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Using community-based flood maps to explain flood hazards in Northland, New Zealand

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ABSTRACT

Floods are among the most common and destructive natural disasters in New Zealand, and climate change is anticipated to make them even more frequent and severe. A clear and comprehensive flood map is critical to communicating flood hazard to communities at risk. Mitigation, adapting, and informed decisions making could be efficiently accomplished with the clear flood maps. However, existing flood maps appear to have been developed for professionals, complex, and not easily available for communities living in flood hazard areas. This study examines how, using flood maps, risk communication between local authorities and the communities can be improved. Observational surveys and in-depth interviews were used to acquire descriptive information and in-depth understanding of risks within the communities in the Northland, New Zealand. Thematic analysis of the findings revealed that the current flood maps are not easy to acquire and hard to comprehend. Without knowledge, communities develop a false sense of security, especially where there is inadequate risk communication and engagement with local authorities. This study highlights the need for a greater understanding of integrating community knowledge and experience with the current risk communication plans. Additionally, this study recommends developing more comprehensive and user-friendly flood maps using community-based information.

1. Introduction

Flood risk communication and flood risk management are the key ways for reducing flood impacts [1]. In Northland, extreme flood events, such as 2007 and 2008 in Kaeo, 2014 in Kaipara and Whangarei districts, 2017 floods in the Far North district, and 2020 floods in Whangarei, Kawakawa, and Moerewa, have shown how vulnerable communities are to flooding. The frequency and intensity of flood events in New Zealand may increase in the future as a result of climate change and therefore create new challenges both for science, authorities, and the population in general [2,3].

Based on the New Zealand National Emergency Management Agency – NEMA, flood risk management follows four phases under their emergency management plan; Reduction, Readiness, Response and Recovery. In Northland, a region in New Zealand, the river flood management program, together with New Zealand's flood preparation guide, suggests that readiness represents the most effective protection against local flood risks [4–6]. The government demands more detailed and extensive flood hazards and flood risk mapping and development to mitigate the effects of flooding [4–6]. The high frequency of flood events, response and recovery processes need to be effectively communicated to the general public to prevent or reduce the impacts of flooding. Communicating the hazard using comprehensible and culturally informed flood maps to the public is an essential element in implementing and improving the New Zealand flood management strategy.

Flood hazard maps and flood risk maps have long been important tools in flood management [7,8]. A flood hazard map displays areas at risk of flooding and graphically depicts the extent and depth of inundation during major flood events, sometimes in conjunction with velocity profile [9]. Flood risk maps provide detailed information on the projected implications of major flood scenarios, such as affected people, physical damage, and economic loss [10,11].

Whereas experts can operate and interpret the information from the flood maps, untrained people find interpretation of flood maps challenging [1,12]. The challenge in communicating hazards through maps has the potential to raising risk awareness but awareness raising is often not achieved [12,13]. Most of the hazard map design did not align with general people needs and preferences [14]. Visuals, language, or access

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can be difficult for the public to understand and follow [12,14]. Literature commonly cites that hazard and risk maps are generally vulnerable to an "all-purpose" approach, meaning that target users, hazard types, and risk characteristics are often generalised [7,14].

In this paper, an observational survey and in-depth interviews were conducted to evaluate current flood hazard maps, used for communicating flood risk to general public, both in print and on web mapping services. The objective was to understand how current flood maps could be enhanced with community-based information. The results contributed to enhanced flood risk communication by improving map products for the general public because they included local information, cultural knowledge, and special requirements of the community of content, readability, and usability.

2. Literature review

As part of a flood risk management strategy, maps can be a useful tool for building a sense of personal responsibility in flood preparedness among communities and empowering them to make informed decisions [15]. Providing information alone to the public is not enough, but combining maps with information about reducing floods, and dissemination at regular times, through various channels, helps people to protect themselves and support initiatives at the local, provincial, and national level. As part of this process, local governments also need guidance on how to communicate hazard risk, how to provide comprehensive information, and how to develop maps that integrate community-based information to encourage flood protection actions.

2.1. Risk communication

Communities' perceptions of flood resilience are influenced by a range of issues. For instance, how impressions of past events are translated, affects communities ability to resist, cope with, and recover from adverse flood impacts [16]. Information about flood risks, flood protection, and personal safety measures is communicated through flood risk communication [1]. The concept of risk communication is defined as the exchange of interactive information about the nature, opinions, issues, and strategies related to risks, between stakeholders – individuals, groups, or institutions – to perform informed decision making [1,17]. A flood risk communication program is a valuable way to connect the expertise and management implemented by practitioners with the development of local-level resilience in flood-prone communities [18].

By communicating risks, people can develop a stronger sense of responsibility as well as to increase risk awareness among the population at risk and motivate them to take preventive actions and be prepared in case of an emergency [19,20]. The current flood risk management in New Zealand encourages individual-level responsibility to protect their own safety [4,5]. However, only part of the Northland's population at risk is aware of self-protection for flood, and only a few that actually doing something in their property [21]. Many people think that flood protection measures are the responsibility of the government [22]. With risk communication, the knowledge level about personal responsibility about local flood hazards should be improved [1,12].

Studies in Germany, UK, and US have shown that people's perception towards hazard risks differ from what responsible authorities assessed. For instance, Handmer (2000) found that people perceive their neighbourhood to be relatively safe from floods, despite being located in the high-risk areas [23]. The purpose of flood risk communication tools, such as flood maps, is to inform the people about the flood risks in their particular area or location [24]. Additionally, risk communication can build trust, decrease tension, and increase confidence of local community to manage flood effects [19]. Flood maps need to incorporate specific needs of communities at risk to give them the possibility of making informed decisions according to preparedness and personal safety measures.

However, despite having a high risk and recurring flood events, the distribution of information of flood hazards is still ineffective due to various reasons [12,25]. Inadequate information about past flood history, out of date information, and insufficient flood protection investment are reasons for ineffective flood risk management [15,26]. Local distribution of flood risk information is often ineffective, and education and training are needed to engage the community and raise community participation [23,25]. Communicating hazards through maps has potential in enhancing flood management, but strategies to communicate and deliver the information through maps need to be improved.

2.2. Information in the flood maps

The New Zealand government has been raising public awareness about flood hazards and encouraging the development of catchment-based flood mitigation [4,27]. In 2010, the government developed a number of initiatives in flood risk management to assist local governments in better managing flood risk and preparing for climate change [4]. In one of the initiatives, flood map information, design, and publication were required to integrate community knowledge, culture, and preferences to avoid the gap caused by scientific language, uncommon references, and incomprehensive information [1,13,18,24].

For example, the 100-year flood term is frequently misconstrued by the public as a prediction that such a flood will occur just once every 100 years, while it actually refers to the likelihood of a flood occurring [28]. The idea of a 100-year flood compared to different flood return intervals is the most commonly referenced depiction of risk in New Zealand flood maps when expressing the hazard through maps [29]. The term "100-year flood" refers to the 1% possibility of a flood occurring in a given year [4,28].

In New Zealand, the nomenclature and content of the information displayed on flood maps are held to a different standard [30]. The Northland region, for example, creates maps that illustrate a 10-year flood event as a base flood [31], while a conservative map uses a 100-year flood [4,2]. Consistency in how councils create flood maps, and standardisation in flood mapping language, is critical in developing the expected standard for the entire country [29,32]. This type of development helps authorities clarify flood risk for the general public.

The information provided in flood maps vary in different countries. Generally, in the Europe, flood maps include information to reduce the financial impact of flooding on individuals and businesses and limit the effect of flooding on new and improved infrastructure [8]. Flood maps in the UK are mainly used for enforcing basic floodplain management laws [9]. In the US, flood maps provide accurate information as part of their policy to reduce the flood up to local level [33]. In Malaysia, maps contain information allowing residents to evacuate safely and efficiently under the uncertainty of flood hazard, thereby reducing the loss of life and the cost of damage [34]. However, in New Zealand specifically in the Northland region, flood maps focus mostly on the zoning identification for flood risk [35]. Although it is helpful as a guide to the community about their risk of flooding, the zoning can create a false sense of security for communities living outside the flood zone boundaries [36,37]. There is no disclaimer that floods may occur outside the flood zones.

In New Zealand, the Ministry for the Environment promotes flood maps created by professionals to identify flood-prone areas and enable appropriate responses to minimise flood impacts [29,37,38]. According to Treaty of Waitangi and the Resource Management Act 1991, the operational management of flood risk is the responsibility of regional government [37,38]. Since flood management is handled locally, flood maps are also the responsibility of regional, unitary and territorial authorities. Fig. 1 shows examples of coastal and river flood maps developed by Northland Regional Council [35]. Containing similar information, with the addition of flood susceptible variations and potentially hazardous activities within the industry areas, Fig. 2 shows the hazard maps developed by district council [39].

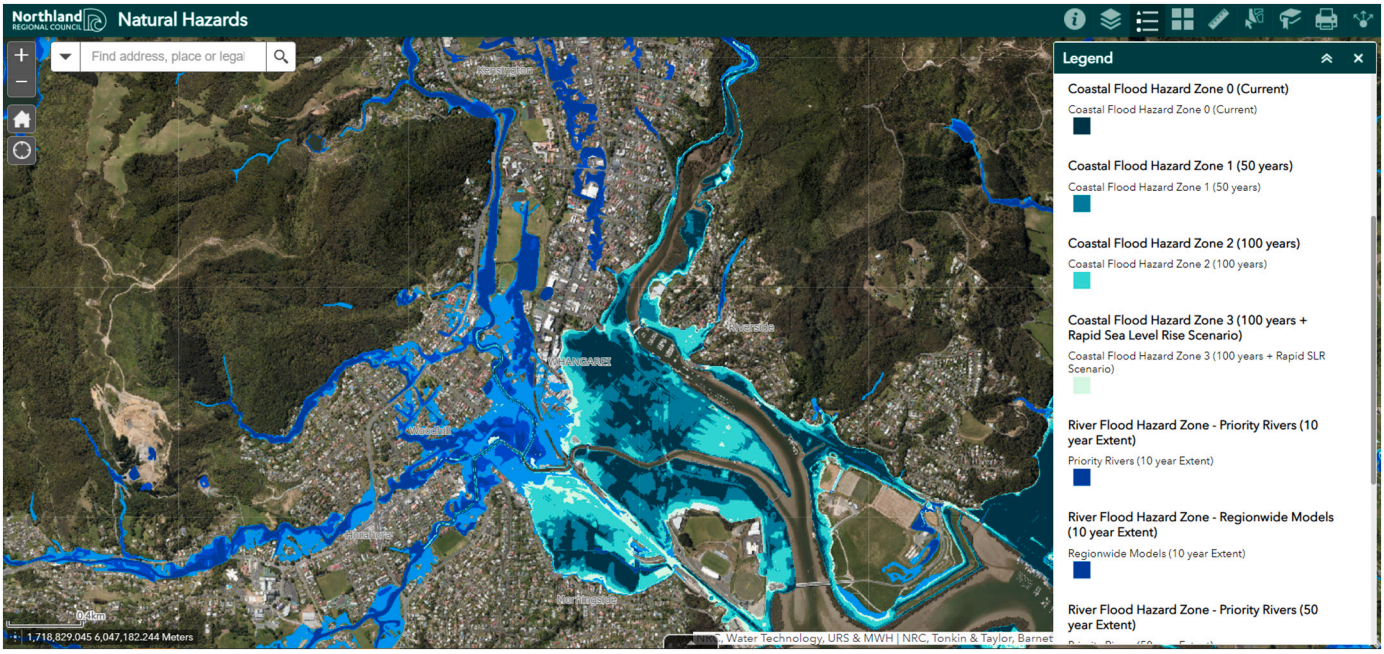

Fig. 1. Northland Regional Council hazard maps for Whangarei area [35].

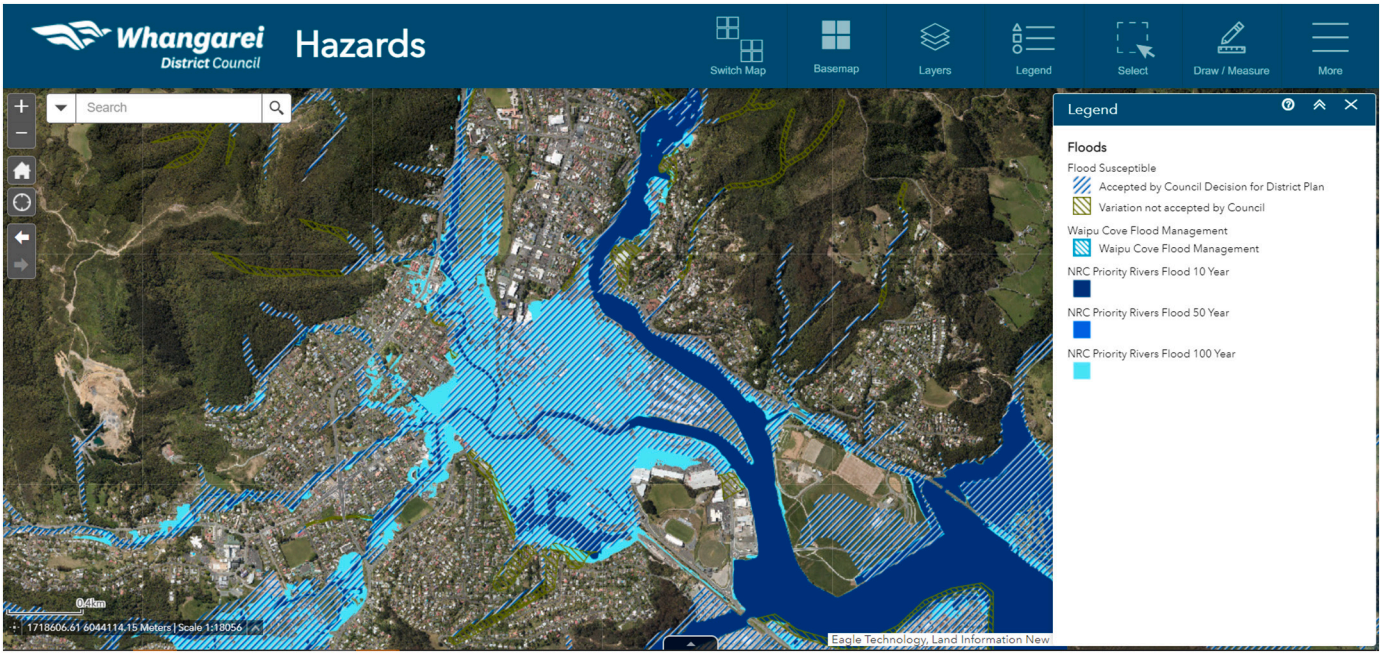

Fig. 2. Whangarei District Council flood hazard maps [39].

Most hazard maps required expert interpretation [40]. Nonetheless, the purpose of publicly available flood maps to communicate risk cannot be met if the public is unable to use them. There are other limitations of the flood maps in evaluating and comprehending actual flood risk for any given property. Regions depicted on maps only indicate the area at risk for a particular flood occurrence called the base flood [34]. Therefore, the property outside the specified flood hazard zone should not be understood to imply that it is not also at risk of flood damage [41]. Because flood occurrences greater than the specified base flood, such as 500-year or 200-year floods, occur unpredictably, such as the Northland flood in 2020 [42] and the Canterbury flood in 2021 [43]. Consequently, while property located outside the projected flood hazard zone may have a lower chance of flood damage, it cannot be deemed risk-free.

2.3. *Flood maps and mapping process*

Flood mapping and flood zoning are necessary to mitigate the adverse effects of flooding by estimating flood characteristics such as depth, velocity, and frequency [15,44]. Over the past few decades, effort has been made in understanding, predicting, analysing, and quantifying floods and their impacts. Common practice of flood mapping is by creating a computerized GIS database for the flood prone areas combined with hydraulic modelling software [44]. Recent studies about

flood mapping often integrate the methods, or combine tools, to develop flood maps that works for pre, during, or post disaster following their objectives and needs [15].

Research has developed more technology-based approaches, such as maps depicting flood susceptibility and hazard perception developed in Rwanda by Mind'je, Li [45]. Combining GIS, computer vision, and crowdsourcing, Alizadeh, Li [46] challenges the conventional methods of mapping process in the USA by developing an intelligent decision support systems that integrates street level flood inundation mapping and data-driven routing system which works in real-time flood event situations. For post flood maps, Syifa, Park Sung [47] combined remote sensing imaginary and artificial intelligence techniques to develop water contamination maps as post-flood damage information that can be beneficial for mitigation action for future flood events.

Following the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) [48] to provide the protection at local level, community-based approaches are encouraged. The Sendai Framework promotes a transparent process and encourages consultation between stakeholders. Community-based approaches provide an infrastructure for efficient knowledge-sharing. Integrating community-based information in the flood mapping aligns the Sendai Framework approach with flood hazard risk management [49,50], flood mitigation [51,52], and also flood preparedness [53,54]. Sendai Framework goals are to actively engage community in their national, regional, or local disaster management programs. The process begins with participatory risk assessments and preparedness measures [49], local capacity building [54], developing early warning systems [52], and/or linking community activities with local policy development [51].

In the early 2000s, Volunteered Geographic Information (VGI) arose in the public through online platforms such as OpenStreetMap (OSM). The platform accommodated the rise of community mapping projects to collect geographical data for pre-disaster, during-disaster, and post-disaster management [55]. Community mapping is defined as the action of producing a map of a certain location together with, or by, the residents often featuring local knowledge and resources [56]. The basic objectives to community mapping aim to collect data in order to create a map of community assets and resources within a defined area [55]. A community map highlights people, physical structures, organizations, and institutions that can be utilized to create a meaningful local information. Using the technique of community mapping with local knowledge-based information and community engagement, combined with the advance tools in integrated flood mapping, flood map making can create visible and commonly understood information.

To create preparedness at a local level, flood maps created for the community have to be used by them to be valuable. New methods and concepts, for example integrating community based information, local tradition, and indigenous knowledge with Remote Sensing [57], Geographical Information Systems - GIS [58,59], and geo-located information, have provided communities with participatory mapping solutions [60]. In this way, the affected community can increase their risk awareness, take responsibility for their own preparedness, and take part in the governance at a local level.

3. Research methods

The research used a mix of quantitative and qualitative methods. Mixing quantitative and qualitative as a research approach is an appropriate option to investigate research questions that cannot be answered by either method alone [61,62]. To do this, a purposeful mix of data collection, analysis, and interpretation is required. By integrating data, researchers can gain a holistic view of their research landscape, viewing phenomena from multiple perspectives and through a variety of research lenses [62]. In this study, quantitative data were collected for evaluating the current flood maps, flood map usage, flood protection choices, and local flood risk management knowledge. The qualitative data were captured to gain an understanding into individuals' information preferences, decision making, flood experience, and factors that influenced their decisions on flood protection activities.

3.1. Study area

This study focuses on the area prone to floods and the floodplains in the entire territory of the Northland Region of New Zealand (Fig. 3). The region is managed by three district councils, the Far North District, the Kaipara Districts, and the Whangarei District. Northland covers an average area of 13,789 km^2 bounded to the west by the Tasman Sea, and to the east by the Pacific Ocean [63]. The region is characterized by hilly terrain with the highest point of 781 m at Te Raupua which also the highest mountain across both Northland and Auckland [64]. The geographical features contribute to the changes in the weather patterns and flooding incidences in the region [65]. In fact, in the winter season (Fig. 4), the area receives much rainfall resulting in landslides and flooding, while during summer (Fig. 5) Northland is vulnerable to droughts due to the climate characteristic and low rainfall intensities [65]. Generally, floods in the Northland happen as a result of different factors such as climatic, topographic nature, environmental settings, ecosystems, and land development [66].

3.2. Survey

The study first used a survey to gather data from communities prone to flooding. The selected sample studied were all from communities prone to flood hazards from the three local districts of Northland. The survey was developed and validated through a process of disseminating it to colleagues and the final revisions was posted online and promoted to using various local social media advertisements. The survey was kept open for 30 days and targeting only users from the areas of the Northland Region. The survey questions focused on three themes, population-at-risk identifications, risk communication management, and flood map evaluation (Table 1). In addition to the online survey interviews were carried out. Site observation and interview surveys were conducted in public libraries and community halls within the Northland area. The observation of river catchment meetings was also conducted. The results from the survey helped in mapping the area for field observations and conducting interviews.

3.3. In-depth interviews

The qualitative data collection method allows for the collection of a large amount of information about behaviour, attitude and perception of interview participants [67]. This method helps to uncover more detailed and in-depth information to complement survey results. While conducting the interviews, it is important to avoid influencing participants but at the same time maximizing the accuracy with which questions are answered [68]. The in-depth interviews targeted experts, community representatives, and government agencies (Table 2), consisting of open-ended questions detailing the experience, awareness and knowledge level, and opinion for flood program improvement. Furthermore, the research used an interview approach suggested by Carpiano [69]. While conducting the interviews with community representatives. The researcher accompanied individual participants on outings in their familiar environments, such as a farms and neighbourhoods to gain more understanding of the flood problems being discussed.

3.4. Analysis

The survey and interviews were analysed using standard statistical techniques. Statistical analysis, thematic analysis were conducted on the data. Questionnaire data were analysed using Qualtrics software and their result summary excluded the incomplete and high value of non-responses questionnaire result. While interviews were transcribed using standard description of the situation and thematic expression, as

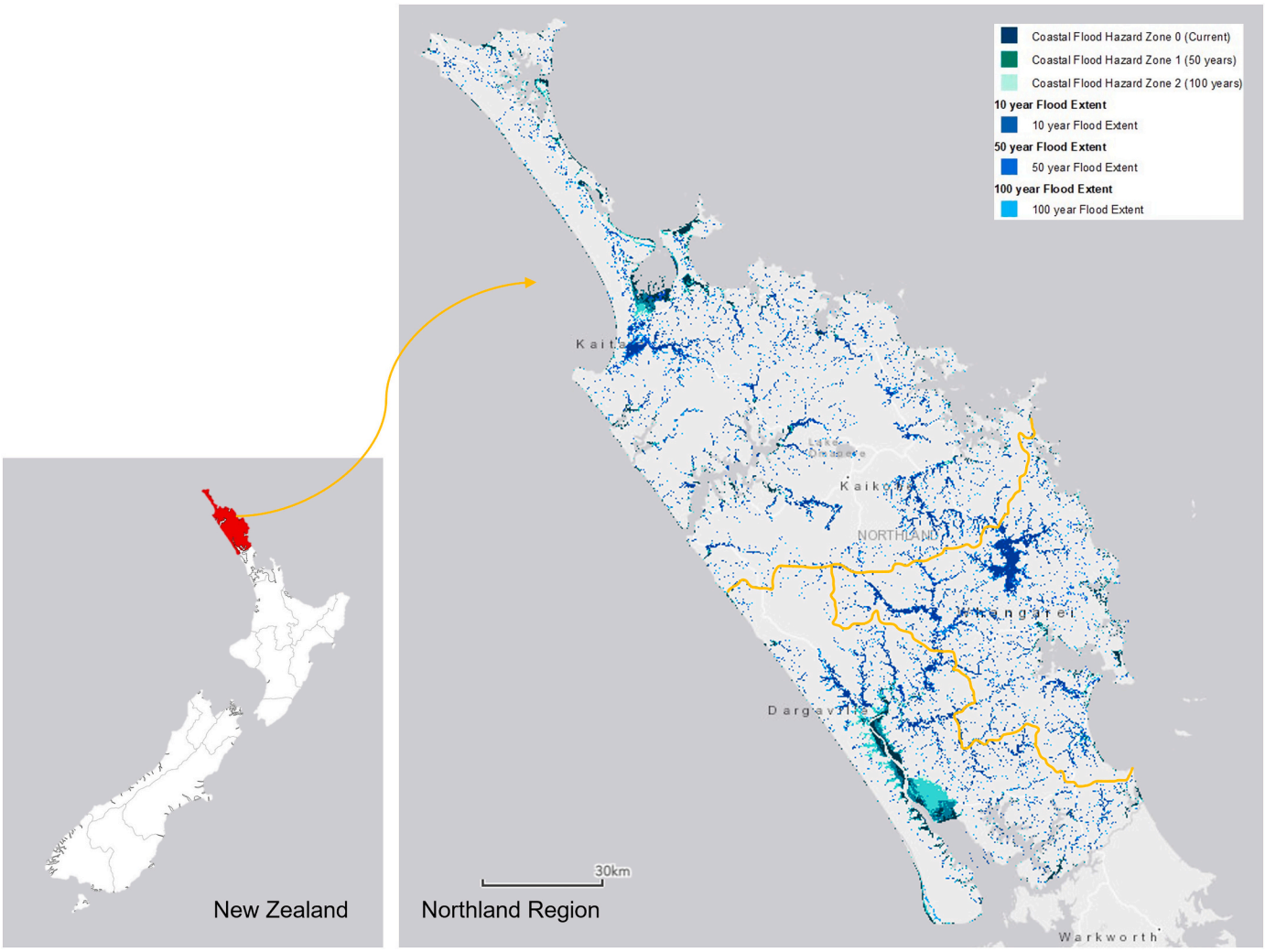

Fig. 3. Northland Region in flood susceptibility maps modified from Northland Regional Council [35].

suggested by Kumar [67]. The interview transcripts were analysed using a thematic approach with the software NVIVO. The visual results of tables and figures were illustrated using various tools: GIS map, Photoshops, PowerPoint, and Excels.

4. Results

The results are drawn from the findings summarising data of 185 surveys, 10 key informant interviews, 3 flood risk management meetings and 15 flood prone area observations. The results presented discuss the flood work program and risk communication issues, flood map influence in decision making, and public preferences for flood maps.

4.1. Communication and community engagement

Given the history of flooding in Northland, most people are well aware of the flood risk as, from the results, it has directly affected 59% of the research participants. Northland Regional Council has comprehensive approaches to managing floods. The Council published river flood hazard maps in 2016 for 28 priority river catchments with the greatest potential flood risk [31,35]. These flood susceptible maps were developed mainly for flood hazard and risk assessment purposes and do not cover the whole river catchments. The maps are used to develop flood mitigation programs. When asked about knowledge of current flood work programs, 45% of research participants were aware of government flood work initiatives in their communities. In addition to the government flood work programme, community level flood protection plays a more substantial role in protecting private homes. 62% of research participants were satisfied that the community helps them better plan for flood protection at the household level.

Community meetings in the Northland are one of the efforts of engaging communities in flood works programs. However, lack of knowledge of community events and community programs exist. Several interviewees, as illustrated by the below quotes, felt that there was minimal public response in certain areas regarding the publication of the flood work programs and believed such programs were not well distributed among the community:

> The problem is not that they do not want to participate. It is because the majority [of residents] have no idea about the program update. People knew about the program, but they did not know about the meeting. (E2 and C2).
> They do not even know about the meeting. They do not realise it until the representative comes or someone asks permission to access their land. (C.3).

Regarding information distribution, the local government representative highlighted an information line where all citizens can ask questions regarding the systems and the transparency of the program. All meetings, schedules, and programs are available online and distributed to individuals who have subscribed to the mailing lists. Furthermore, the

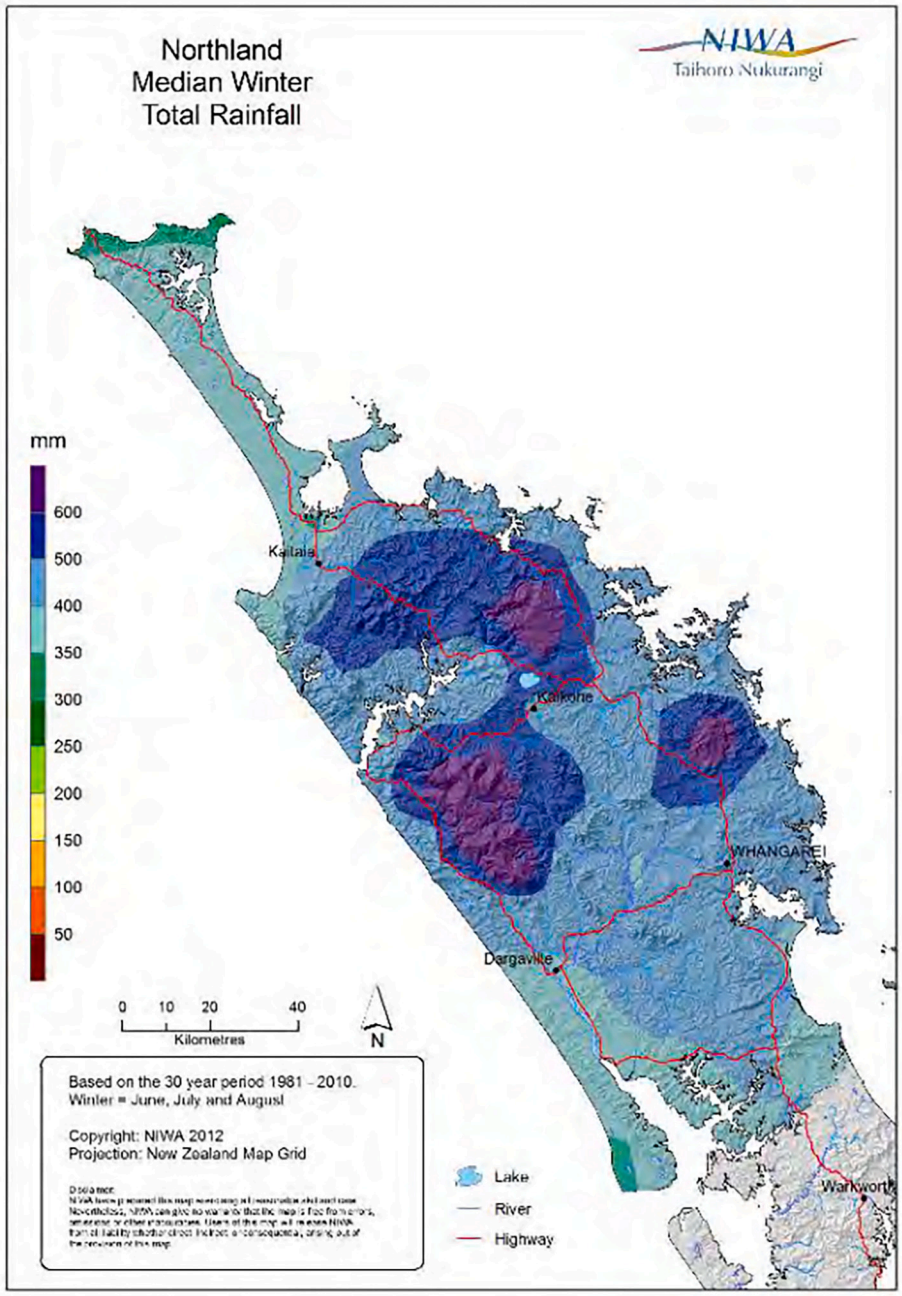

Fig. 4. Winter rainfall median of the Northland Region by NIWA [65].

government encourages communities to share information on any public platforms that are available:

> The council website provides various information. All meetings, publications, and schedules were published there. Council also has people to assist the residents with any information they need from us. (G.2).
> Anyone can attend flood works meetings; we collaborate with the communities. We encourage the community to circulate the information, we utilise community platforms available. However, we are also working to improve the publication system as we are also aware that some of the residents cannot access these platforms. (G.1).

While nearly half of the residents were unaware of the government's flood work programme (Fig. 6), the strong community ethos of protecting one another helps fill the gap in flood work programme publication. The use of online platforms to distribute information between communities is encouraged. However, for some community members, who are unfamiliar with the online platform, or who have difficulty accessing such information, other strategies, such as using community notice boards in public places, posters, newspapers, and announcements in public places (groceries stores, libraries, prayer rooms, or schools) were suggested.

4.2. *Northland risk communication issue*

Because most of the Northland's towns are constructed on flood plains, affected interviewees were keen to learn about, and discuss, flood risk while discussing flood events. Unaffected people, however, tended to be uninterested in flooding and flood risk, owing to the fact that they are not personally affected. In some situations, analysis of flood maps showed their property was just outside of the flood zone, giving them a possible false sense of security, especially with climate change

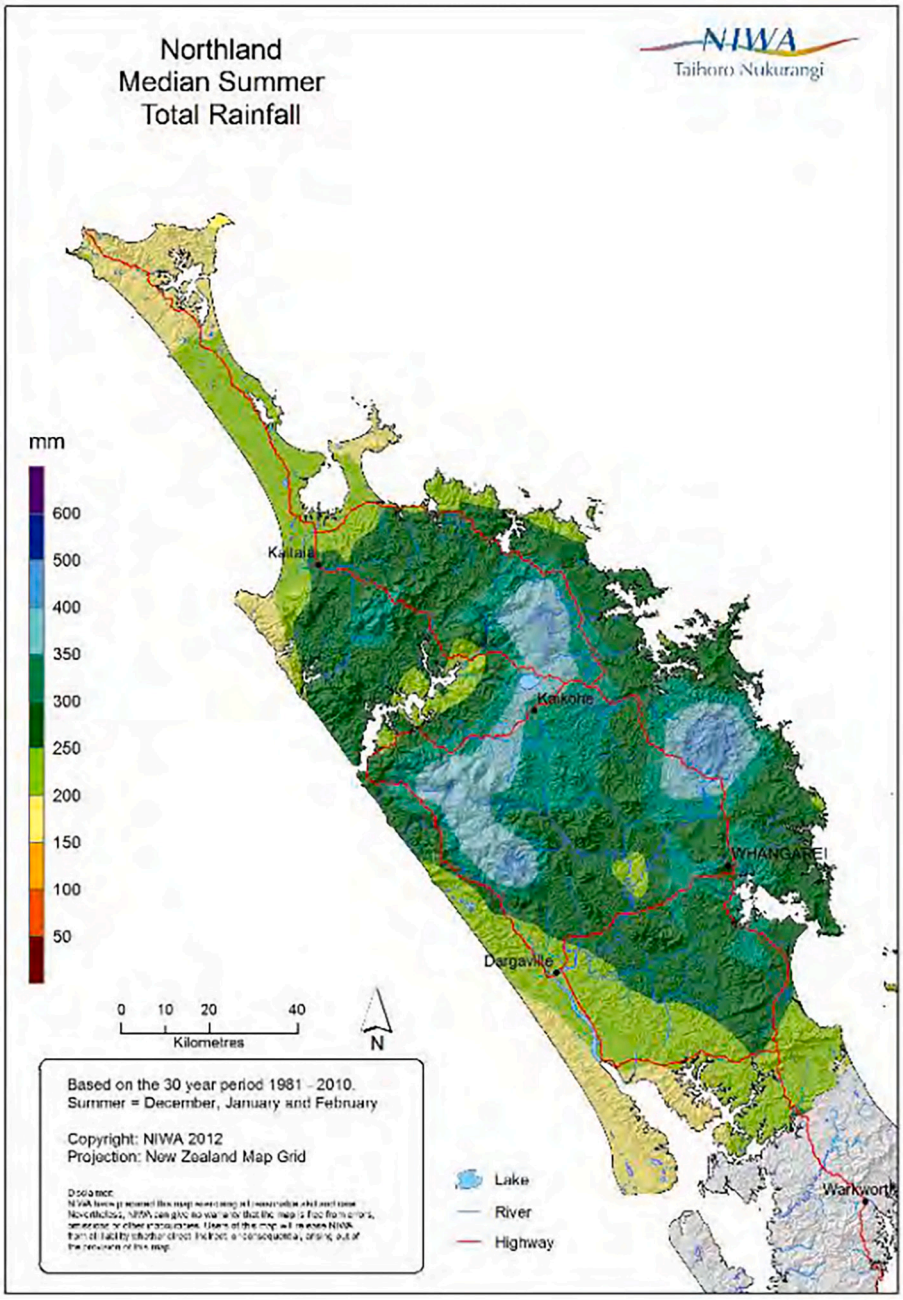

Fig. 5. Summer rainfall median of the Northland Region by NIWA[65]

conditions increasing flooding in the area.

> Most people already know that the area has flood risk, but they are not happy with increasing the flood rates for extra protection because they are not directly affected. (E.3).
> I think people living in the higher ground will not be interested in discussing this [flood risk] unless their access got affected (G.2).

Furthermore, it was asserted that locals were already aware of the flood risk in their regions due to the area's history of floods.

> This town is well-known for its flood. Even the former Prime Minister visiting this town after a major flood in the past once said, "Geographically speaking, the town should not be built in here". But this is where my family is living and this is my family land. Here people learn to live with the flood. (E.1).

In other words, flood maps may not provide much benefit to those who have experienced floods and are familiar with the area's flood history and have mitigation strategies in place.

According to the research, most people believed flood maps are advantageous, with less than 5% stating the flood maps are not helpful. Those who felt them unhelpful, believed that many of the regions depicted on the maps were incorrect. However, the majority want to be informed about flood risk and potentially involved in the map-making process to improve map accuracy. The government provides a platform for public feedback on flood maps. The following show the level of understanding of flood maps and their uses.

> I do not use flood maps, but I know that my areas are prone to flood. My farm was flooded last year [2020] and 2019 too. (C.3).
> I checked the flood maps on the last flood meeting, but the areas shown to be at risk is wrong. It said my land was not affected, but it

Table 1
Survey questionnaire themes.

Question themes	Data collected
Population at risk identification: Demographic and household information Flood experience and impacts	Data on affected areas, households, community, industries, and general information that affects the understanding of maps and flood risk. Further the questions ask about the impact on flood events in Northland from 2010 onward. This section discusses how the community responded to the flood events. Key Question: Do communities know their flood risk?
Risk communication and FRM: Community and government perspectives	Collaboration is significant in flood risk management. This section provides information on the risk communication role and impact, protection actions, current flood works, and community participation Key Question: What are the current risk communication and floor risk management practices?
Flood map: Publication, knowledge, and use	This section provides information on how the community views accessibility, instructions, features, visuals, and communication for reducing the impacts of flooding. This section also finds information on awareness and its effect on individual decision making Key Question: What are the things that can make flood maps user-friendly?

Table 2
Key Participants for Interviews.

Categories	Identifier
Government Agencies:	G.1
Northland Regional Council, Whangarei district Council, Far North District Council, and Kaipara District Council	G.2
	G.3
	G.4
Experts:	E.1
Flood related engineers	E.2
	E.3
Community representatives:	C.1
Business, Cultural, and Farming sectors	C.2
	C.3

Source: Authors

> flooded in a previous couple of years. They should consult with residents that living in the area. (C.2).
> The maps are developed using computer models considering historic flood levels, topography, rainfall, and river flow to indicate areas potentially exposed to flood risk. (…) if you have information that you think may not have been taken into account, get in touch with the regional council (E.3).

The research results showed that communities appear to value flood protection infrastructure and technical solutions as flood risk reduction measures because they believe this approach directly works to protect the area at risk. However, each region has limited funds for flood mitigation, and raising the flood rate payment is problematic for the community. Northland Regional Council allocates the flood rate payment for mitigation projects. However, because not all community representatives attend the meetings, and some decline or do not get invitations, tensions can arise between members of the community and Council on fund use:

> They [Council] only invite groups that support them and leave us with a problem [proposed program]. Suddenly they came and said the community representative agreed on it. I do not feel represented. (C.2).

Council response to those with complaints to the flood management programs can be seen in the following:

> All are welcome to the meeting. The group have TOR for nominating the representative; everyone should be represented as this work is for them and to help them. The regional council facilitates the meeting, but the flood work committees agree on the works. (G.3).

Limited funding, limited capacity, and disagreement with communities, combined with increasing flood management demand, are some of the issues being managed by the Council and community.

4.3. The relevance of information in flood maps for encouraging individual protection

Local councils agree that flood maps assist in informing residents about the flood risk to their properties (G.2, G.3, and G.4). The local council advises individuals to examine their flood risk before purchasing land and constructing a home. The regional council's maps were regarded as one of the most essential components for promoting flood awareness and giving information for personal and community protection:

> The [flood] map is a great tool to show people their risk. You can say, "This is your house, and it is located in the flood zone. Here is the information about flood insurance you might need, this is [the guidance] for saving your belonging, this is [the information] for planning the evacuation" (G.3).
> Flood maps support the engineers to explain the flood works area to the public. They can show [to the public] the flood depth and flood return period and even explain land use or areas where building houses is not permitted. When your area gets flooded, to prevent the water going inside the house, having a flood gate or sandbags ready is always good" (G.2 and G.4).

Further, the majority of those surveyed agreed that preparing for floods improves living conditions and that property values can also be improved. Most also agreed that flood protection is essential to reduce damage.

According to the survey results (Fig. 7), the community believed it was their responsibility to prepare for flood risk, and flood maps gave helpful information. Almost every interviewee had a story on how communities help one other during floods. Shared knowledge has led to encouraging individuals to:

1. Use flood-proof structure protection
2. Follow floodplain regulations.
3. Prepare an evacuation plan and a private flood response strategy.
4. Consider getting flood insurance
5. Be more cautious when storing investments (farming tools, goods appliances that can be destroyed by floodwater)

When discussing with those who owned floodplain property and the options for improving personal safety, the following sentiments were expressed:

> We are our land. Our land provides our life. Finding another place is not an option,(…) we will lose our identity. We can protect our land and our house. (C.1).
> People here know their risk. We are living [with the flood] and no problem. Everyone would understand and get ready if someone knew something, (…) helping each other during a difficult time. (E.1).
> The residents actively protect the property after the flood, claiming insurance or raising the house level, cleaning the sewer, and building the wall. The local government supports every protection action by the community if they need any primary job done, which was discussed during the flood work meeting. (G.3).

Flood maps highlight the risks, which empowers the community at the individual level of protection. However, one of the representatives stated that the technical terminology (e.g., return period) used in the

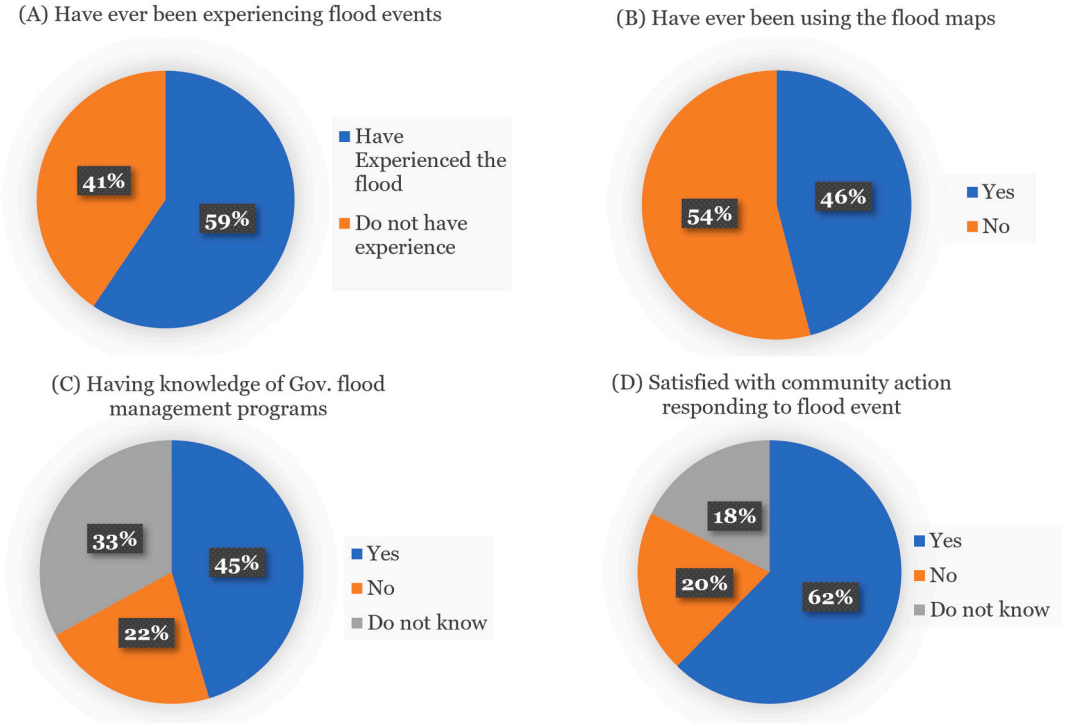

Fig. 6. Flood experience (A), Flood maps experience (B), government flood work familiarity (C), Community response satisfaction (D).

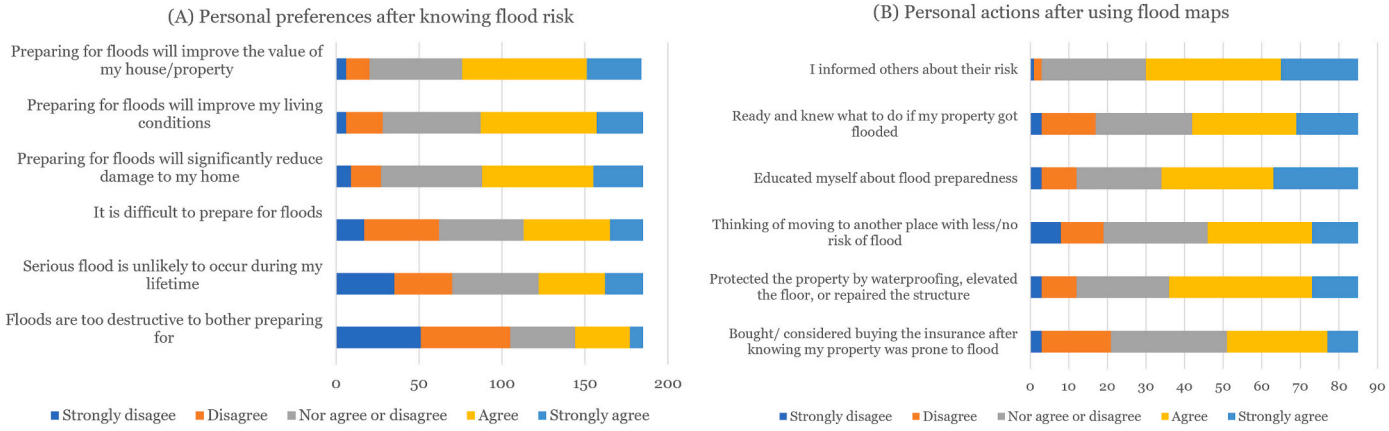

Fig. 7. Actions after knowing the risks (A) and using the maps (B).

maps meant nothing to the public unless they had personally experienced the flood (C.3).

4.4. Public preferences and use of the maps

As the flood maps are used for communicating flood risk to the community, knowing what kind of features, design, and operation that are preferable by the community on these maps is important. While all government representatives say that the community was involved in developing the flood hazard map, local council representatives (G.2 and G.3) noted that the mapping is mainly managed by the engineer in the regional council. The public can provide feedback on how to improve the maps. The current flood maps are regarded as a passive method of communication because flooding information is only offered to residents who request it, and input comes from those who are familiar with it:

> There was a recent update in the hazard maps in end of 2021, and the council encouraged the public to see and give their opinion. (…) we provide information when a resident requests or inquiries for further flood information. For example, "is my area in the floodplain? How deep is the water level? How frequent is the flooding?" for the answers, we will refer to the maps and other guidelines, all accessible on the website. (E.3).

Personal local experience and awareness demonstrates the use of these maps:

> When my family was about to purchase some land for expansion, we had to comply with the resource and building consent, so we need to know if it is in the flood zone because how we construct relates to where it is located [in terms of flood zone]. (C.1).
> Some people believe that they will not be directly affected by the flood and just build the land as they own it, and some (buildings) are not recorded. The problem happens when they later need to claim the damage after the flood, without insurance, without a consent record, it is hard for the household to get help. (G.1).

However, on interviewee believed that flood maps had little impact without wider distribution:

> The maps may be helpful in some people dealing with floods directly. However, the distribution to all residents has to be conveyed; otherwise, such a good communication tool sits in the website corner waiting to be used. (E.2).

In Northland, the government tried to develop a more proactive approach to flood mitigation by forming priority catchment grouping meetings. The maps helped to illustrate the problem and give the foundation data for flood mitigation efforts in the affected areas. Hazard maps were explained at the meetings, along with techniques for residents to secure their property, as well as a guides for self and community protection, insurance, and how to safeguard their farms and businesses. The results of the survey showed that information can be hard to understand.

> After looking into flood maps and flood works proposals. The new infrastructure works might stop the flood in one area, but how to ensure that it will not impact the land surrounding it? (…) now we cannot build in our land as the access often get flooded because of the river channelling. (C.2).
> I don't really understand where I can get the required data for insurance or construction purposes when I need information. I cannot get the printed document too. I often contact the council directly, or sometimes the property agent. I don't really know what I can and cannot do in my area [property located in flood zone area] (C.3).

Furthermore, the surveys show that flood maps provide certain information about the flood risk to the area and that the language and instructions are straightforward for the majority of people to understand. However, more than a quarter of respondents (44%) claimed that it is not easy to access, to print, and locate their property on maps (Fig. 8). Although the functionalities are simple for some, users must become accustomed to the design and graphics before completely comprehending the information provided in the maps.

5. Discussion

The research has demonstrated how flood maps are used in Northland. The result provides information about Northland risk communication, flood management, and current flood maps capacity as a tool to communicate flood risk. One way to improve flood risk communication to the community in the Northland is to find a more effective way to disseminate the information to those that find it difficult to access current information, including providing developing more user-friendly, less technical maps.

According to researchers, hazard mapping quality, content, and visual design are not the only variables that must be considered [49,60]. Effort is required to make the map design more appealing and intuitive to the community [25]. The findings from the surveys indicate that some individuals do not understand the maps and are not engaged in the community forums which promote flood risk management mitigation. The results showed that the community generally wants to be included in the flood management process, including in designing flood management programs. The flood works forum has been used to create more active communication between the Northland Councils and the communities [64]. However, further work needs to be done to make sure all those who want to participate are able to attend the forums and have their say. Currently, to get the data community needs a person to be proactive by requesting information from the Council.

Flood risk management in New Zealand encourages individual-level responsibility [4,5]. However, based on the survey results, not all of Northland's population at risk are aware of how self-protection for flooding works, and fewer appear to actually be doing something to protect their property. Reasons for this include a belief that regional and local council are responsible for flood protection measures funded by the local flood rates. To improve the community knowledge of flood impact and flood risks, effective distribution of information as well as community engagement are crucial to develop flood resiliency. One aspect of flood protection from the results was the strong community bonds and the reality of protecting each other in adversity.

The research showed that half of the respondent living on the flood plain in Northland did not feel the threat of flood hazards as their property was not in the high-risk zones. Ali and Lamond have shown that even though property outside of the projected flood hazard zone may have a lower risk of flood damage, it cannot be deemed risk-free because susceptible maps only show the area at risk for one particular flood event [34,41]. Respondents living outside flood zones still require flood management information.

Hagemeier-Klose & Wagner suggest that when the community becomes involved in the flood mapping development process, the Council will understand community preferences better, and the community will understand flood mapping better by participating in flood mapping creation [1]. In Northland, the Council encouraged people to give

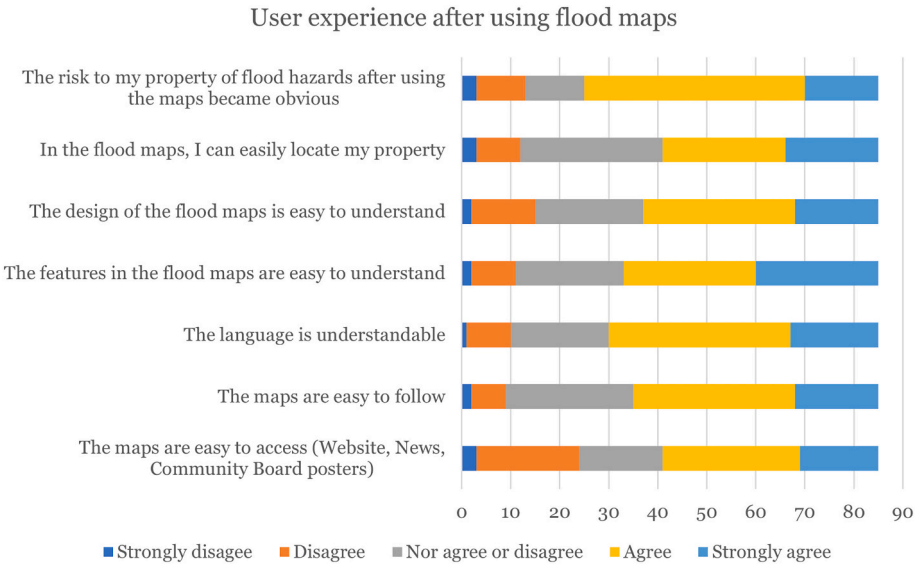

Fig. 8. Existing flood maps evaluation (before the December 2021 flood maps update).

feedback on the flood maps, suggestions to incorporate local knowledge and how to make the maps more usable for the local community.

The Northland flood maps were developed using computer models taking into consideration historic flood levels, topography, rainfall and river flows to provide an indication of areas potentially exposed to flood hazards and subsequent potential risk [6,35]. As the results show, the maps' display can be difficult for people to use. In the study, more than half of the participants can follow the instructions on the flood maps platform, but other participants require additional support to fully comprehending the material. Therefore, efforts to improve map quality, information, visual design, and how maps are displayed and communicated are critical to develop maps for community at risk. This includes helping people gain access and utilise technology, and making the maps more easy to interpret.

6. Conclusion

Flood hazard maps can effectively communicate the hazard risk and help people to improve protection of people and places. Flood maps can clarify the risk and demonstrate the impact of climate change associated with flood hazards, improve people's knowledge and enabling discussion about the risk at the local or individual level. This study showed the use of flood maps and how the utilisation of these maps can be improved. The outcome shows that the current flood prevention program has certain challenges with communicating and disseminating information among community groups. The flood working groups for priority catchments try to reach as many people as possible, but in future might need to develop ways of reaching all vulnerable community members. However, what is evident from the research is that the region has a strong sense of community and community assisting each other in times of adversity and that people are interested and willing to be involved in flood map development and flood management programs. Internationally, risk communication assists people in minimising damage by being prepared and knowing how to respond to a hazard. Community-based flood maps are critical for raising awareness and strengthening social networks, improving community resilience. Councils in Northland are already working closely with communities, but this research should help strengthen areas where there are identifiable problems, including suggestions on how to make improvements.

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Widi Auliagisni: Conceptualization, Methodology, Software, Investigation, Writing – original draft, Visualization. **Suzanne Wilkinson:** Supervision, Writing – review & editing. **Mohamed Elkharboutly:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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