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Hydrological Risk Mapping Experiment Using Volunteered Geographic Information: Case study in the municipality of Riachão do Jacuípe - Bahia [1]

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A B S T R A C T

Flash floods are frequent hydrological disasters throughout the Brazilian territory and have a major socioeconomic impact on the affected population and municipalities. In Brazil, in the last decade, hydrological disasters has caused the amount of 70 billion reais in damages and losses. Given this situation, risk areas mapping is a fundamental instrument, and, in some cases, it is also a legal obligation for hydrological risks management. Given the importance of this instrument and the scarcity of resources and cartographic data of many Brazilian municipalities, a proposal was made to map areas of hydrological risks using Volunteered Geographic Information (VGI), contemplating a mobile geocolaboration solution (Hidromapa application). This paper presents the results obtained by applying this proposal in the municipality of Riachão do Jacuípe-BA (urban population of approximately 20,000 inhabitants), in order to evaluate the performance of this collaborative mapping solution. The results of the research showed that it is possible to carry out preliminary mapping of areas of hydrological risks using the Hidromapa application, although, actual flood elevation data were not available to compare with flood level information extracted from Hidromapa. In addition to these results, this paper addresses aspects related to collaborative spatial data collection, such as user motivation, consistency evaluation and spatial comprehensiveness.

Keywords: Volunteered geographic information, Collaborative mapping, Flash flood, Hydrological risk, Risk management.

Mapeamento de Riscos Hidrológicos Utilizando Informações Geográficas Voluntárias: Estudo de caso no município de Riachão do Jacuípe-Bahia

R E S U M O

As inundações são desastres hidrológicos frequentes em todo o território brasileiro e com grande impacto socioeconômico para a população e municípios afetados. No Brasil, na última década somou-se aproximadamente a quantia de 70 bilhões de reais em danos e prejuízos causados por desastres hidrológicos. Diante desse quadro, o mapeamento de áreas de riscos constitui um instrumento fundamental, sendo em alguns casos legalmente obrigatório na gestão de riscos hidrológicos. Dada a importância desse instrumento e a escassez de recursos e de dados cartográficos em muitos municípios brasileiros, foi elaborada uma proposta de mapeamento de áreas de riscos hidrológicos utilizado Informações Geográficas Voluntárias (VGI), contemplando uma solução mobile de geocolaboração (aplicativo Hidromapa). O presente artigo apresenta os resultados obtidos, ao aplicar esta proposta no município de Riachão do Jacuípe-BA (população urbana de aproximadamente 20.000 habitantes), com o objetivo de avaliar o desempenho do aplicativo Hidromapa para o mapeamento colaborativo de áreas de riscos hidrológicos. Os resultados da pesquisa demonstraram que é possível realizar mapeamentos preliminares de áreas de riscos hidrológicos utilizando o aplicativo proposto, mas que no entanto, as informações coletadas sobre cotas de inundação não foram consistentes, impossibilitando a análise da intensidade dos eventos hidrológicos no que se refere à altura da lâmina d’água. Além desses resultados o trabalho aborda aspectos relacionados à coleta de dados espaciais colaborativos, como a motivação dos usuários, avaliação da consistência e abrangência espacial dos dados coletados.

Palavras-chave: Informações geográficas voluntárias, Mapeamento colaborativo, Inundação, Risco hidrológico, Gestão de riscos.

Introduction

The incidence of natural disasters in urban areas in Brazil have been recurrent, mainly due to the accelerated process of urbanization and population concentration in large cities. This urbanization model, called by Rolnik (2001) as risky urbanization, promotes unequal access to land, particularly for housing, and enhances the occupation of risky areas, such as hillsides and riverbanks, mostly by low-income populations (Rolnik, 2001).

Hydrological disasters are among one of the major natural disasters that occur in Brazil. the Brazilian Disasters Classification and Coding (COBRADE) document defines that this type of incident is related to damage caused by water flows that rises above the capacity of the drainage infrastructure or of the natural water bodies, which can be exacerbated when there are high flow velocity. Tucci (2007) uses the term "river flooding" to characterize hydrological threats, and consider the floods as threats only when occupied areas (such as villas and other types of urban settlement) are reached by an over rise of a natural water body, as a result of heavy rainfall, called sudden flooding.

According to Materials Damage and Losses Report about Brazilian Natural Disasters, between the years 1995 and 2014, approximately 9000 occurrences of hydrological disasters were recorded, which add up to the amount of about 72 billion reais in damages (UFSC, 2016). In the Northeast of the country, during the same period, there were approximately 2000 occurrences of hydrological disasters, totaling a loss of 14 billion reais in damages, while in Bahia these values are close to 3 billion reais in 322 incidents recorded (UFSC, 2016).

The social damage can be even more impactful. For example, during a single occurrence in the State of Bahia, in December 08, 2013, in the city of Lajedinho, the flood resulted in the death of 17 people and left more than 10% of the city population, about 300 families, homeless, in addition to the destruction of shops, public agencies and other urban facilities.

Among other recommended measures in the hydrological risks management, there is the risky areas mapping activity, which consists of a spatial identification of areas where there is a flood disaster likelihood and of a measurement of risk for each of these areas (Tucci , 2007; Brazil, 2007).

The risky areas maps are essential for all phases of disaster management, contributing to: mitigation, necessary for the land use planning and for identifying areas that require infrastructure to reduce risks; preparation, identifying sites that require monitoring, implementation of emergency plans and warning systems; response to disasters, since areas where the greatest impact will potentially happen are known; and also recovery, being used for recovery actions planning, especially in the resettlement of the affected population. Therefore, the new National Policy on Civil Defense and Protection (PNDPC), Federal Law No. 12.608 / 2012, considers, for the first time in Brazil, mapping of risk areas maps production mandatory for those municipalities included in the Brazilian national registry of cities susceptible of sudden floods occurrence.

On the other hand, Hydrological risks mapping involves the collection and the analysis of various types of spatial information, which are not always available. Due to this unavailability of cartographic data or technical and financial resources necessary for its development, many municipalities, especially the small ones, have not done their risky areas mapping.

Goodchild (2007) and Goodchild and Glennon (2010) point out that one of the main problems encountered in disaster situations is the availability of spatial data of the affected area. The authors emphasize that for the planning of emergency actions, the necessary geographical information should be available immediately. Even in areas with available data, it is necessary that the information is updated in relation to the disaster occurrence period, and in some cases this update should be performed in real time.

About obtaining geographical information, Goodchild (2007), Castelein et al. (2010), Parker (2012) and Esmail, Naeser and Esmail (2013) mentioned that since the emergence of cartography until the last two decades, this process was carried out using conventional mapping techniques, performed by specialized companies and government agencies. Many parts of the world still lack the official cartographic information, especially those with limited technological or financial resources, or those areas which are not considered of interest by the official cartographic data producers. In this places it is impossible to carry out most of the basics analyzes required by the land management.

Despite the unavailability and high cost of obtaining data in general, the expansion and widespread access to the internet in the last decade has contributed to the development of collaborative tools based on the concept of collective intelligence, internationally known as crowdsourcing (Segaran, 2008). Sites like Wikipedia, whose content is produced and constantly updated through collaborations, are now as an important data source, although there are some doubts about its information quality.

Regarding the collection of spatial information, Goodchild (2007) used and popularized the term Volunteered Geographic Information (VGI), meaning georeferenced information produced collaboratively by people who do not necessarily have expertise in cartography and related sciences. Such VGI applications have been developed for various purposes and have enabled the collection and dissemination of spatial information with low cost, obtained in short periods of time and even in real time (Goodchild, 2007; Elwood, 2008; Castelein et al., 2010). A example of a tool that uses of collaborative information is the Waze app, which provides traffic data information supplied by its users location and displacement.

As an example of the potential use of this data source, there is the disaster in Haiti in 2010, when an earthquake hit the country. The rescue teams needed some georeferenced information such as alternate paths, shelters, affected areas and other geographic information that were not included in the official databases. It was possible to observe the negative consequences brought by the absence or lack of cartographic data during crises (Zook et al., 2010; Crooks and Wise, 2013; Shelton et al, 2014). In Haiti, the initiatives based on VGI aggregated hundreds of volunteers, including ordinary citizens and international organizations. After few hours, volunteers had mapped the needed information from up-to-date satellite images of the region, contributing to the reduction of the earthquake impacts across the country (Zook et al., 2010; Crooks e Wise, 2013; Shelton et al., 2014).

Zook et al. (2010) pointed out that through these applications, involving volunteers of different profiles and countries, it was possible to perform rapid mapping and to produce a large volume of information about affected areas, location of victims and routes available for providing relief. Thus, the authors mention the potential of these applications at crisis situations, especially at places where the official cartographic databases are inadequate and outdated, and, at the same time, there are no financial and technical resources to carry out emergency mappings.

The possibility of VGI flooding applications was already mentioned by Poser and Dransch (2010); Hirata et al. (2013), Horita et al. (2015), Degrossi et al. (2014), Fazeli et al. (2015), Restrepo-Estrada et al. (2018), among other authors. However, we realize that most applications that are already developed have focused on disaster situations, such as alerting and gathering information for response and relief, while applications aimed to attend the pre-disaster phase are further reduced, as pointed out by Horita et al. (2013).

In this context, this paper aims to present the results obtained in the preparation of a hydrological risk areas mapping, using VGI, for Riachão do Jacuípe county, state of Bahia, Brazil. Besides the results related to evaluating the existence of hydrological risks in the study area, the research addresses issues related to the collection of VGI, the use of collaborative mapping tools in schools, and also the motivation of users and the quality of the data collected.

Material and methods

For collaborative spatial data collection was used the Hidromapa Application developed by Oliveira (2017), while still in the prototype format (Figure 1). The application enables collaborative mapping of information on hydrological events and is designed to be used by high school students as a pedagogical activity at geography classes for example.

Using the application, volunteers can inform points in the city that were hit by floods and their estimated water level, as well as other information such as damage and residence where a vulnerable citizen lives. In this study, we used only the information about points affected by floods and their elevation values.

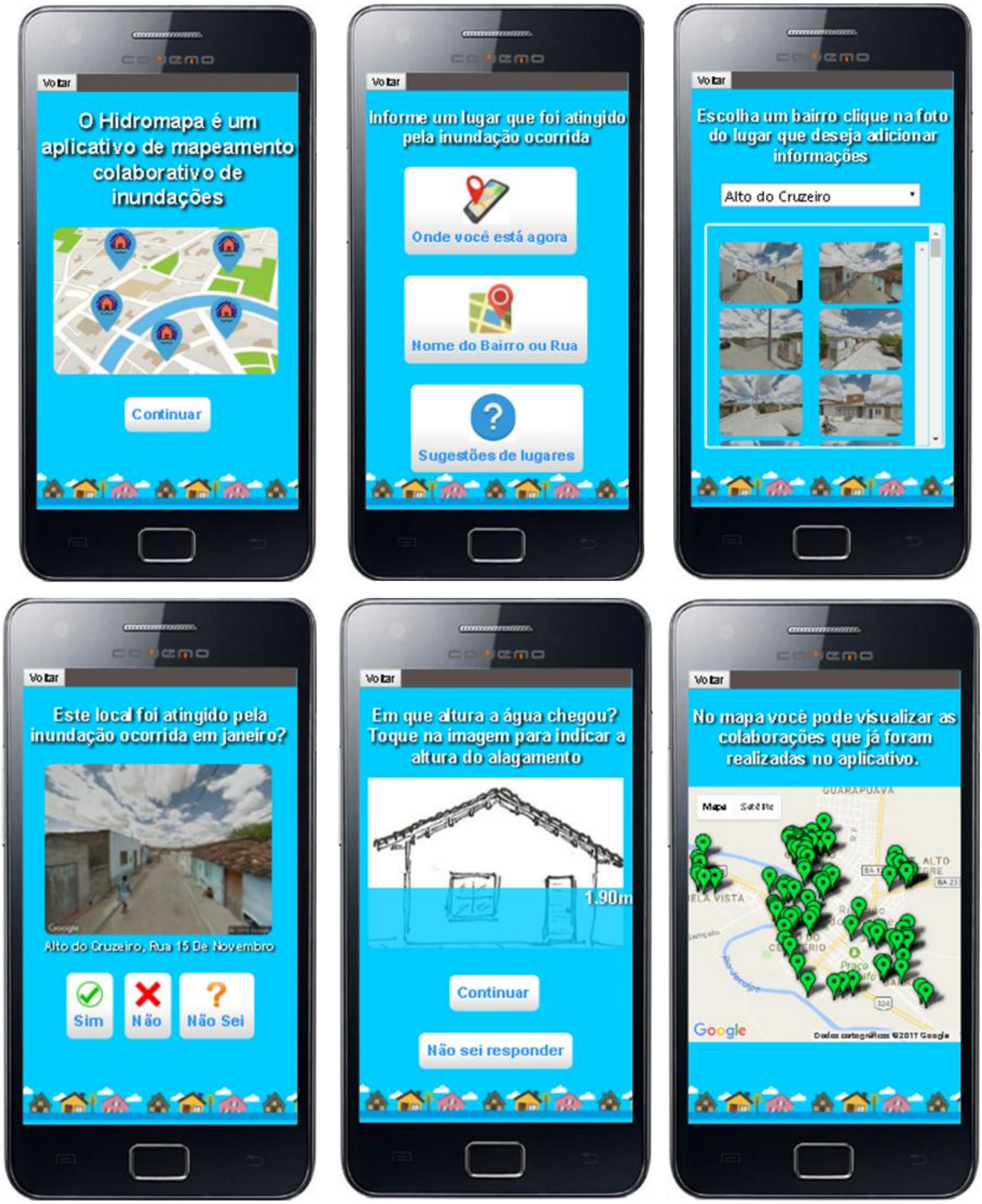


Figure 1. Hidromapa application interface.

To enlarge the positioning reliability of the collaborated information, the system has features that make it easy to identify the places desired by users, such as geocoding (location by address), and also from geographic coordinates automatically obtained by location services (GPS) existing in smartphones. The application also features street images taken by Google Street View API, facilitating the place identification and improving positioning reliability.

The case study was conducted in the municipality Riachão do Jacuípe - BA (Figure 2), involving 37 students of João Campos State high School of geography class. This location was chosen as it suffered in January 2016 a sudden flood at its urban area, which has put the municipality in public calamity. Besides, Riachão do Jacuípe also have historical records of other floods that have already occurred. Thus, information about the event can be considered recent, if compared to the work period of development, and collaborative information obtained from participants would be, in principle, based on the experience lived, directly or indirectly, by those who are collecting the information.

Figure 2. Location map of Riachão do Jacuípe Municipality / State of Bahia, Brazil.

Initially, school geography teachers were contacted to schedule the activity. As the activity was not included in the annual planning of the course and had to be held during the last week of class, it did not influence the student final grades or presence, being strictly voluntary.

Then, the author of the proposal presented the Hidromapa Application for the students, proceeding to its installation (on the student's smartphones) and training. During training, the students were instructed about the use of the system and about the data collection campaign. In the campaign, we asked each user to use the application and to register collaborative information at least 10 times, within a period of 10 days.

The establishment of a minimum number of collaborations aimed to evaluate the motivational aspect of users, in order to observe after the end of the campaign: what were the number of collaborations obtained in relation to the expected (10 * N, where N = number of participants). Thus, considering the participation of 37 members in the case study, the motivation of users was evaluated considering the expectation of 370 contributions (10 per participant). The number of collaborations obtained in the campaign also aimed to assess the motivation of the participants individually, seeking to identify users who have achieved or extrapolated the set target and those whose number of collaborations was below the minimum requested.

For the spatial coverage assessment of the collected data, it was observed if users conducted collaborations, regardless of its consistency, on areas that are considered of greater hydrological risk and if there were left risky areas not mapped.

The analysis of data consistency was carried out comparing overlapping information (information provided by different users on the same address), and information at a radius of 100 and 200 meters. The distance to validate the information was defined using the Moran index (CARVALHO, 1997), seeking to establish distances in which data presented high spatial correlation.

For each of the defined distances (overlapping, 100m and 200m), validation of the collaboration was carried out calculating the difference between the amount of information that resembled the user response and the number of different information. To an information to be considered consistent, it was necessary that the difference between similar and divergent information was greater than the average contributions made by point (most users agree with the assessed information). If the number of similar collaborations was equal to or less than the number of differences, the collaboration was evaluated as inconsistent (disagrees with the majority of the information measured by users).

To intermediate values between 1 and the average, the information was classified as partially consistent (the number of users who agree with the measured data is higher, but little margin of difference). Finally, the points that did not have collaborations in the vicinity were categorized as "unable to assess".

In order to assess the consistency of the flood height reported by users it was necessary to perform its conversion to flood elevation, as shown in Figure 3. The only altimetry data available for the study area were provided by SRTM (Shuttle Radar Topography Mission). The SRTM product used in the work is a raster with a corresponding grid on the ground and containing 30 x 30m altimetry values. It is estimated that the vertical error of the product can reach 6m, equivalent to about a house with two floors. However, the discrepancies between the actual value of the terrain elevation and the value obtained by the SRTM are not presented at random points. Therefore, considering that the relative differences between neighboring observation points are smoothed, the SRTM were applicable to the proposed experiment.

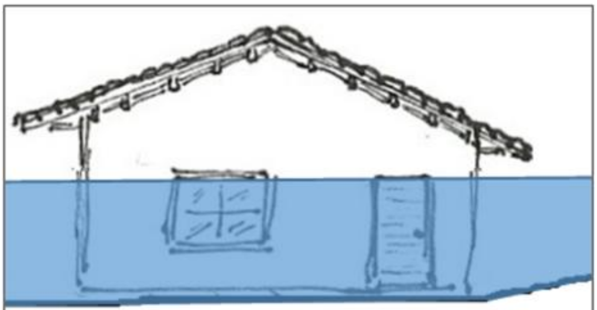


Figure 3. Conversion between flood heights collected into flood elevations.

After conversion to flood elevation values, the consistency of the data was assessed by comparing the overlapping and the surroundings information. However, since flood elevations in urban areas can vary over short distances, the analysis was performed only from comparisons between information provided for the same point (overlapping) and around 50 meters (surroundings).

An information provided by a user was classified as similar when the difference among values did not exceed 0.5m. For example, for a flood elevation of 210,5m, the values reported by other users at the same point and near surroundings must be between 210m and 211m, otherwise the values would be considered outliers. The margin of 0.5m tolerance takes into consideration the subjective evaluation of the user and the fact that this margin can be considered an acceptable error value in hydraulic-hydrological modeling.

Finally, the collaborative data considered consistent and partially consistent were analyzed in relation to information of other users of the same study case, which evaluated the applicability of the method and of Hidromapa for hydrological risk mapping.

Results and discussion

From the first contact, teachers have expressed interest in participating in the case study, indicating the feasibility of the method at a school context. The teachers mentioned the importance of including innovative and practical activities in the school context, especially when it comes to such important issues for the city in which they live and, consequently, for their life quality.

Teachers also mentioned the constant use of cellphones by the students and the need to introduce other uses of this appliance, beyond social networking, games and messaging applications. For those reasons, educators accepted was well the use of the application in the school context.

The users participation was initiated at the training conducted in the classroom (Figure 4), in which the application was first presented and then installed on the students devices. Only one student didn´t have a mobile phone and at two other didn´t have success installing it due screen resolution-related problems. This last situation pointed out the need to design an application responsive and compatible with smaller displays too.

The practicality and the intuitive character of the system interface and the possibility of the own residents to map flood risk areas were mentioned among the points assessed positively by the students. On these aspects, the system interface was validated and students recognized the importance to participate and to contribute on important issues of their city, which sometimes are restricted to the technical sector. Likewise, it is clear that the population feels recognized when participating in initiatives related to VGI, so the application can contribute to population inclusion on disaster management programs.

Figure 4. Students training.

On the other hand, among the difficulties encountered in its use, students mentioned that need to have internet connection made it more difficult to use the application, and that the images from Google Street View, used at geocoding tools were outdated, what did not contributed so much at the identification of points in the city.

Despite the difficulties mentioned related to Google Street View, geocoding was the geo-referencing feature most used by users in the case study, accounted for 85% (118) of the information added by users, while the geo-referencing feature using the GPS signal was little explored. In this respect it would be necessary to conduct focus groups and interviews with users to understand the factors that led them to use geocoding feature massively.

Considering the use of the application in the school context in future school projects, the GPS feature should be encouraged, especially for collecting information on unknown places by students. Thus, in addition to allowing the collection of more information through field research, the GPS feature use can contribute to the rise the student's territorial knowledge, as they will be encouraged to explore and experience the effects of flooding in different areas of the city.

The application improvement, regarding the location of the information entered by the user, can consider the inclusion of features that allow georeferencing through notable sites, such as parks, shopping centers and other spatial references that are used in the daily life of the population.

Regarding the motivation of users, some problems were found related to the fact that the activities were carried out close to the last week of the school year, late November. Certainly, this factor reflected in the low number of user's contributions. The minimum collaboration expectation was of 370 points in the campaign (10 collaborations times 37 students), but only 134 points were marked and a large number of participants did not use the application.

As can be seen in Figure 5, 21 students (57%) did not register any collaboration in the application, while only 06 students (16%) achieved or extrapolated the minimal contributions requested at the training class, and were responsible for 65% of the collected information. The remaining participants collaborated below the minimum required, reinforcing motivation problems.

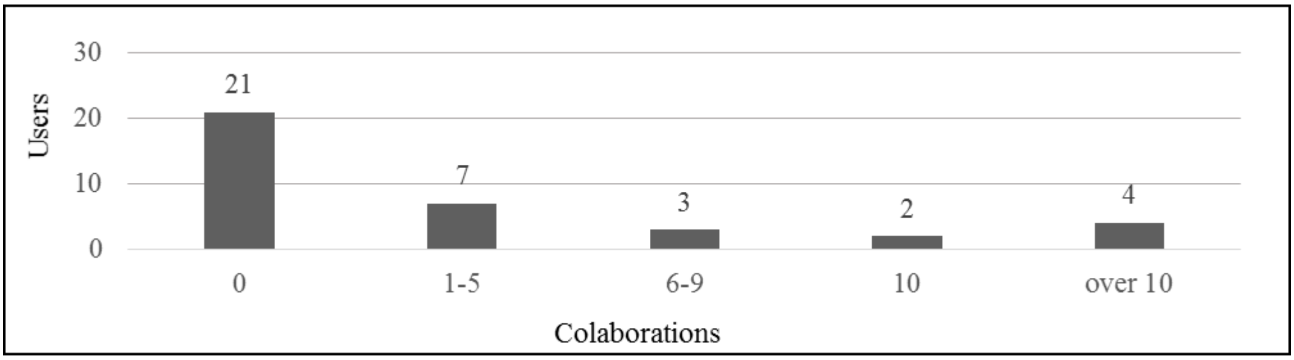


Figure 5. Distribution Graph users by the number of collaborations made.

These data demonstrate that the motivation factor can be one of the problems to be investigated in VGI initiatives, although to confirm it, it is necessary to conduct further case studies with a larger number of schools and students participating, including the need to analyze different contexts (public and private schools).

Thus, the period in the school year where the campaign is conducted can be better adjusted, and the deadline of 10 days set for the collection campaign can be reduced or divided into more than a campaign. In addition, we identified the need to involve more schools and to implement system features aimed to motivate users, such as an user rank and the delivery of tasks and challenges for users.

The results of the spatial coverage showed that users performed collaborations spatially distributed in most of the study area, except for some districts. Still, according to information obtained by one of the authors, the neighborhoods that did not have collaborations were not affected intensely by floods. Thus, the method gathered information on the areas of greatest interest in the city for this propose.

Figure 6 shows the spatial distribution of the contributions made by users, and indicates that the students were able to perform collaborations throughout the city and that there was not a pattern of concentration of the collected information. It is also observed that there was no concentration of collaborations in the vicinity of College João Campos, which was not hit by flooding.

The neighborhoods with the highest number of collaborations were Alto do Cruzeiro, Bela Vista Bar and Centro, as can be seen at Figure 7. With the exception of the Centro, all other mentioned districts were affected by the flood, especially the Alto do Cruzeiro neighborhood, where the flood resulted in major damage according to the author’s field survey. The districts of Alto do Cemitério, Ranchinho and Jatobá were also affected by flooding in January 2016 (Figure 7), but had a smaller number of collaborations.

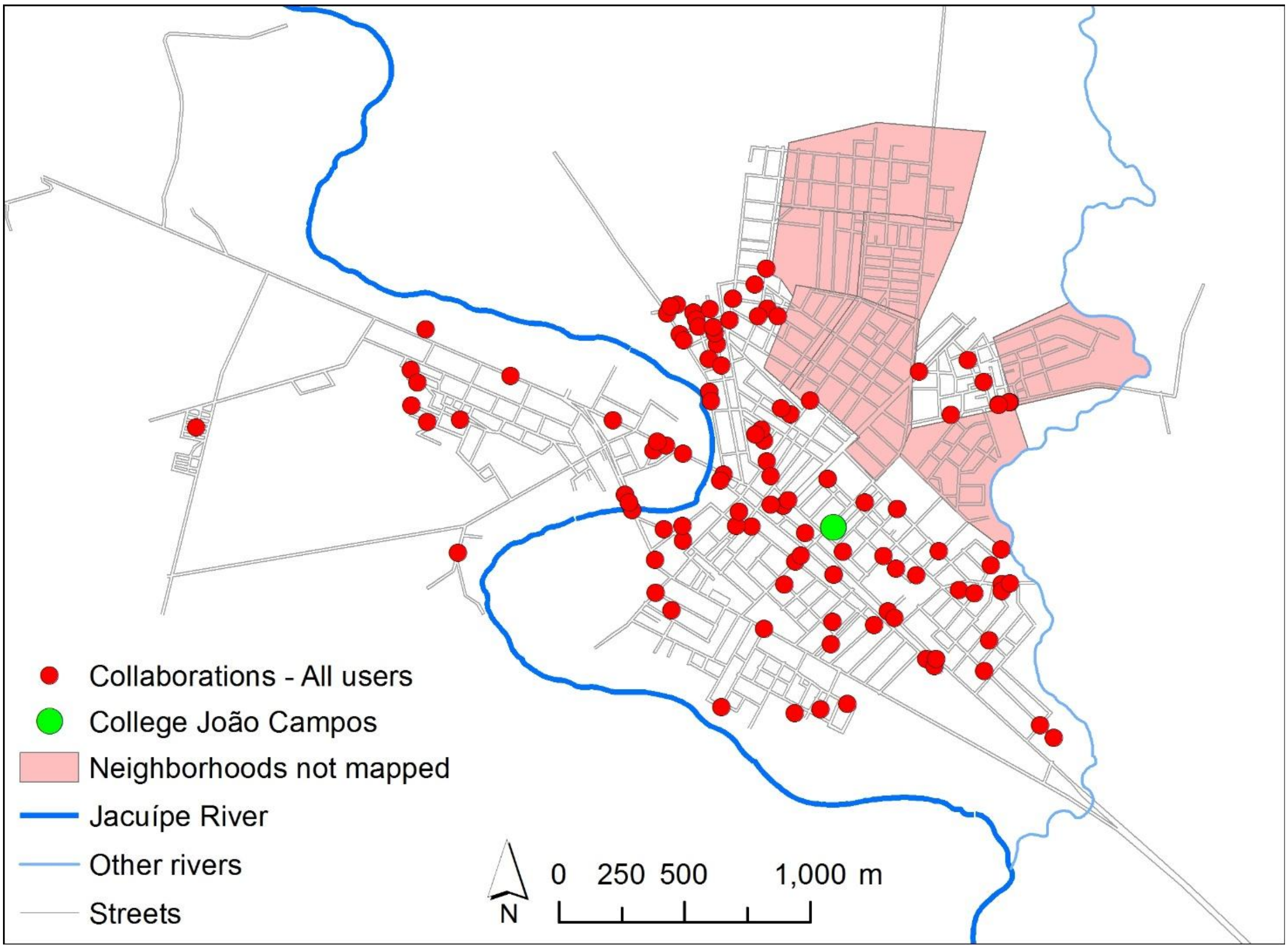


Figure 6. Map of collaborations carried out by students.

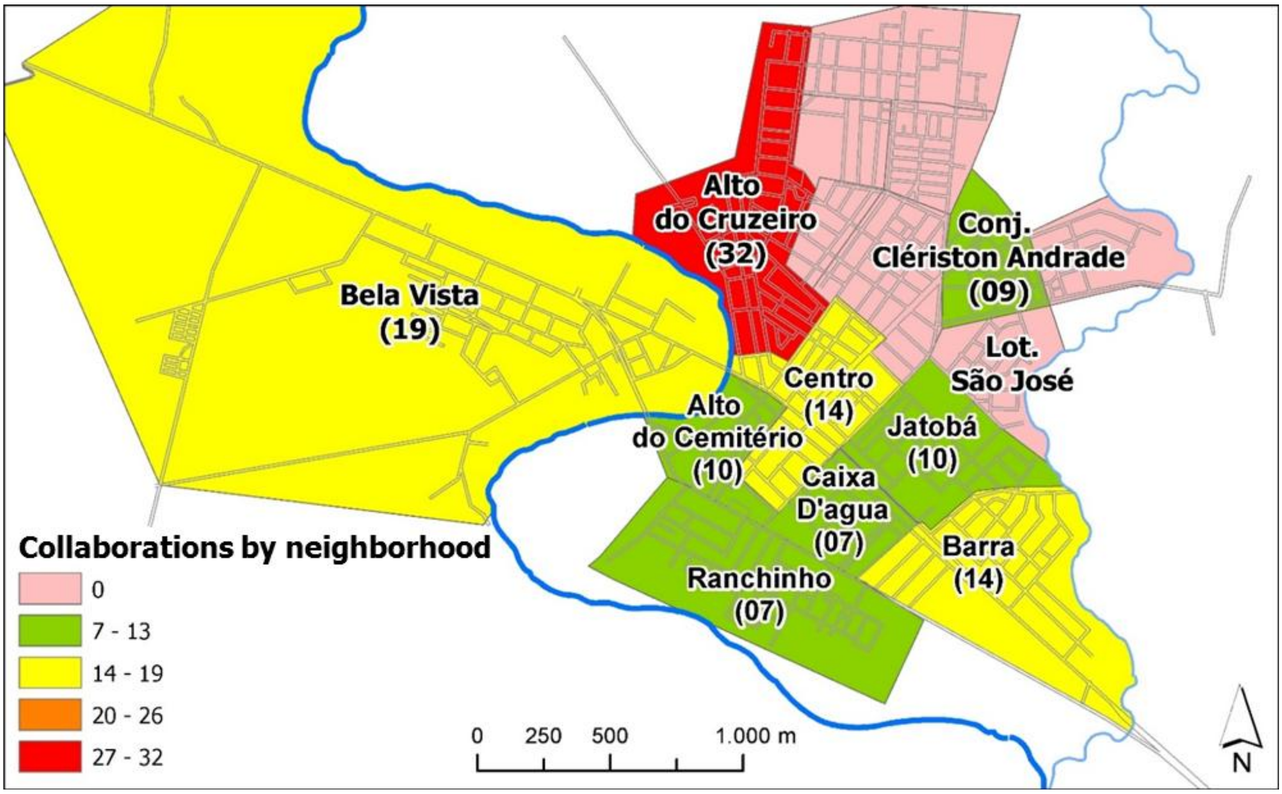


Figure 7. Map of distribution of collaborations by neighborhood.

There were also areas not mapped by users, which were hit by the flood, including the Lot. São José neighborhood, indicating, in smaller proportions, information completeness problems. Therefore, we recommend the implementation of features in the application devoted to the spatial coverage of information, to ensure the collection of information better distributed across the study area.

Concerning the spatial extent of the information collected, the case study objectives were achieved by the experiment with high school students, since it supported the specification of new features to be implemented in the application. However, these results relate only to the spatial coverage of the information, and do not consider their consistency, as it can be seen below.

As parameters for assessing the consistency of the information, regarding its completeness, the average value of one (1) overlapped collaboration was found, for example, for each collaboration performed by a user, we found another collaboration on the same point. For the 100m and 200m radius, the value used as a parameter to validate the information was four (4), indicating that at the 100m radius we found an average of four collaborations, and the same amount was found at 200m radius. These values indicates that although comprehensive, there was a small number of overlapping collaborations and that the information collected in the case study were as spatially dispersed as it could be, considering the extend of the area and the amount of active users.

At Figure 8 it can be seen that the small number of overlapping contributions makes it impossible to validate most of the information for this criterion. Similarly, this resulted in a large amount of information that could not be evaluated or have been partially validated in partial and final evaluations, demonstrating the need to expand the number of overlapping collaborations.

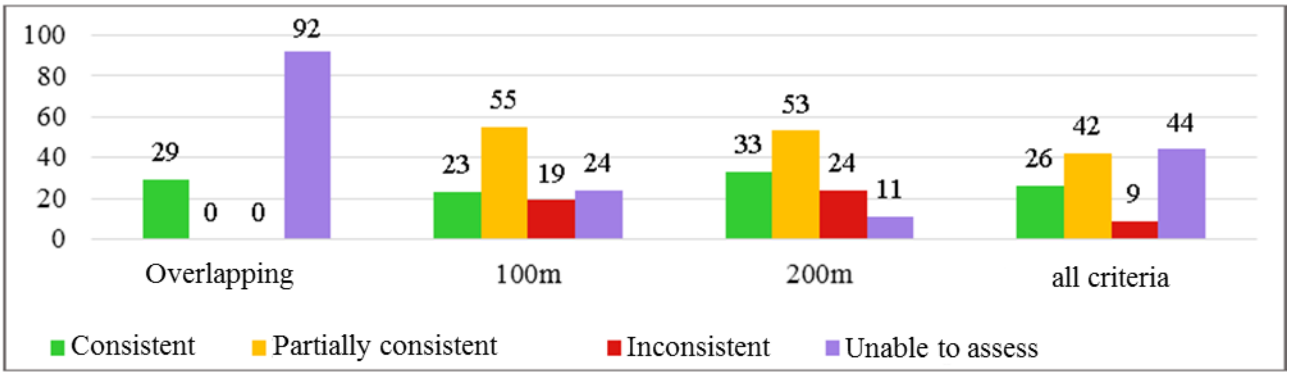


Figure 8. Distribution Graph the consistency of information on hits of the flood.

The number of consistent information was higher than the inconsistencies in all evaluation criteria, indicating that it was possible to collect consistent information, even in low numbers, on the sites that were hit by the flood, and also on points that were not affected by a flood event. It was observed that there was a greater number of contributions marked on places that have been hit by flooding comparing to collaborations marked at unaffected locations.

As an example of this observation, the bridge considered the main access to the city, by the BR-324 road and the Alto do Cruzeiro neighborhood, is the place affected more strongly by floods, and it had the most consistent information related to affected sites. These results indicate that the tools implemented in the application for the collection of this information have been validated, and also show that users were able to map the main areas of hydrological risks of the city.

The assessing method allowed the identification of consistent information and most of the inconsistencies, although it is necessary to make improvements and reviews of the procedures. After removal of inconsistent information, the data spatial correlation increased from 0.88 to 0.99 in the 100m radius and 0.85 to 0.97 in the 200m radius.

Finally, Figure 9 shows the flood hit points map with the contributions made by users that were evaluated as consistent or partially consistent. Thus, based on the students information, the main areas of hydrological risks in Riachão do Jacuípe urban area are at Alto do Cruzeiro neighborhood (Figure 10), specifically on the banks of the River Jacuípe and on the section of the BR-324 that corresponds to the bridge destroyed during the event held in January 2016 (Figure 11).

Figure 9. Hypsometric map of the study area and points hit by flood classified as consistent and partially consistent.

Figure 10. Flood in Riachão do Jacuípe, bridge destroyed the BR-324 (2016). Source: http://g1.globo.com

Figure 11. Flood in Riachão do Jacuípe, Alto do Cruzeiro (2016). Source: http://g1.globo.com.

Regarding the flood levels, it was identified a large number of inconsistent information and of information that could not be evaluated, either by the absence of overlapping or near collaborations. Considering the consistency of the information, at both analysis criteria, only one (1) flood elevation was evaluated as consistent, and validated using overlapping information and the 50 meters vicinity radius.

It was noted that the analysis of overlapping information enabled the identification of a greater number of consistent flood levels in relation to the analysis of the 50m radius, demonstrating that in order to do this evaluation it would be necessary a greater number of data collaborated at the same point. Therefore, it is recommended the implementation of features directed to increase the number of overlapping and near collaborations by different users. With a larger number of information at one radius of analysis, it is possible to perform a more judicious and consistent assessment.

On the other hand, it is necessary to evaluate the collaborative information in comparison with actual field data or results from hydraulic and hydrological modeling. We should also remember that flood levels can vary sharply over short distances, and inconsistencies generated by vertical and positional uncertainty of elevation data extracted from SRTM images may also be diminished by using a altimetric map based on topographic or photogrammetric survey.

Figure 12 shows the map with the spatial distribution of flood levels reported by users, classified according to their consistency. On the map we can see that the assessment of most of the information was limited and that only one flood elevation, located in Alto do Cruzeiro, was classified as consistent for the two evaluation criteria used. To better understand these results, Figures 13 and 14 show in detail the information located in the neighborhood Alto do Cruzeiro and at the BR-324 bridge, respectively, where we can see the inconsistencies found among collaborated data.

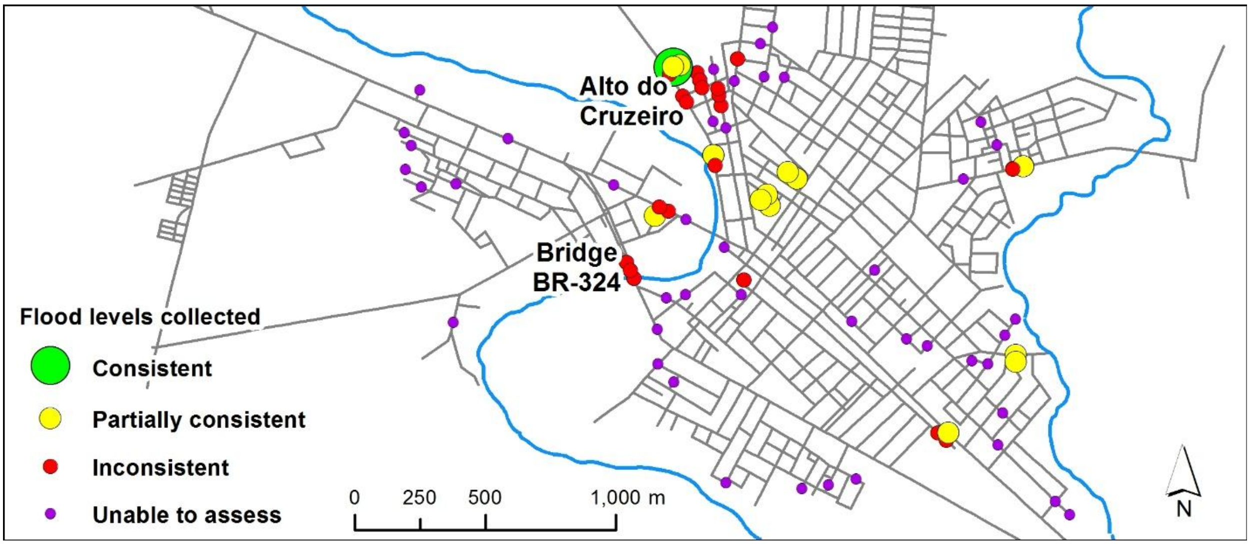


Figure 12. Map information on flood levels classified by the degree of consistency.

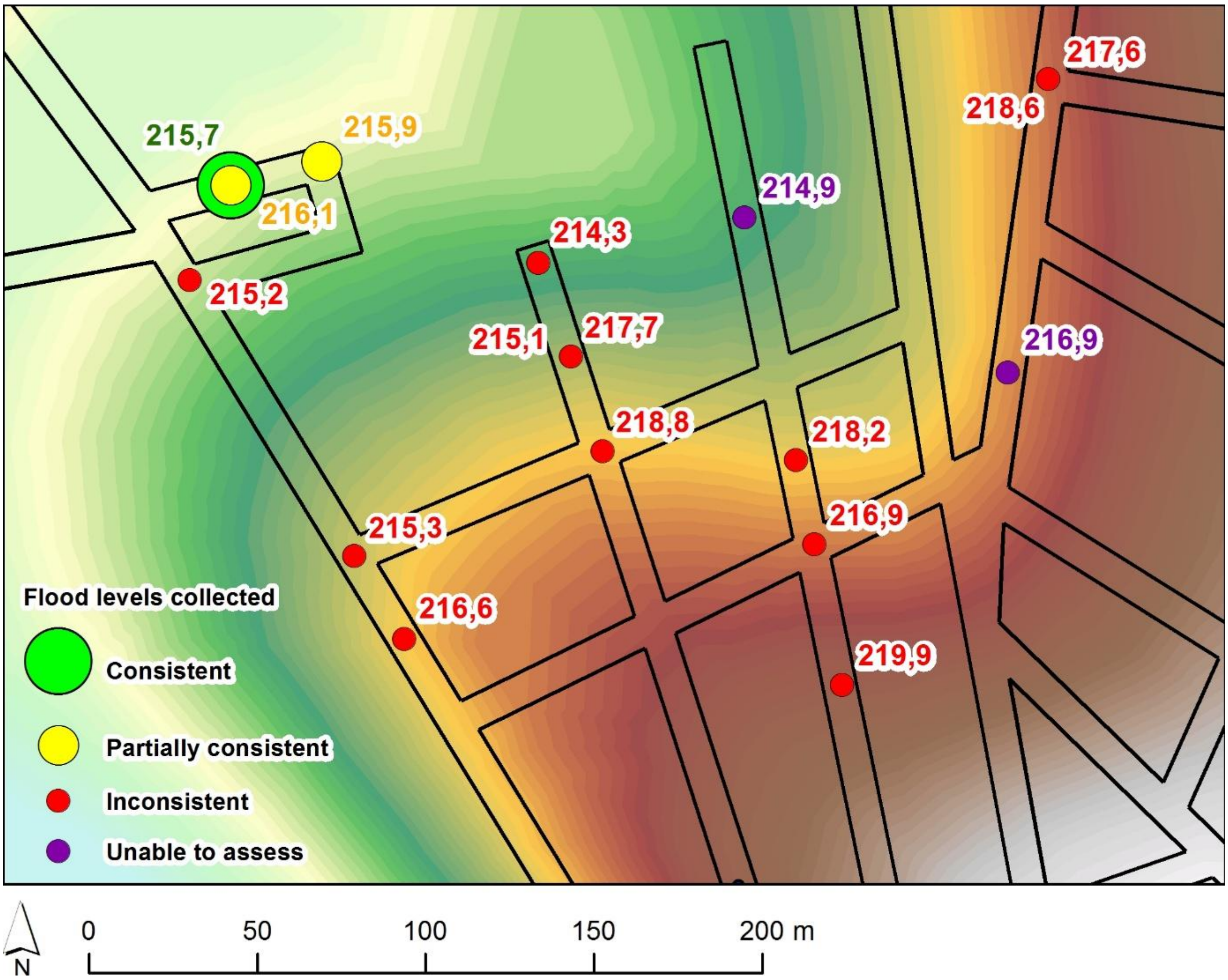


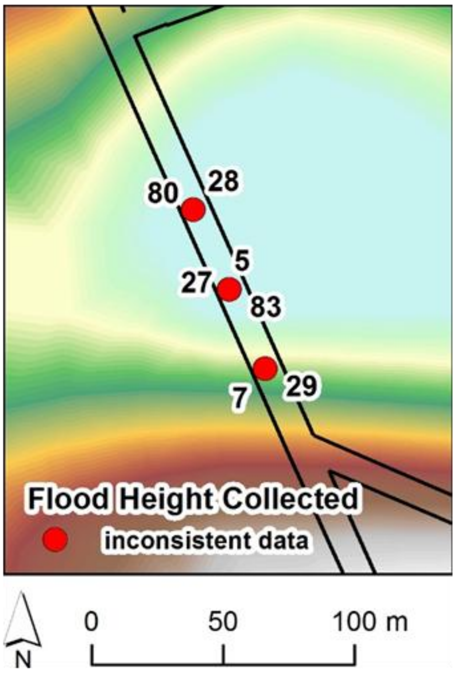
Figure 13. Consistency of flood levels at the Alto do Cruzeiro neighborhood.

As can be seen in Figure 13, the dimension considered as consistent (215.7m) was similar to the overlapping and the 50m radius dimensions, which showed differences in the range of -0.5m and 0.5m. The elevation of 216.1m, assessed as partially consistent, had a value similar to the overlapped dimension (215.7m) and the elevation in the 50m vicinity (215.9m), but it was discrepant of the 215.2m elevation at the 50m vicinity. Finally, the 215.9m elevation was similar to the two other values in the 50m vicinity (215.7m and 216.1m), but had no overlapping values, therefore it was consistent only at one evaluation criteria.

In Figure 13 it is also possible to observe the differences found in flood elevation evaluated as inconsistent, which had outlier (with differences above or below 0.5m) in relation to the overlapping or the 50m vicinity information. Furthermore, it was observed that the spatial distribution of the data also reduced capacity of flood elevation consistency analysis.

The bridge at BR-324 road had the highest concentration of overlapping and also of 50m vicinity information, confirming the hypothesis that users tend to collaborate with information about the places that were hit more severely by a flood event, although no unknown flood elevation was evaluated as consistent. It was noticed that some users used the height of the bridge as an altimetry base reference to inform the flood elevation, while others determined the flood elevation based on the river current level (Figure 14).

The use of the figure of a house as altimetry reference in the application did not contribute to the reduction of these kind of inconsistency. It is necessary to insert mechanisms that help users to inform flood elevations independent of its context, or that present different options of illustrative pictures more appropriate to the context of the observation point. Finally, it was also noticed that the conversion of the height informed by the user into flood elevation through SRTM images cannot be applied at situations like this one occurred at the BR-324 bridge.



Point	Flood Height Collected (m)	Terrain Elevation (m)	Flood Elevation (m)
80	0.6	210	210.6
28	3.1	210	213.1
27	3.1	210	213.1
5	4.9	210	214.9
83	0.6	210	210.6
7	2.3	211.5	213.8
29	3.1	211.5	214.6

Figure 14. Consistency of flood levels on the bridge (BR-324).

As it was not possible to assess the elevation informed by users in relation to real values collected in the field, or in relation to results obtained by hydraulic and hydrological modeling, the assessment of the consistency of the data considered only the comparison between values reported by users. It is possible that values assessed as inconsistent are close to real values and vice versa. However, there was no convergence between users information, which is the basic principle of consistency evaluation of voluntary collaborative geographic information data in general.

Thus, information on flood levels could not be used to establish the degree of risk in the study area, as regards of the estimation of water depth. The use of such information associated with the data points affected by the flood would enable comprehensive mapping and analysis of hydrological risks. Hence, the map produced can be considered as a preliminary map of hydrological risk areas. This results also indicates the need for adjustments in Hidromapa application for the collection flood levels information.

Conclusions

The Hidromapa application, and its use by high school students, enabled the preliminary mapping of hydrological risks areas, through the identification of sites affected by flooding in the study area. However, at the experiment carried out, it was not possible to raise flood elevation information. This prevented the analysis of risk grades considering the relationship between "elevation x damage". There were also limitations regarding the motivation of users and the difficulties for assessing the consistency of the data, since the number of collaborations was below expectations.

It was identified that the reliability of users information, their motivation and the platform's usability are the main aspects that should be considered in the development of systems based on VGI. It is important that the system is appropriate to the profile of its users since its conceptual project, and the findings of this research may help with that. About reliability, it is understood that the assessment process of Voluntary Geographic Information consistency is complex, and requires the development of specific research. However, the methodology, although simplified, allowed a preliminary assessment of the information and can be considered as an outline for the development of functionalities in this regard.

Considering that only 16 users were responsible for the total information collected, the survey results demonstrate the feasibility of using the system in the school setting and its application in small towns context. On the other hand, less than 50% of trained students participated registering information in the application, demonstrating that motivation was a problem encountered at this experiment. For further understanding of these results it would be necessary to conduct focus groups after the data collection campaign, in which participants could mention the factors that interfere in motivation.

For future applications of Hidromapa in the school context we suggest the envolviment of more schools are involved, including also middle school students. Campaign activities should also be incorporated into the teaching plan and be held in the first semester. It is also recommended that the activities are carried out continuously, involving other related activities, and the expansion of the participation of students and teachers, working with the comprehension of flood risks beyond the collection of collaborative information.

Among the main problems detected in Hidromapa application, stands out the need to implement features that enhance the number of overlapping and vicinity information and that can increase the spatial coverage of data, generating enough information for consistency comparative analyzes. The need to implement features that allow the use of the tool even if not connected to the internet is also one of the main problems mentioned by users.

Finally, the contribution of applications based on VGI for small municipalities was presented by the study, since, in general, these municipalities, in Brazil, lack technical and financial resources to carry out risk areas mapping projects. In this concern, the research demonstrated the feasibility of performing collaborative mapping, having students as the main group of contributors.

However, although several positive factors on the development of systems based on VGI have been identified, it must be considered that this technology is just one of the tools in promoting social participation. For our guarantee, it is necessary to expand the participation of society in addition to data collection, involving participants in other stages of the process, and especially in decision-making.

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