Assignment 4: Disaster management in GIS

Student name: Hok Him Lu (Marcus) - 980651
Hester Lim - 1044793
Tiffany Lim - 1151929
Kennedy Guok - 1039169
Subject Name: Application of GIS
Subject Code: GEOM20013
Submission Date: 7th June 2020.
Word Count: 2225

Table of contents

Table of Figures and Tables

Abstract

In this study, the risks of flooding in Victoria are assessed by considering hazards, elements at risk, and vulnerability. Factors including slope, elevation, rainfall, infrastructure (i.e. residential buildings, care facilities, power facilities, communication services), land uses, population density and age distribution, and distances from/to emergency facilities are considered. Hazard and risk levels are classified based on existing GIS flood-hazard assessments. Western suburbs in Victoria are determined as areas with the highest hazards and risks, with topography, population characteristics, and infrastructure density playing a significant role in these results. Recommendations for improved disaster management are proposed, which include building on higher elevations, implementing more effective drainage systems, increasing overall density, and improving relevant data collection.

Introduction

This study aims to apply GIS for disaster management by estimating the risk of flooding in Victoria. The risk of flooding includes three main components - hazards, elements at risk, and vulnerability. To address the ongoing risk of flooding in Victoria, hazards such as slope, elevation, rainfall, and flow accumulation are considered. In determining potential damage and risk levels, power facilities, communication services, forests, residential buildings, and care facilities are also included in the study. From collecting data and analyzing elements at risks, hazards, and vulnerability, risk levels are assigned within Victoria with further discussions on disaster management recommendations for authorities.

Literature Review

To form our methodology, literature was first assessed to determine potential and proper considerations for managing the risk of flooding in Victoria. In an existing study, Pham et al. (2020) notes that assessing the distance to rivers may be the most important aspect of analyzing factors specific to flash floods, which can result from heavy rainfall, slow drainage, and/or lack of efficient drainage systems. Areas closer to rivers are more prone to damage due to flooding, rise in water, and increased velocity. According to another study conducted by Patz et al. (2014), human activities, such as fossil fuel combustion and deforestation, are a major component of global warming, which increases the risk of natural hazards and the ability of areas to cope with natural disasters. In analyzing flood hazards and risks in Ambo town, Ethiopia, Ogato et al. (2019) have shown the relevance of considering factors such as slope, elevation, rainfall, population density, and land use types (i.e. bodies of water vs. forest areas) in quantifying the susceptibility of areas to flood damage. For each of these factors, excluding land use types, five equal-sized sub ranges are used to classify hazard levels (Ogato et al., 2019). Research conducted by Kourgialas & Karatzas (2011) on flood-hazard areas further highlights the use of a classification method that assigns relative weights to factors that form and influence floods.

<u>Flood Hazard Index</u>

In a GIS assessment of flood-hazard areas in Greece, Kazakis et al. (2015) created a Flood Hazard Index with seven parameters: flow accumulation, rainfall intensity, geology, land use, slope, elevation, and distance from drainage network. Rainfall intensity was expressed using the Modified Fournier Index (MFI), which is the sum of the average monthly rainfall intensity at each rain gauge station. The spatial distribution of the rainfall intensity has been performed using spline interpolation, considering the allocation of stations in the studied area and the relatively sparse set-up (Kazakis et al, 2015). Coupling their study with a sensitivity analysis for data validation, Kazakis et al. (2015) found that tributaries and rivulets were important as a necessity in flood prevention plans. The rating and weights of each parameter used for the Flood Hazard Index (FHI) in their study is summarized in Appendix A.

Methodology

The methodology employed in analyzing the flood risk level in Victoria involved several main phases. These three main phases can be identified: (i) preparing data sources (ii) processing data (iii) creating useful maps. Each of these main phases will be discussed in the following sections in no particular order. The dataset used in this study are Statistical Area 2 (SA2) regions in Victoria for 2016, Vicmap Features of Interest (FOI), Victorian Land Use Information System 2016, Native Vegetation - Modelled 1750 Ecological Vegetation Classes (with Bioregional Conservation Status), Urban Development Program - Industrial Land 2018 and Victorian Primary Production Landscapes (PPL).

Preparing Data Sources

This report focuses on the flood risk level of Victoria region and the data collected are mentioned above. In particular, the dataset related to elements at risk are Native Vegetation - Modelled 1750 Ecological Vegetation Classes (with Bioregional Conservation Status) and Vicmap Features of Interest (FOI). The datasets related to hazards are Victorian Primary Production Landscapes (PPL) which consists of data related to rainfall and VicMap DEM while other hazard factors are derived from the geoprocessing tools of ArcGIS Pro. Below are the tables about hazards and elements at risk which are presented in separate tables.

Table 1 - Hazards

Factor	**Dataset / Geoprocessing**
Rainfall	Victorian Primary Production Landscapes (PPL)
Elevation	VicMap DEM
Slope	Geoprocessing with Slope tool
Flow Accumulation	Geoprocessing with Flow Accumulation tool

Table 2 - Element at Risk

Factor	**Dataset**	**Remark**
Low Forests	Native Vegetation - Modelled 1750 Ecological Vegetation Classes (with Bioregional Conservation Status)	-

Industry Facilities	Vicmap Features of Interest (FOI)	Filter by Industry Facility
Power Facilities and Communication Services	Vicmap Features of Interest (FOI)	Filter by Power Facility and Communication Service
Residential Buildings and Care Facilities	Vicmap Features of Interest (FOI)	Filter by Residential Building and Care Facility.

The datasets imported are then further processed in order to convert each factor into raster layers for analysis. Since most of the datasets imported are polygons, the 'Polygon to Raster' tool is used to create raster layers. In order to classify the raster layer according to the classes and rating of Table 3, the raster layers are then reclassified into ratings ranging from 1 to 10. Below are the ratings and weights for each hazard parameter.

Table 3 - Rating and Weight on every units

Parameters	Class	Rating	Weight
Flow Accumulation (pixels)	> 15,125	10	**3**
	3,415-15,125	8	
	2,915-3,415	6	
	731-2,195	4	
	0-731	2	
Elevation	0–124	10	**2.1**
	124–288	8	
	288–476	6	
	476–699	4	
	> 699	2	
Rainfall intensity (mm)	>1152	10	**1**
	1123-1152	8	
	1094-1123	6	

	1065-1094	4	
	1036-1065	2	
	0-1036	0	
Slope (Degrees, °)	0–2	10	0.5
	2–5	8	
	5–15	6	
	15–35	4	
	> 35	2	

Processing data

Hazard maps are produced by adding raster together with weighted factors using the Flood Hazard Index (FHI) using Eq.(1) (Kazakis et al., 2015).

$$\text{FHI} = \sum_{i=1}^{n} r_i \cdot w_i = F \cdot w_F + I \cdot w_I + S \cdot w_s + E \cdot w_D \quad (1)$$

Where:

r_i the rating of the parameter in each point
w_i the weight of each parameter
n the number of the criteria
F flow accumulation
I rainfall intensity
S slope
E elevation.

$$Risk = Hazard\ value \cdot Vulnerability\ value \cdot Elements\ at\ risk \quad (2)$$

The risk value is obtained using Eq.(2). Each value within the hazard maps are applied to each element at risk which are Residential Buildings and Care Facilities, Power Facilities and Communication Services, Industry Facilities and Low Forests to obtain the risk value. This step is done by using the ‘Extract Values to Points’ tool for point layers and ‘Extract by Mask’ tool for polygon layers. The previous step introduces a new hazard value field into the attribute table.

The vulnerability value is the sum of four factors, including distances away from emergency facilities and hospitals, population density and population of vulnerable age groups. Greater distances away from emergency facilities and hospitals means greater vulnerability. The vulnerable age group is set for those who can't drive or have difficulty moving quickly, which include ages 0 to 19 and senior citizens aged above 65. Regions with higher population density are more vulnerable when it comes to flooding. This is mostly because scarcity of resources, including daily supplies and medical help may occur.

Creating useful maps

Once the previous two main phases are completed, a series of maps are then created in order to highlight the hazards and process of obtaining the risk value. These maps include Victorian flood hazard map, factors used to create hazard map, Victorian flood risk level of industrial facilities, Victorian flood risk of power facilities and communication services, Victorian flood risk level of low forests, Victorian flood risk level of residential buildings and care facilities and Victorian flood risk map.

Results

Fig1. The Victoria Flood Hazard Map

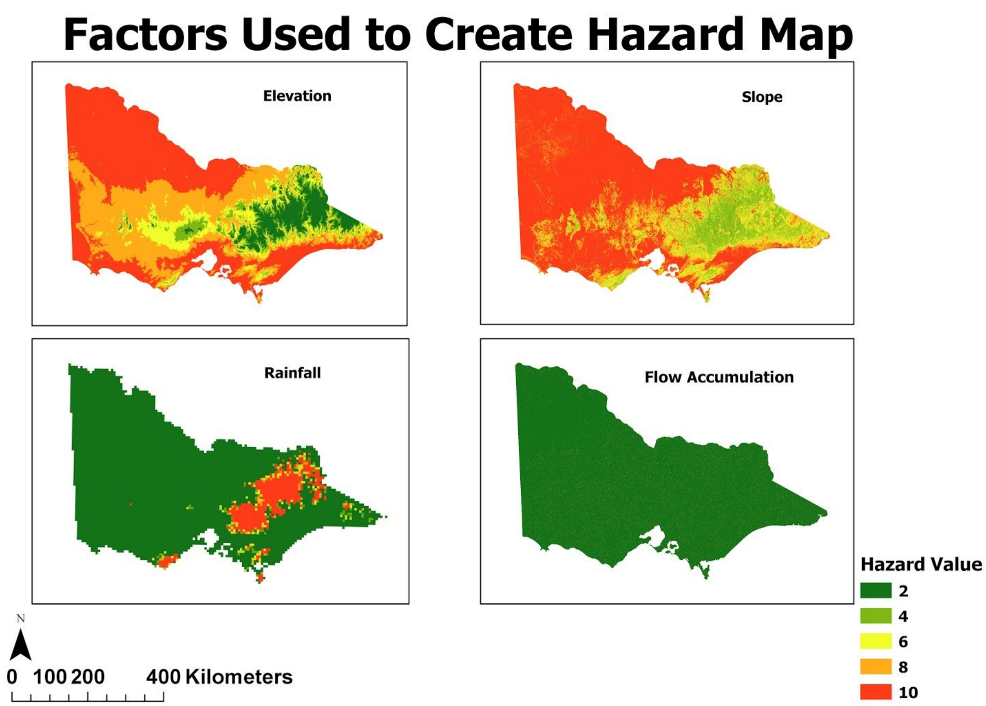

Fig2. The factors that have approached for the formation of hazard map

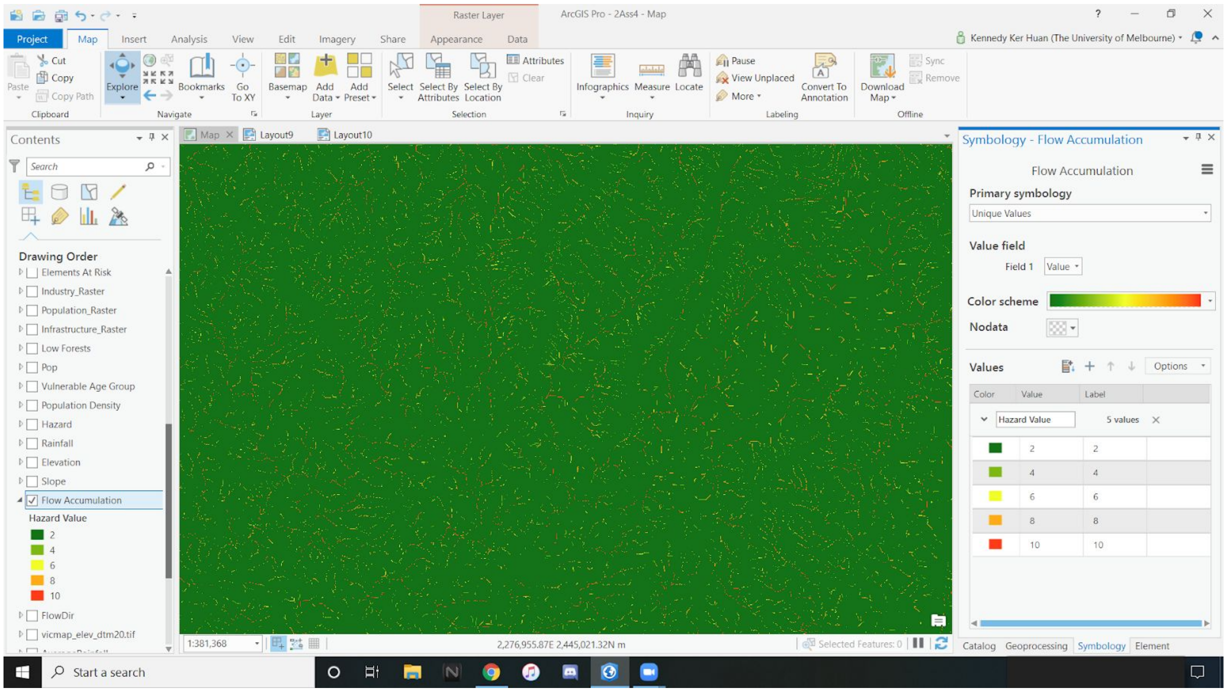

Fig3. The screenshot on flow accumulation in details

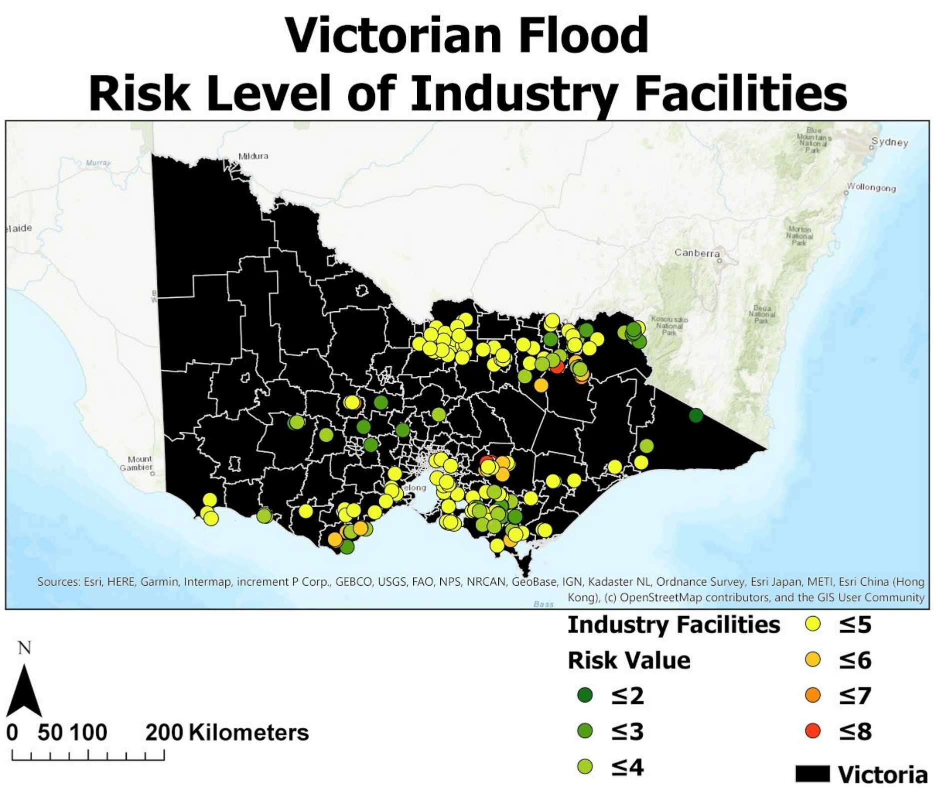

Fig4. The Flood Risk Level of Industry Facilities in Victoria Map

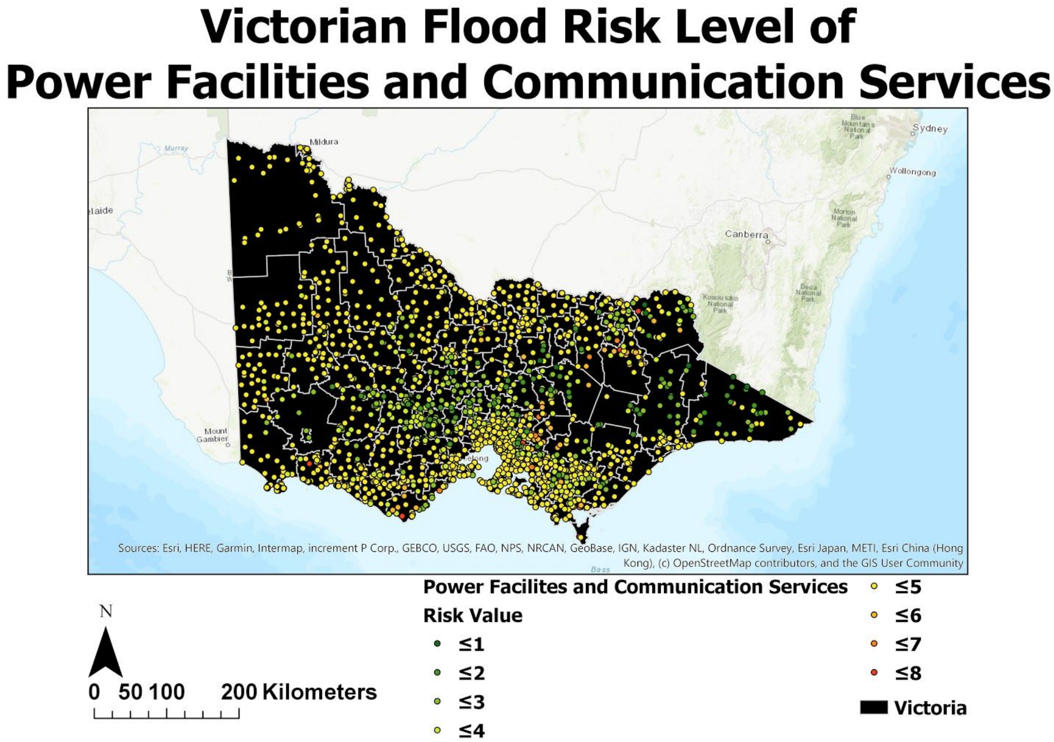

Fig5. The Flood Risk Level of Power Facilities and Communication Services in Victoria Map

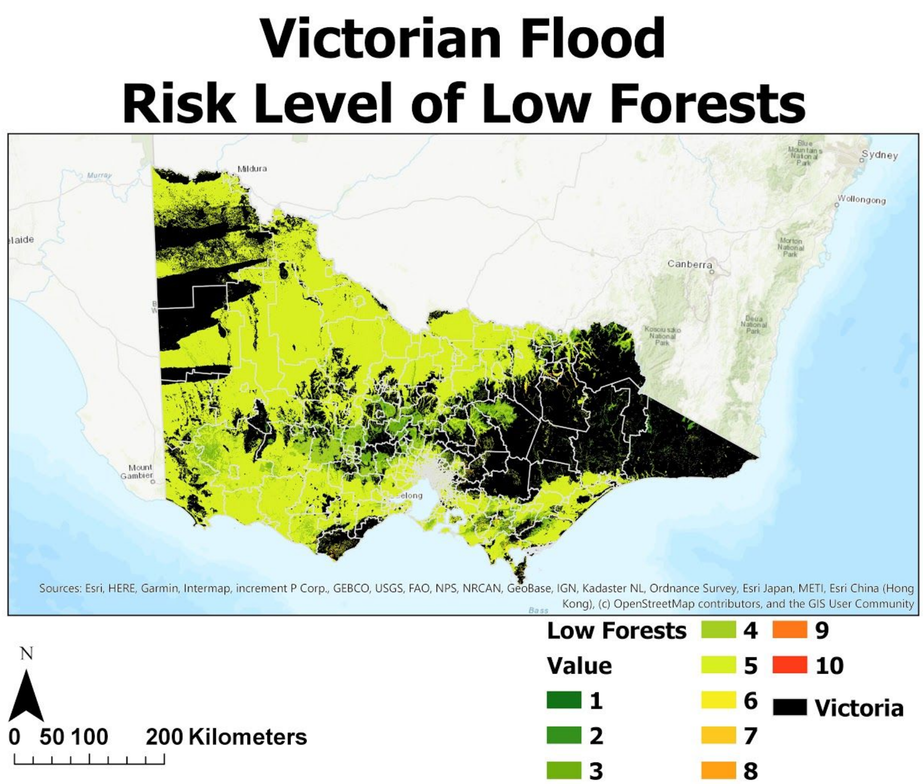

Fig6. The Flood Risk Level of Low Forests in Victoria Map

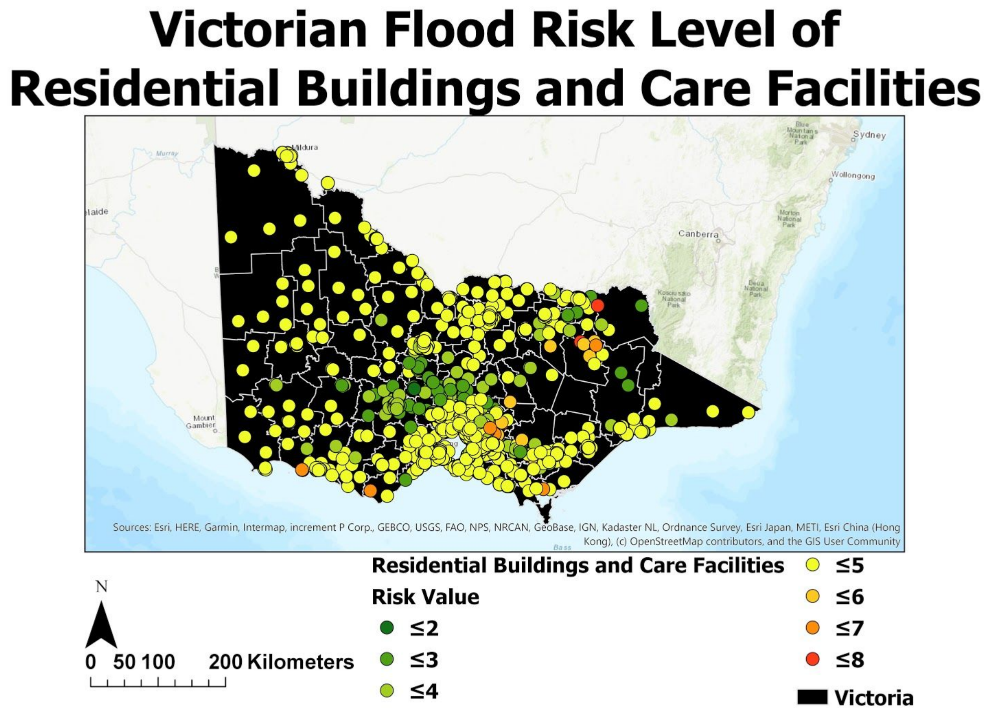

Fig7. The Flood Risk Level of Residential Buildings and Care Facilities in Victoria Map

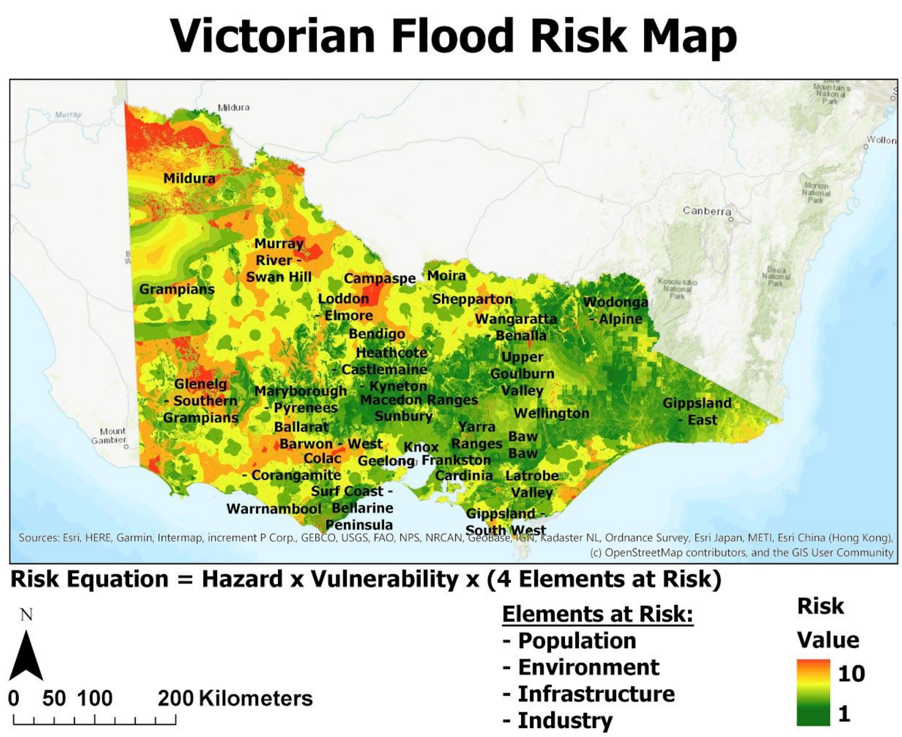

Fig8. Victorian Flood Risk Map

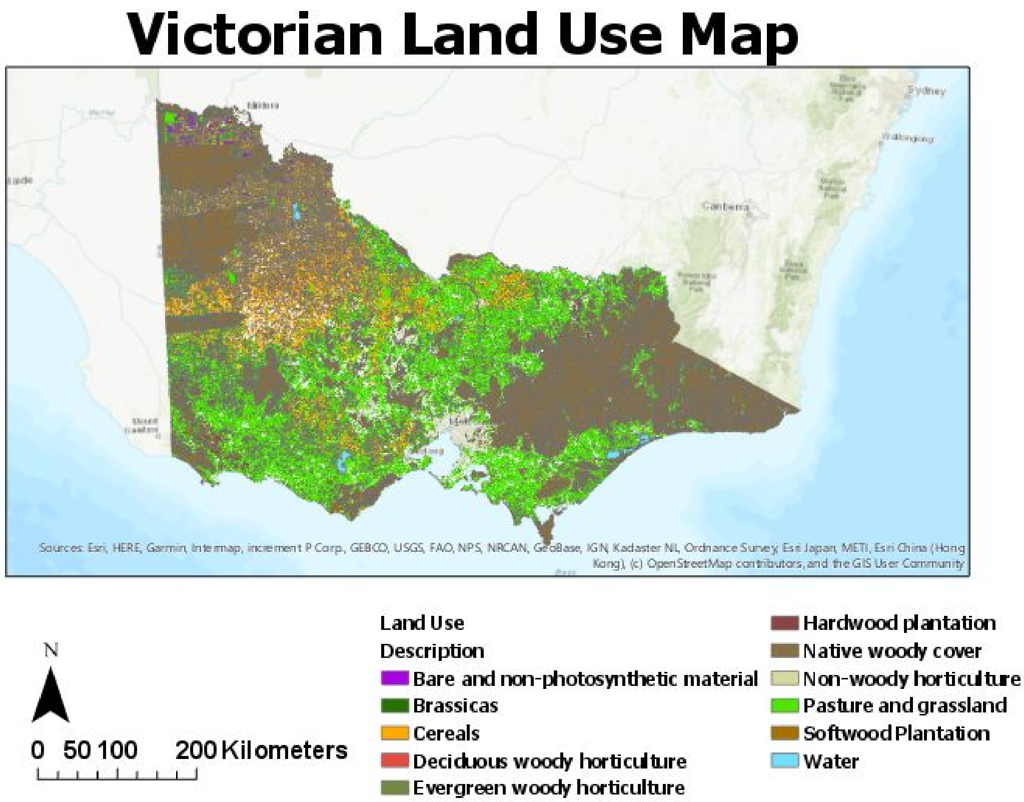

Fig9. Victorian Land Use Map

Discussion

The Victorian Flood Hazard Map generally displays areas with national parks and forest reserves with the lowest hazard value and bodies of water (i.e. rivers, streams, ponds) with the highest hazard value. In areas with national parks and reserves, elevation and slope tends to be higher than its surrounding areas, resulting in lower hazard values. Hazard values with respect to elevation and slope generally increase as distance away from areas with national parks and reserves increases. Rainfall hazard, however, is highest in these areas with national parks and reserves, including areas with rivers.

In assessing the results of the hazard and risk maps together, western suburbs of Victoria are generally more vulnerable to flood risk due to its topography, population age groups, and spatial layout, or density, of infrastructure. As elevation and slope tends to be lower in these areas, flood hazards and risks increase due to the potential flood accumulation and/or higher velocities in the case of high rainfall. The presence of scattered residential buildings and care facilities in the western half of Victoria may also contribute to higher risks with increased distances to/from emergency facilities and hospitals. Additionally, the risks posed by the lack of forest areas, which can act as natural drainage systems, in the western suburbs potentially describes the condition of existing (or the lack of) drainage systems. Though areas in the center of Victoria, such as Melbourne, also have a similar lack of forest areas compared to western suburbs, the risks are compounded by the potential lack of an effective drainage system, and lower densities of both population and infrastructure. The results of our hazard and risk maps may also be explained by looking at Victoria's land-uses. Ogato et al. (2019) studied land-uses and stated that risk ratings increase from low to high in this order of land types: forests, grasslands, cultivated, built-up, and water bodies. In general, we can see that western suburbs have higher cultivated (i.e. cereals) areas while areas like Melbourne that pose similar hazards have characteristics such as higher pasture and grassland use which contribute to lower overall risks in those regions.

Our study had various limitations and challenges, such as rainfall data with large pixels. Flow accumulation proved to have its own limitations either due to data logistics or symbology, creating an almost uniform map, which made it difficult to extrapolate accurate conclusions on velocity and/or accumulation based on larger regions in Victoria. Additionally, though we were able to craft a methodology from existing studies in our literature review, we were unable to apply Appendix A when calculating our hazard map as there was insufficient data related to drainage networks, geology, land-use with proper classifications, and rainfall intensity. Rainfall tended to be measured by units of metres which is subjective and would be more useful if provided in different units (i.e. MFI) as displayed in our literature review and Appendix A.

In order to tackle topographical, population, and emergency response concerns, future infrastructure should be developed in a way that increases overall density by concentrating residential areas and care facilities where possible, potentially on areas with higher elevations and slopes. The drainage system in Victoria should also be well-considered due to the occurrence of flooding areas being unequally distributed, therefore, further studied to analyze the drainage system's effectiveness and efficiency in the case of floods for more susceptible areas, specifically the western half of Victoria. Flood warning services should also be reassessed and prioritized, especially in areas with higher age groups and increased distances to/from emergency facilities due to potential roadblocks in times of extreme floods. The state should consider increasing the funding of the Bureau of Meteorology where possible as they are responsible for flood forecasting and warning services, which are important in such timely situations (Flood Victoria, 2018). Specifically in our study, we found a lack of sufficient data on geology and would recommend rainfall intensity units (MFI) to be collected for better analysis. Flood warning services, provided by the Bureau of Meteorology, should be reassessed as the service level specifications have limitations due to "funding, the existence of reliable and ongoing supply of quality real time rainfall, water level, and flow data, and the reliable and ongoing availability of computing and communication infrastructure required for the performance of the services" (BOM, 2013). Efficient data collection should be considered a priority to ensure rapid emergency response, especially for high risk areas.

Conclusion

In conclusion, analyzing the flooding hazards and risk requires to consider various factors which are all weight based, Kazakis et al. (2015) have provided us enlightenment ideas on how to weight factors to demonstrate areas with level of risk. After analyzing the data, the report would recommend that the middle of Victoria contains the lowest risk based on all determinant factors. With the recommendation of further studies on drainage systems for improving its effectiveness and efficiency and the urban planning on concentrating the population, it would be convinced as the better alternatives on reducing the damage from flooding hazards and provide more times on better drainage infrastructures.

References

Bureau of Meteorology (BOM). (2013). Service Level Specification for Flood Forecasting and Warning Services for Victoria – Version 2.0. Retrieved from http://www.bom.gov.au/vic/flood/brochures/SLS-2014-15-VIC.pdf.

Department of Education and Training. (2020). Regions. State Government of Victoria. Retrieved from https://www.education.vic.gov.au/about/department/structure/Pages/regions.aspx

Flood Victoria. (2018). Government and Related Agencies' Roles. Retrieved from https://www.floodvictoria.vic.gov.au/prepare-prevent/government-and-related-agencies-roles

Kazakis, Kougais, & Patsialis (2015). Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope-Evros region, Greece: *Science of Total Environment*, 538(2015), 555-563. http://dx.doi.org/10.1016/j.scitotenv.2015.08.055

Ogato, G. S., Bantider, A., Abebe, K., & Geneletti, D. (2020). Geographic information system (Gis)-Based multicriteria analysis of flooding hazard and risk in Ambo Town and its watershed, West shoa zone, oromia regional State, Ethiopia. Journal of Hydrology: Regional Studies, 27, 100659. https://doi.org/10.1016/j.ejrh.2019.100659

Patz J.A., Frumkin H., Holloway T., Vimont D.J. & Haines A. (2014) Climate Change: Challenges and Opportunities for Global Health. JAMA.

Pham, B. T., Avand, M., Janizadeh, S., Phong, T. V., Al-Ansari, N., Ho, L. S., Das, S., Le, H. V., Amini, A., Bozchaloei, S. K., Jafari, F., & Prakash, I. (2020). Gis based hybrid computational approaches for flash flood susceptibility assessment. Water, 12(3), 683. https://doi.org/10.3390/w12030683

Appendix A

Parameters	**Class**	**Rating**	**Weight**
Flow Accum. (pixels)	15,125-50,250	10	**3**
	3,415-15,125	8	
	2,915-3,415	6	
	731-2,195	4	
	0-731	2	
Distance from the drainage network (m)	< 200	10	**2.1**
	200-500	8	
	500-1,000	6	
	1,000-2,000	4	
	>2,000	2	
Elevation	0–124	10	**2.1**
	124–288	8	
	288–476	6	
	476–699	4	
	699–1440	2	
Land use	Urban-wetlands	10	**1.2**
	Pastures	8	
	Agricultural	6	
	Sparsely vegetated	4	
	Mixed forest	2	
Rainfall intensity (mm)	>1152	10	**1**
	1123-1152	8	

	1094-1123	6	
	1065-1094	4	
	1036-1065	2	
	0-1036	0	
Slope (Degrees, °)	0–2	10	**0.5**
	2–5	8	
	5–15	6	
	15–35	4	
	35–60	2	
Geology	Crystalline rocks	10	**0.3**
	Lacustrine, marbles	8	
	Neogene sediments	6	
	Continental deposits	4	
	Alluvial	2	

Table 4: "Classes of the parameters and according weights" (Kazakis et al., 2015)

Individual Reflections

Marcus

I was majorly involved in introduction, literature review, results, discussion and conclusion. I am glad that our groups' workloads are equally distributed, as before the formation of the map, we have decided to do our own literature review, then connected together to form a strong idea on what we would intend to research. After that, my major work would be connecting what we have approached and distributing those ideas to the introduction, literature review, parts of results, part of discussion and conclusion.

One of the limitations that I faced is discussing the result of flow accumulation, as the whole layer is under green colour, thankfully, while we zoom in, the details can be observed. There were many limitations on mapping that have occurred between our literature review and the data collection, especially with what we considered and what we have approached. Therefore, it is hard but important to make sure the map presented is correlating with what we have considered.

Through this assignment, I have learned better with approaching ArcGIS. Although the mapping were majorly assigned to Kennedy, we would also discuss challenges that facing ArcGIS for forming our map, therefore every of us would also require research and find approaches on distributing our data. I have also learnt how to discuss the map layers and consider more stakeholders who will approach our analyzed datas, as the literature review might bring up the evidence for us to discuss why those factors are important, but how to discuss and distribute those issues with recommendations and consideration on our limitations with further improvements would be able to provide better living environment.

Hester

I was in charge of reading one of the literature reviews, discussing the works involving ArcGIS Pro with Kennedy, importing most of the relevant dataset from data.vic and writing the methodology.

For this assignment, I have taken a much different role than the previous assignment. For this assignment rather than being in charge of the written part of the assignment, I was in charge of the works involved to create the maps needed. Firstly, I started by reading the journal and I have picked up some tips on reading journals, mainly by reading the abstract and the conclusion first before deciding if the journal is useful for the assignment. Then, I went onto the data.vic and imported all the dataset that I believe is useful for the assignment. When reading the metadata about some of the dataset, I realized that some of the attributes of the dataset collected are different to the one mentioned in the journal and this is one of the limitations of the dataset collected.

After that, I have counted that me and Kennedy have spent about 18 hours working on the ArcGIS Pro only, discussing how to reclassify the dataset, how to perform the risk analysis, how to create the hazard map from all the factors and so much more. This has given me confidence in using the ArcGIS Pro tools and the value of working with reliable teammates. We finished creating the maps needed. Then, I worked on writing the majority of methodology after going through the process with Kennedy in ArcGIS Pro.

Through this assignment, I was not as active in the group as before as I have trusted my group mates much more in contributing to the projects following the experience from the previous assignment. I did provide rough planning on what to do initially but the group members have been able to perform albeit less communication between the group members. I am fortunate to have been involved in this project and I felt bad for Tiffany for not being able to enjoy much of what Melbourne can offer before travelling back to the US. I hope we can keep in contact. In this pandemic situation, I realized the importance of maps in communicating with the general public and I have no doubt that this assignment has equipped me with the tools needed for me to analyze a variety of data.

Tiffany

For this assignment, I did part of the initial literature review, conversed with my team on initial considerations, edited the introduction and literature review, and mainly wrote the abstract and discussion sections of the report. In assessing my contribution to this project, compared to Assignment 3, I was not as involved in terms of leadership, but still kept in touch in the group chat to make sure I was on the same page. Due to technical logistics, we decided to split the work in a way that mainly had two people focus on GIS and two people focus on writing the report. Even though I did not directly work on the maps this time, I reviewed what was done, looked at the workflows, gave comments on the layouts, and comprehended the maps for the discussion. My responsibilities in Assignment 4 were more on the written analysis, which gave me a better understanding of the importance of the scale of representation, data accuracy, and data categorization used. In order to understand the data and results, I sometimes had to reach out to clarify my confusions and/or suggest edits for the layout and symbology with Kennedy, who mainly worked on the maps.

In reflection of this assignment, this project has specifically highlighted the importance of fully understanding the purpose behind the chosen results of our study and clearly visualizing data in a way that is catered to a specific audience. Through understanding and analyzing the results for the discussion, I realized what goes into risk analysis both on a quantitative and qualitative basis, noticed the complexity and limitations of our study and results, and better understood what made an effective map visualization that would both be easy to understand for a specific audience and provide relevant information that backs up our points. I will definitely be referring back to these workflows for future projects, whether personal or professional, in my academic career (i.e. my senior thesis and current summer research project on architecture and planning post-COVID in New York City). As a last point, I would like to thank my team members for working through this assignment remotely and accommodating me with my different time zone.

Kennedy Guok

I was in charge of all works involving ArcGIS Pro in this assignment. After working on the literature review together, I created all the maps together with Hester and performed risk analysis. After that, I created the map layouts for the results. Then I finished up by writing methodology.

Through this assignment, I learnt how to use ArcGIS Pro even better. I learnt new tools like Reclassify and Extract Values to Points, how to perform risk analysis from raw data using ArcGIS Pro. These allow me to understand risk analysis and its application to projects. I also know how to use information from literature reviews to help decide suitable methods in selecting data and performing analysis. I realised there are lots of factors that cause flooding, and many other issues have to be taken into account during risk analysis. After this assignment, I have the confidence to use ArcGIS Pro correctly and efficiently, and also collect relevant information for future analysis. Since this assignment requires ideas and opinions from multiple perspectives, and is impossible to complete the assignment alone, I learned that communication between group members is very important in completing a project. Despite the lack of face-to-face communication, we managed to communicate with Zoom, where I shared my screen on ArcGIS Pro while my group member assisted me throughout the risk analysis and mapping process.

One of the tough parts I faced in this assignment was writing the literature review, because we had to look over many articles and choose information relevant to our assignment. Besides, deciding data and methods to perform risk analysis is one of the difficulties I faced. There are so many things that have to be taken into consideration: whether our methods match our literature review and whether datas are relevant to what we want during risk analysis. There are so many different methods and datas we have to go over and select appropriate ones for our analysis. We also had to go through all data collected, and filter those data to obtain specific ones that are suitable for our assignment. I wouldn't be able to complete my task without help from my group mates. Due to limitations of computer power, I am unable to create a map that clearly shows the details of flow accumulation, which might affect the discussion of our risk analysis.