than 10% of respondents also reported damage to roads and highways, flooding, and damage to their homes.
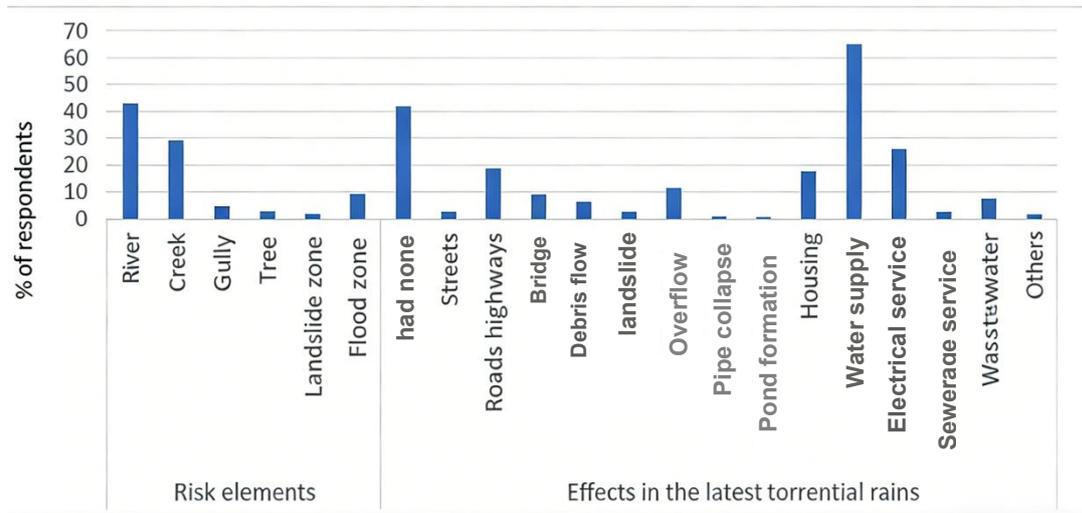
Figure 6. Risk elements and Effects of torrential rains

The disaster memory (Figure 7) indicates that events such as flooding due to excessive rainfall and landslides were reported by at least 49% of the population, while landslides and land conflicts were reported by at least 18% of the population. Regarding return periods (Table 1), landslides, floods, and the destruction of bridges and roads were mostly reported with periods of less than one year, while conflicts between communities showed consistent periods ranging from less than one month to more than five years.

Table 1. Event Return Periods

Percentage of the population reporting the event				
	Less than a month	1 month to 11 months	1 to 5 years	More than 5 years
Landslide	0.7	27.4	0.7	
inundation		43.0	1.5	
Land conflict	5.9	0.7	4.4	6.7
Bridge destruction		54.8		
Others	0.7	1.5		

Emergency preparedness (Figure 7) shows that at least half of the respondents have witnessed flooding and the destruction of bridges and roads; 69% of the population has not received training; more than 10% of respondents reported having received training in first aid techniques and drills; 45% of respondents reported owning a flashlight and 16% a first -aid kit. Regarding the distance to a safe point (Figure 8), more than 50% of respondents are between 101 and 500 meters from the safe point, and 25% are between 11 and 100 meters away.
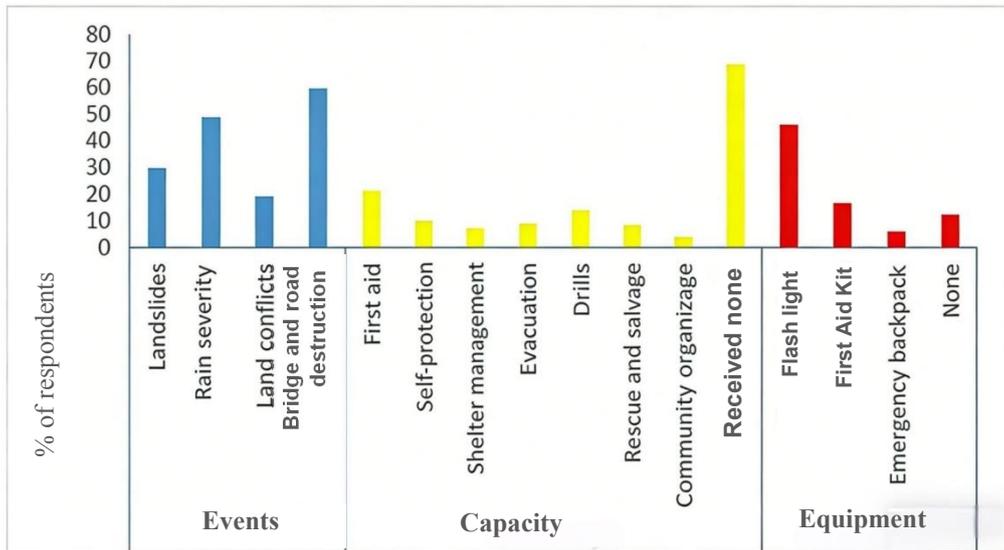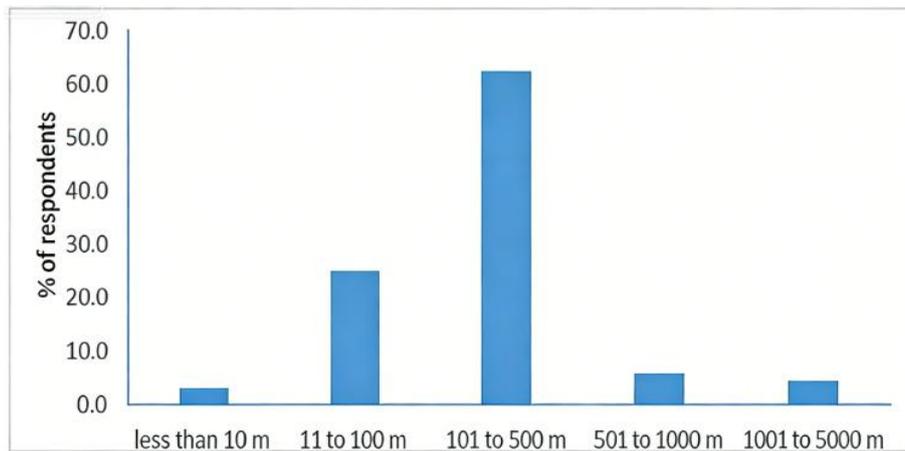
Figure 7. Emergency preparedness

Figure 8. Distance to the safe point

River flooding events generate effects in different areas such as the sweeping away of trees, animals, and building debris; flooding of floodplains and destruction of crops; disruption of road traffic; the washing away of bridges due to obstructions caused by thick tree trunks; and the flooding and evacuation of houses near bridge areas (Sánchez and Ollero, 2017). In the case of the aforementioned event, surveys of the riverbed in its headwaters revealed five accumulations of logs carried by the current, which created dams within the river and, at the time of the flooding, generated a greater erosive force. This, in turn, caused the destruction of the Tourist Dam located in the Shell parish, as well as flooding in the Puyo canton in the Las Palmas, Picolino, and El Dorado sectors.

At the regional level in communities of the Napo province, Ecuador, there are reports of damage from floods, destruction of bridges and roads, with the main emergency equipment being the flashlight (more than 75% of the population) and the first aid kit (less than 40% of the population), in addition to reporting less than 50% of the population having training in first aid, self-protection techniques, evacuation and rescue (Abril et al., 2022).

The analysis of variance showed no significant differences in disaster memory responses with respect to the variables sex, age, length of residence, and level of education. Multivariate analysis with rotated components, considering the factors age, time since the most frequently reported disasters occurred, distance to the nearest point of origin, and number of people residing in the household, yielded a Kaiser-Meyer-Olkin coefficient of 0.54 and a Cronbach's alpha of 0.95. Toro et

al. (2022) state that Cronbach's alpha coefficient is used to measure the reliability of an instrument used to generate the information, with values between 0.8 and 0.9 considered acceptable. Shrestha (2021) states that the Kaiser-Meyer-Olkin coefficient is used to determine if the sample size is adequate, with a range between 0.5 and 0.6 being acceptable if the sample size is between 100 and 200.

The two-dimensional analysis based on cases (Figure 9) shows that most of the respondents are grouped into a single set, while the analysis based on variables (Figure 10) shows the age variable as the furthest from the centroid and therefore the one that represents the greatest variability, followed by How long ago did the landslides occur.
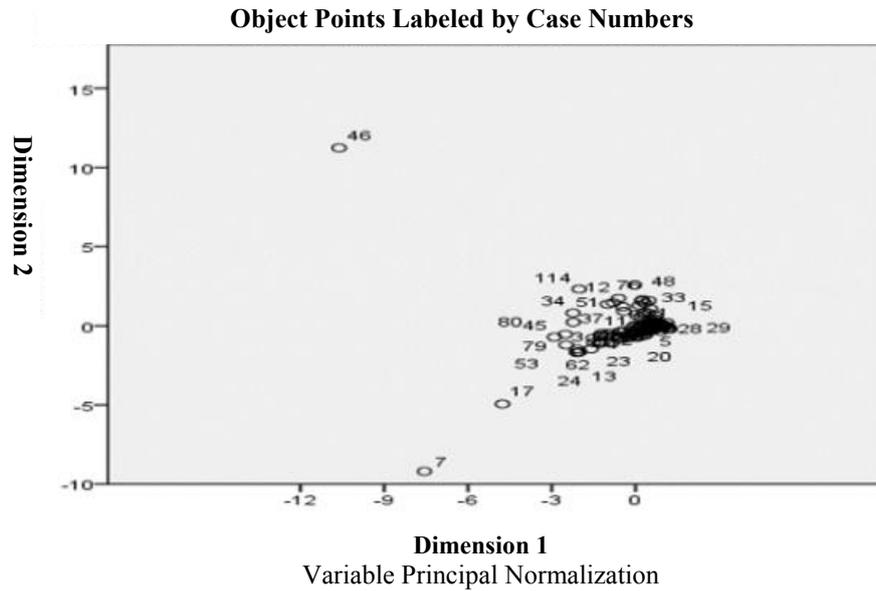

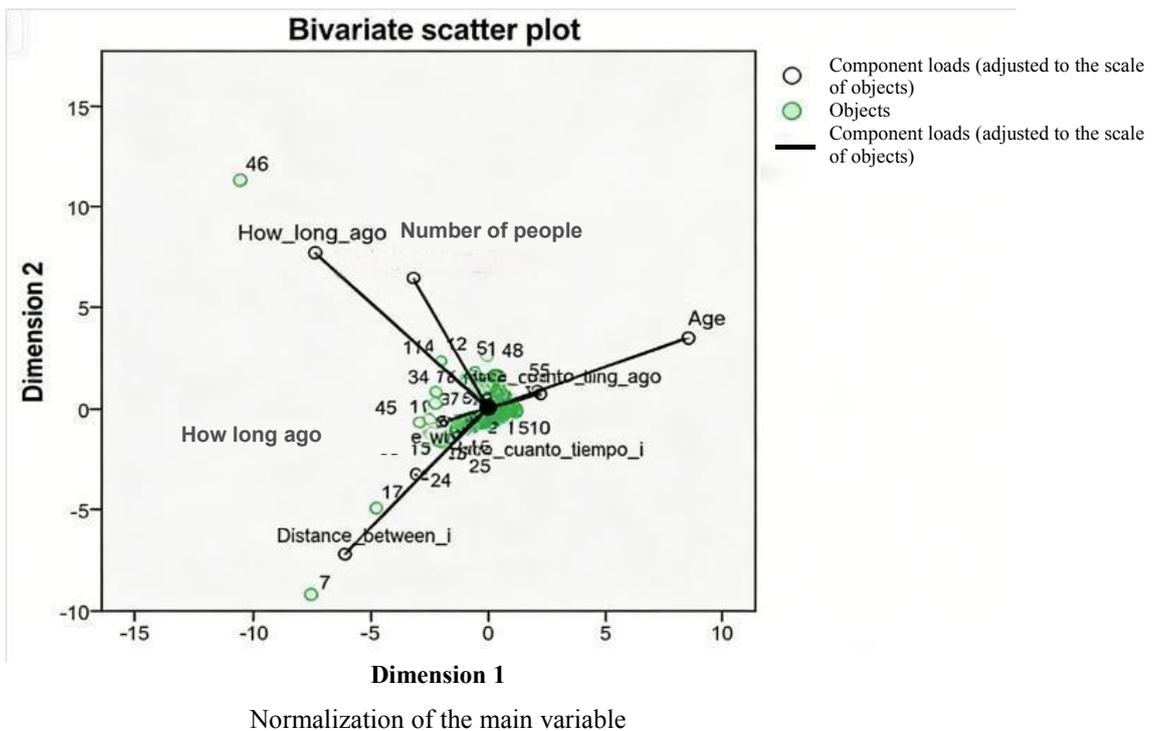Figure 9. Two-dimensional analysis based on the cases

Figure 10. Two-dimensional analysis based on the variables

It is concluded that the areas surrounding the river are exposed to risks from flooding; the main impacts of the torrential rains were damage to the water supply, with significant impacts also being on the electricity service, damage to housing, and destruction of roads and access routes.

The disaster report states that these events are frequent, and that the flashlight is the most frequently reported emergency equipment item among the population, most of whom have not received training on emergency management.

Acknowledgments

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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