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Vulnerability and Geoethical Responses to Flooding in Informal Settlements: A Dual Study from Western Cape, South Africa, and Odisha, India

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Abstract

Climate change has led to an increase in the frequency and magnitude of hurricanes, floods and wildfires. These events can have devastating impacts on human lives, infrastructure and the environment. Floods, in particular, are a major concern in many regions, as they can lead to widespread damage. Informal settlements are the most vulnerable places where marginalized communities are highly exposed to the risk and the impacts of floods, as they often lack proper infrastructure and are located in low-lying areas. Combining geosciences, human, and social sciences, with in mind, geoethics principles applied to disaster risk reduction, this work intends to analyze factors associated with flooding in the Western Cape (southwest South Africa) and in Odisha (West Bengal, India) for two case studies of informal settlements where people are at a higher risk because of prior vulnerabilities.

Keywords: Floods; Informal settlements; Social; Geoethic; Vulnerability; Western Cape; South Africa; Odisha; India

1. Introduction

Climate change is now of great concern all around the world with increased sea level rise, extreme weather events, erratic rainfall with changing frequency patterns, flash flooding, associated triggered landslides, snowstorms and storm surges. Informal settlements, places where people with prior vulnerabilities from inequalities (social, economic, health) and lack many fundamental rights are gathered and segregated from other communities, are frequently found in locations like low-lying areas, floodplains, and steep slopes that are more susceptible to pre-existing geophysical hazards whose are in parts enhanced by climate change [UN-Habitat, 2020]. This section of society doesn't have access to the most basic services and facilities that are required within any community to act as coping capacity during the changing climate and associated risks. Analysis of prior vulnerabilities and factors associated with hazards in exposed places are essential to provide these communities at risk then with solutions for sustainable development.

Inspired by the United Nations 2030 Agenda, where sustainable development goals are defined around seventeen issues aiming at ending poverty and other privations while improving health and education and tackling climate change challenges[1] (Figure 1), this research focuses on the flooding risks people are exposed to in informal settlements in South Africa and in India.

Figure 1. *Sustainable development goals extracted from the seventeen adopted after the United Nations 2030 Agenda (source: Authors, adapted from the United Nations website[1]).*

[1] https://sdgs.un.org/goals (accessed 21 November 2023).

Our attention focused on the Mbekweni Informal Settlements located in the Western Cape, South Africa and in Penthakotta, Puri, West Bengal, in the Odisha District, India (Figure 2). While an ocean apart, both locations are 1) exposed to flooding risk, and 2) inhabited with people facing segregation who, consequently, have difficulties in accessing employment and facilities (water, clean and healthy food, education and health care) because of social and spatial inequalities. Ethical principles can be applied to disaster risk reduction by considering societal attitudes and examining prior – vulnerabilities factors of exposed communities to natural phenomena such as flooding or wildfires. These principles are well highlighted when the United Nations defined its sustainable goals as shown in Figure 1. In this work, we adopted a multidisciplinary approach to tackle vulnerabilities associated to flood risk considering field trips and existing literacy and website resources on social and environmental issues. Field survey and administration of questionnaires were conducted thanks to Community Risk Assessment (CRA) [Kulatunga et al., 2010; Holloway and Roomaney, 2008]. Analysis of existing published literature and the Colaizi method [Edward and Welch, 2011] helped to identify factors associated with flooding in these informal settlements. This work aims for a deeper understanding of factors affecting the impacts of flooding and coping strategies in these settlements, and consequently highlights the existing sustainable solutions that, unfortunately, are not always yet applied on the ground to meet the United Nations 2030 Agenda. It is a well-established fact that due to the location of informal settlements they are at a higher risk for multiple exposure pathways. This also prompts a consideration of the social justice perspective, questioning the locational attributes of informal settlements and their heightened vulnerability, as explored in this research.

Figure 2. *Location of the informal settlements (a): Mbekweni, Western Cape, South Africa (source: OpenStreetMap, Google Earth); (b) Penthakotta, Puri, Odisha District, West Bengal, India (source: Slum map from Puri municipality[1]).*

2. Methodology

2.1 The research approach

To gain insights into vulnerabilities that emphasize flooding risks for segregated populations, we present field surveys conducted in Western Cape (South Africa) and in Odisha (India). These two case studies have been selected as both well represent common roots and characteristics for poverty, social geoethics challenges and for being located in low-lying areas exposed to storms and floods.

This research mostly consisted in using a qualitative and empirical approach. Questionaries, interviews, and social debates with participants were part of the field trips. To complete the data and information collected from the interviews and observations, digital resources and literacy provided as well a deeper understanding of the study from the knowledge of pre- existing geohazards, and the environmental, social, historical framework for a broader data analysis. All the investigation was carried out considering the ethical principles applied to disaster risk reduction.

Firstly, a community risk assessment (CRA) was conducted in July 2011 in the Informal Settlements of Mbekweni (Figure 2a) in the frame of the PERIPERI U Program for Disaster Training (University of Stellenbosch, Western Cape, South Africa) and in 2022 in Puri (Odisha, West Bengal, India). Holloway and Roomaney [2008] describe the participatory risk assessment as a range of methodologies that engage communities who actively participate in the investigation process. Observations or experiences are mostly reported from these field surveys. Answers after questionnaires and discussions with debates with members of the community provided some insights for sustainable livelihoods and challenges faced by people who live there as a community at most risk because of prior vulnerabilities. Finally, published literature (peer-reviewed journal articles, reports, books) and digital resources (online videos, blogs, social media, digital articles from reporters) provide quantitative or qualitative data that help to measure the impact of disasters (flash flood, cyclone, monsoon, tsunami, flooding due to the break of a dam, etc…) for places prone to flooding and related health and environmental risks on communities. Since time has passed from the first survey that was conducted in 2011, on ground situations have been validated through relevant recent literature.

2.2 Data collection using ethical principles applied to disaster risk reduction

The 5W's method is a powerful way to assess the needs of a community at risk. Who, What, Where, When and Why are common key questions that help to target the context, the problem and the conditions applied to disaster management and emergency response. This approach not only has been practiced for digital humanitarian technology related to crisis mapping but constitutes the core of participatory risk assessment on the ground. In addition, one can add How for more development on the risk identified during the survey (online for digital, on the ground for interviews with members of the community). In addition to being considered the foundation of the Participatory Risk Assessment method [Holloway and Roomaney, 2008], this approach was the core for all United Nations digital humanitarian deployments (earthquakes, flood, storm, political…) and online crisis mapping (many kinds of disasters) with the StandByTask Force volunteers' organization (SBTF) (from 2010 to 2022) [Meier, 2011; Balog and Babos, 2022]. For CRA, the questions raised are [Holloway and Romney, 2008]: (1) Who is at most risk, (2) Why are they at risk, (3) When are they at the most risk, (4) What is increasing (or reducing) the risk, (5) What is the outcome of the risk and (6) How do at-risk groups reduce and cope with risks?

Quantitative or qualitative information and data are collected with in mind the 5W's method to explore and analyze the factors associated with flooding in informal settlements. The research here presented is mostly empirical.

Answering questionaries, as defined by Holloway and Roomaney [2008] and defined by the 5W's method, for risk assessment agrees well with Colaizzi's phenomenological approach to inquiry [Edward and Welch, 2011]. Here, the inquiry is: how do communities at risk because of segregation and living in poor conditions find coping strategies to deal with flooding and consequent related risks (health like outbreak, environmental, etc...).

Risk identification for segregated or isolated communities who face daily hard life conditions for basic needs (income, poverty, lack of security/safety, social tensions, environmental and related health issues…) has to be carried out considering ethical principles: The dissemination of results to (1) raise the awareness of the society and the stakeholders so that they could act closely with members of vulnerable communities and (2) acknowledge the socio-cultural role of the geoscientists are today a major concern and a priority [Di Capua and Peppoloni, 2014].

In July 2011, the University of Stellenbosch (Western Cape, South Africa) organized a series of trainings on disaster management for professionals (private, public sectors) and academics (universities) for risk reduction in Africa (PERIPERI U program[2], 'Partners Enhancing Resilience of People Exposed to Risks') with field trips that included visiting the informal settlement of Mbekweni (Drakenstein Municipality). Training before the participatory risk assessment with this settlement included presentations with debates and discussions of social, historical and health issues so multiple cases of disasters experienced by vulnerable communities frequently around the world (Africa, Asia mostly) could be considered. This training provided the core of the geo-ethics discussions necessary and inherent for crisis and disaster expertise. In the Odisha district (Puri, West Bengal, India), the same methods for ground observations were adopted by Misra S. [2022] and the outcome of these investigations is reported here to complement the exploratory analysis of factors for flooding in informal settlements.

Specifics of the questionnaire used in this dual study rely on the foundation of ethical principles and considerations applied to disaster risk reduction. In the aftermath of disasters, long-term recovery consists in rebuilding and restoring communities, infrastructure, and the well-being of individuals and affected areas. Geo-ethics seeks to fostering community cohesion and resilience, economic rehabilitation, psychological, emotional recovery, health care and social services, and environmental restoration and education on how to mitigate the impact of future disasters for long-term sustainability of the affected area. As a consequence, the 5W's approach was adapted to the needs of each community to better highlight the vulnerabilities inherent to their life conditions due to segregation and isolation.

Finally, Table 1 lists brings together all sources of data and/or information (social, flood, environmental and health) from peer-reviewed journal articles, reports, books, and digital resources (websites, blogs/social media, videos) that contributed to the research here presented.

[2] https://www.riskreductionafrica.org/ (accessed 21 November 2023).

	Papers		Digital	
	Western Cape (South Africa)	Odisha (India)	Western Cape (South Africa)	Odisha (India)
Social	[d]; [l]; [m]; [t]; [v]	[i]; [n]; [q]; [r]; [s]		[1]; [12]; [13]
Floods; Storms	[h]; [j]; [u]	[a]; [b]; [n]; [o]; [p]; [r]; [s]; [t]	[3]; [10]	[2]; [4]; [6]; [13]
Environmental	[c]; [e]; [f]; [g]; [j]; [k]; [t]; [u]	[a]; [i]; [n]; [p]; [r]; [s]	[5]; [7]; [8]; [9] ; [10]	[11]; [12]; [13]
Health	[c]; [e]; [f]; [g]; [j]; [t]	[i]; [n]; [r]	[7]	[13];

Papers:

[a] ACAPS 2022; [b] Bathla et al. 2020; [c] Brown and Maguba 2009; [d] Cinnamon and Noth [2023]; [e] Clarke 2007; [f] Cole et al. 2018; [g] Cullis et al. 2019; [h] De Kocke et al. 2021; [i] Dhyani et al. 2023; [j] Dube et al. 2022; [k] Harebottlle et al. 2008; [l] Lodge 1979; [m] Lodge 1982; [n] Misra 2022; [o] Padhan and Madheswaran 2023; [p] Patel 2016; [q] Patel et al. 2020; [r] Panda and Mishra 2020; [s] Panigrahi and Bakshi 2014; [t] Swapna et al. [2022]; [u] Tyler et al. 2011; [v] University of Stellenbosch 2011.

Digital (websites accessed 21 November 2023):
[1] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1795154
[2] https://www.preventionweb.net/news/blame-it-hirakud-flood-management-issues-river-mahanadi-india
[3] http://www.dowrorissa.gov.in/HistoryofFLOOD/HistoryofFLOOD.pdf
[4] https://simple.wikipedia.org/wiki/List_of_districts_of_Odisha#cite_note-4
[5] https://www.acaps.org/en/
[6] https://thinkhazard.org/en/report/17818-india-orissa-puri/TS
[7] https://www.capetownetc.com/news/artificial-wetland-cape/
[8] https://www.capetalk.co.za/articles/304515/r2-5bn-fake-wetland-could-save-wc-farms
[9] https://www.mbekoeco.org.za/
[10] https://www.groundup.org.za/article/environmental-group-say-masiphumelele-road-project-approval-flawed/
[11] https://timesofindia.indiatimes.com/city/bhubaneswar/govt-undp-join-hands-to-protect-states-mangroves/articleshow/93245143.cms
[12] https://behanbox.com/2020/05/14/a-resilience-fund-by-women-in-coastal-odisha-is-helping-them-cope-with-covid-19-story-of-women-of-penthakata-urban-slum-in-puri/
[13] https://storymaps.arcgis.com/stories/547d29edad8e4816bc7a5e74549fbdb5

Table 1. *Sources for data (quantitative and qualitative); Environmental, floods and health data/information are reported with letters between brackets.*

2.3 Analysis method

Information and qualitative and quantitative data collected in the field trips were examined using photos interviews and QGIS mapping. Google Earth and QGIS software for mapping and histograms (Excel) helped to represent the distribution of data gathered from peer-reviewed papers.
Analysis of all these sources of information (CRA, literature and digital resources) represent a powerful method to then propose sustainable solutions to well-defined challenges and satisfy the United Nations 2030 Agenda for sustainability, risks issues, social inequalities and consequently, the geoethics necessary to reduce the impact of climate change and flood hazards because of prior vulnerabilities. That is the outcome of the work that we present here.
In the following section, we first provide a brief summary of the two case studies in South Africa and India with respect to the social, historical, or physical geography data / information. The results of the research are then used to help identify the main factors for flood risks and vulnerabilities for both regions.

3. South Africa and India Informal Settlements case studies

3.1 Case study of Informal Settlements in Western Cape (South Africa)

Located in South Western part of South Africa and situated between Paarl and Wellington, Mbekweni (Drakenstein municipality) is a mixed colored and black community township and belongs to the district of Cape Winelands, Western Cape province (Figure 2a). When facing common hazards (floods, storms, drought, fires…), isolation due to various causes including ethnicity and poverty can only increase the exposure for segregated and isolated people within a community at risk.
Segregation was the primary root of settlements in these low-lying areas (like between Paarl and Wellington) when these urban and peri-urban dwellings had to evolve with time while facing permanent conflicts like the Paarl insurrection in 1962 [Lodge, 1979; 1982]. Table 2 displays on the major events related to Apartheid [University of Stellenbosch, 2011]. For example, the presence of migrant workers began to add more tension in these narrow places where

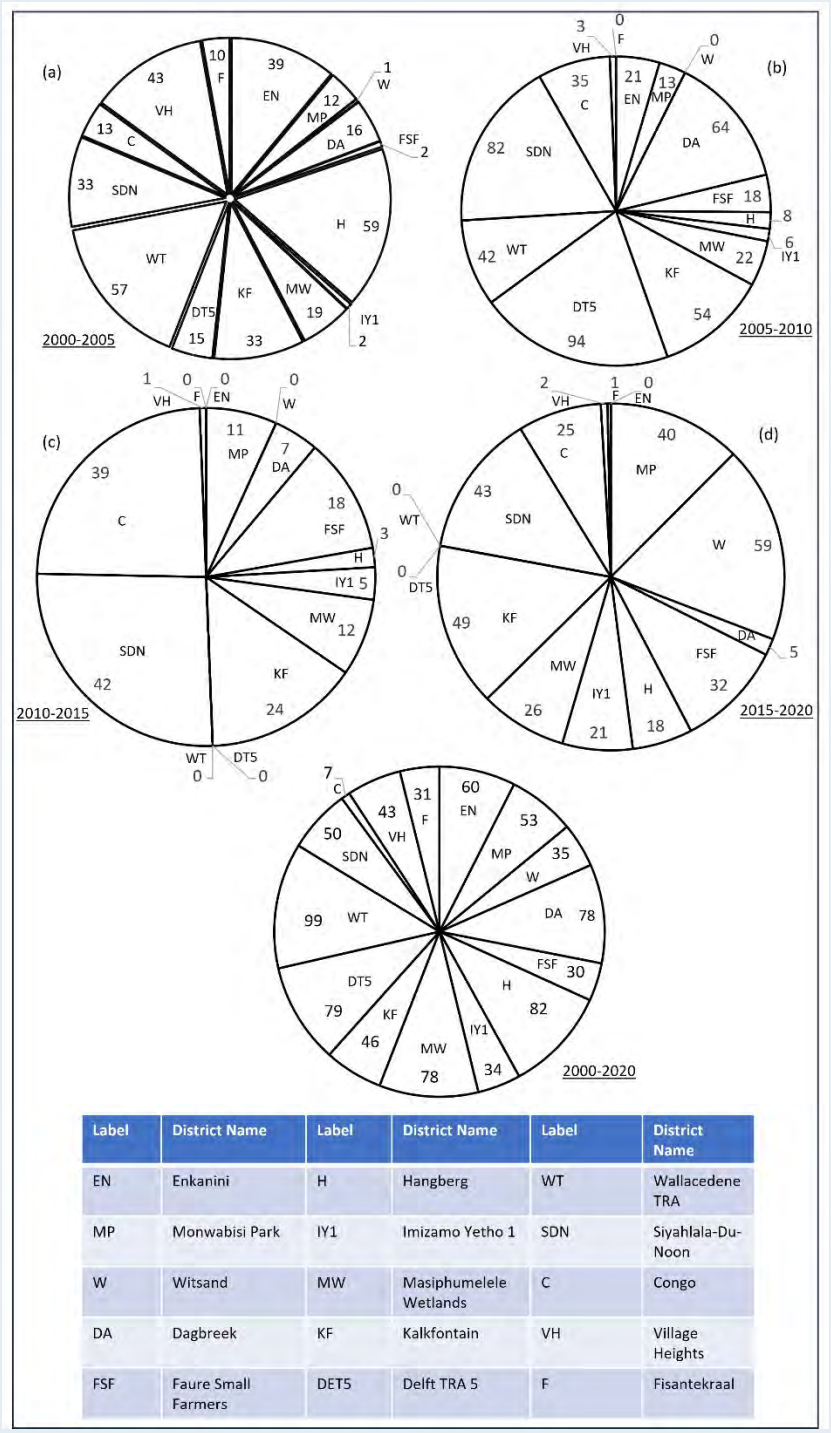
livelihood is still a crucial source of concern (riots, crimes). Conflicts and consequent crimes due to social inequalities then are raised when diversity and / or segregation is concentrated in small areas where people have to coexist and face natural disasters in a century where climate change is now a global emergency[3].

Date	Major Event / Tendency related to the Apartheid
1945	Act 25 / 1945: City Area Consolidation Act Restriction of the residency of African people in « white » areas so that all Africans who had not worked for 10 years or more for the same employer or who had not resided in the same area for more than 15 years became illegal residents
After 1954	1. Loose implementation of influx control measures (anti-apartheid era) 2. Attraction of large numbers of African who had been dispossessed of their property in the Paarl area during the Apartheid regime

Table 2. *Major events related to the Apartheid (source information: Introducing Mbekweni report, University of Stellenbosch [2011].*

Unfortunately, informal settlements arise as a result of rapid urbanization and a shortage of formal housing. The Cape Flats area, in the outskirts of Cape Town, is a low-lying region frequently subjected to heavy rains while struggling with the daily poverty that typifies informal settlements in South Africa. Cinnamon and Noth [2023] recently proposed an open data approach to assess the spatiotemporal development of informal settlements in Cape Town between 2000 and 2020. Change in built-up land was examined from geospatial information and remote sensing [Cinnamon and Noth, 2023] (Figure 3).

[3] https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/ (accessed 21 November 2023).



Label	District Name	Label	District Name	Label	District Name
EN	Enkanini	H	Hangberg	WT	Wallacedene TRA
MP	Monwabisi Park	IY1	Imizamo Yetho 1	SDN	Siyahlala-Du-Noon
W	Witsand	MW	Masiphumelele Wetlands	C	Congo
DA	Dagbreek	KF	Kalkfontain	VH	Village Heights
FSF	Faure Small Farmers	DET5	Delft TRA 5	F	Fisantekraal

Figure 3. *Growth in Built-up land for top 15 settlements in Cape Flats (Western Cape) from 2000 to 2020 (% of overall settlement size in 2020. Data source: Cinnamon and Noth [2023]).*

The Landsat data showed that for a 5 years interval during this 20 years study period, the growth in built–up land could reach more than 70% for several of the 15 top informal settlements detected in the Cape Flats [Cinnamon and Noth, 2023] (Figure 3). Some of them developed in coastal wetlands, where the exposure to storms, heavy rains and floods is higher.

In 2011, Tyler already pointed out the physical vulnerabilities faced by the first communities who set up in the Masiphumelele wetland settlement, south of Cape Town, one of hardest hit during storms and floods in Western Cape. Exploring and understanding factors due to more prior vulnerability before a natural disaster like flooding is then here of huge concern for the informal settlements of Mbekweni [Tyler, 2011].

Surrounded by vineyards and mountains (the bold mountains complex, eastern part of Mbekweni), the region is a low-lying area, marked by a floodplain that exposes its inhabitants to flooding when storm and heavy rains hit in particular at winter. Impacts of floods in Western Cape on coastal communities have been examined by Dube et al. [2022] and provided data to better understand factors that increase the risks for flooding in the frame of sustainable development goals and the Sendai Framework for Disaster Risk Reduction 2015-2030[4]. While the Cape Winelands are favored for agriculture and vineyards thanks to the Berg River, flooding of informal and formal housing close to the banks of drainage canals is a serious threat in case of dramatic and sudden rise in water levels [Clarke, 2007]. Pastimes concentrate around the Berg River, like swimming (recreational) or religious and cultural activities, so people live and interact with the river on a daily basis, accruing factors for flooding [Clarke, 2007]. In the Western Cape, coastal flooding and heavy rains also occur before and after severe episodes of droughts because of anthropogenic and non-anthropogenic reasons [De Kock et al., 2021; Dube et al., 2022]. Hence, the degradation of the consequent low permeability of the soil that increases the impact of heavy rains, and storms in terms of structural and agricultural damage but as well on coastal vulnerable communities is today a field of research that grows and aims to propose solutions to meet the UN 2030 sustainable agenda. The figure 4 below presents the most significant floods that hit the western cape from 1905 to 2018 after Dube et al. 2022. All areas are here represented, with both structural and the human damage types reported. The worst floods recorded in Paarl and Wellington in 1973, in Laingsburg in 1981 and in Cape Town in April 1993 are as

[4] https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030 (accessed 21 November 2023).

well highlighted. In 1999, Cape Town was as well severely hit by a mudslide triggered by the flood (Figure 4).

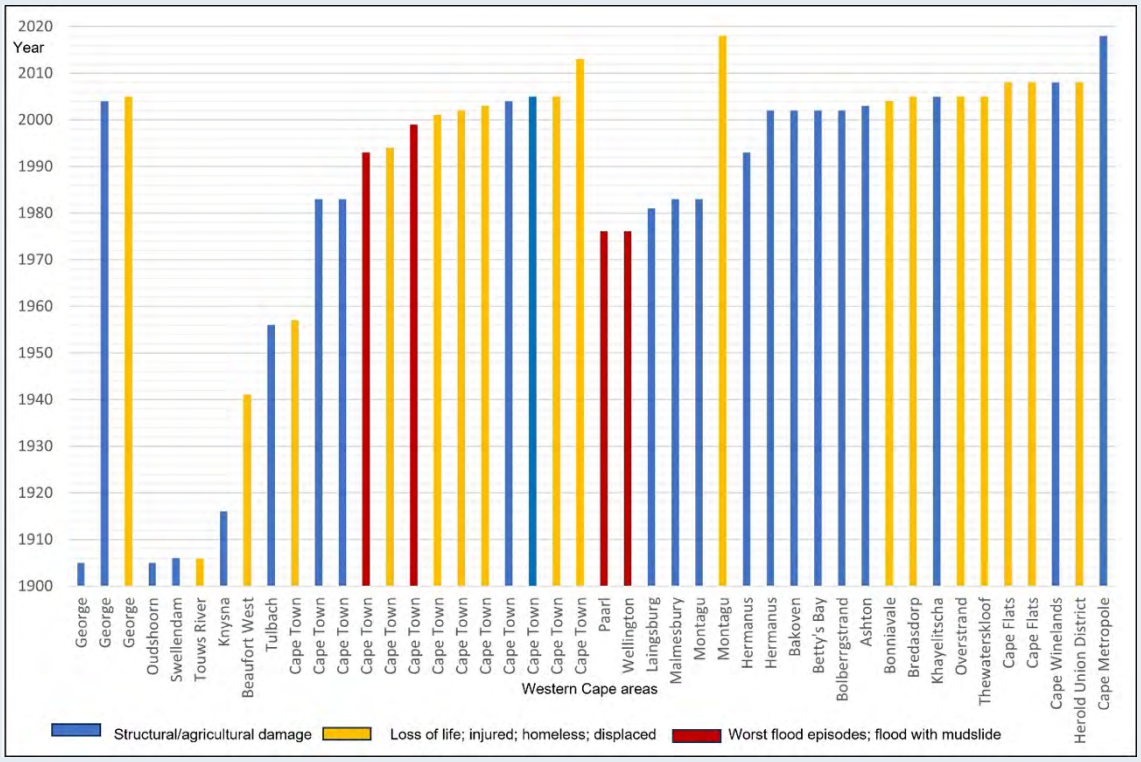


Figure 4. *List of flood events recorded in the western cape province from 1905 to 2018 (source: Dube et al. [2022]).*

1.2 Case study of the Informal Settlement of Puri (West Bengal, Odisha, India)

Extensive studies on the occurrence and frequency of tropical cyclones in the North Indian Ocean and in particular for the Bay of Bengal [Bhatla et al., 2020; Swapna et al., 2022] have shown the great need to examine the factors associated with flooding for vulnerable communities. Located in the eastern state of Odisha, the coastal city and municipality of Puri (Figure 2b) is part of the Bay of Bengal, 60 km (37 mi) south of Bhubaneswar, the state capital. In fact, more than 306 cyclonic storms have been documented and reported by Bhatla et al. [2020] for the Bay of Bengal. In particular, Odisha's geographic location and

climate have significantly contributed to damage and losses due to disasters over the years [GOO, 2002]. Between 1963 and 1999, about 22,228 people have been killed during disasters in Odisha. Cyclones have claimed lives, destroyed infrastructure, and caused significant damage, particularly to those who live along the coastline due to its socioeconomic profile, reliance on agriculture and other nature-based livelihoods [Patel S.K., 2016; 2020].

India faces a challenge of managing impacts of cyclones on exposed coastal communities with high population density with ongoing anthropogenic global warming that increases the occurrence of intense cyclonic storms [Swapna et al., 2022]. Selected as one of the heritage cities thanks to the Government of India's Heritage City Development and Augmentation Yojana (HRIDAY) program that has been launched and adopted in 2015 for city development[5], Puri is severely exposed to coastal damage and is mostly an informal settlement. In Odisha, a higher tropical cyclone frequency is commonly observed during pre-monsoon seasons [Swapna et al., 2022]. Causes of floods in the region are (1) heavy rainfall risk in water levels of rivers like the Mahanadi which is the largest river of the state, the Brahmani, and the Baitarani and (2) occasional discharge from dams like the Hirakund Reservoir located close to the Mahanadi River (Figure 5, Figures 6 and 7). While the Hirakud Reservoir discharge into the floodplain and helps to regulate the water flow, the discharge from this dam can and has already causes the flooding of the coastal plain and villages in the Odisha districts located close to the Mahanadi River[6].

Collected by the Water Resources Department of Odisha[7], a list of past floods that affected the Odisha district is reported below in Figures 6 and 7. The data here reported shows the impacted districts (represented with numbers from the Office of Registrar General and Census Commissioner of India[8]) and the rivers from floods that hit Odisha between 1960 and 2008. The disasters mostly occurred during the monsoon season, between June and September[8]. Recently, Odisha faced floods and damage at an unprecedented scale due to the Fani Cyclone in 2019 that slammed and ruined south of Puri town and the Penthakata area with gusting wind speeds reaching 185-213 km/hr [Panda and Mishra, 2020]. Launched in 2009, the Assessment Capacities Project[9] (ACAPS) undertakes field needs assessments all around the globe and provide humanitarian data and analysis. In 2022, the ACAPS team reported torrential

[5] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1795154 (accessed 21 November 2023).
[6] https://www.preventionweb.net/news/blame-it-hirakud-flood-management-issues-river-mahanadi-india (accessed 21 November 2023).
[7] http://www.dowrorissa.gov.in/HistoryofFLOOD/HistoryofFLOOD.pdf (accessed 21 November 2023).
[8] https://simple.wikipedia.org/wiki/List_of_districts_of_Odisha#cite_note-4 (accessed 21 November 2023).
[9] https://www.acaps.org/en/ (accessed 21 November 2023).

monsoon rainfalls in Odisha, which led as well to overflowing rivers and landslides [ACAPS, 2022]. Aggravating factors like (1) poverty, (2) pre-existing transport challenges, (3) frequent natural phenomena and impact on the agriculture essential as a livelihood for these rural communities and (4) existing housing vulnerabilities have been reported by the ACAPS in the aftermath of heavy rains and the related flooding [ACAPS, 2022].

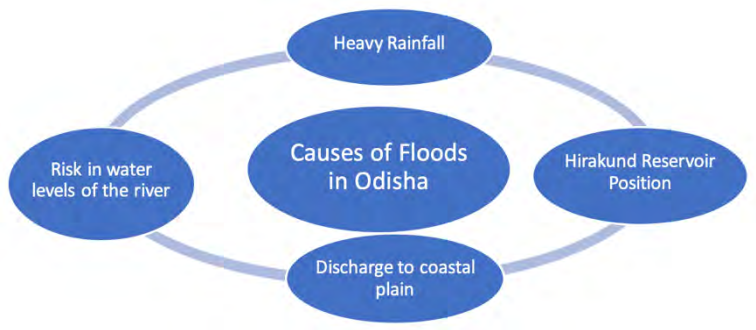


Figure 5. *Causes of flood in Odisha.*

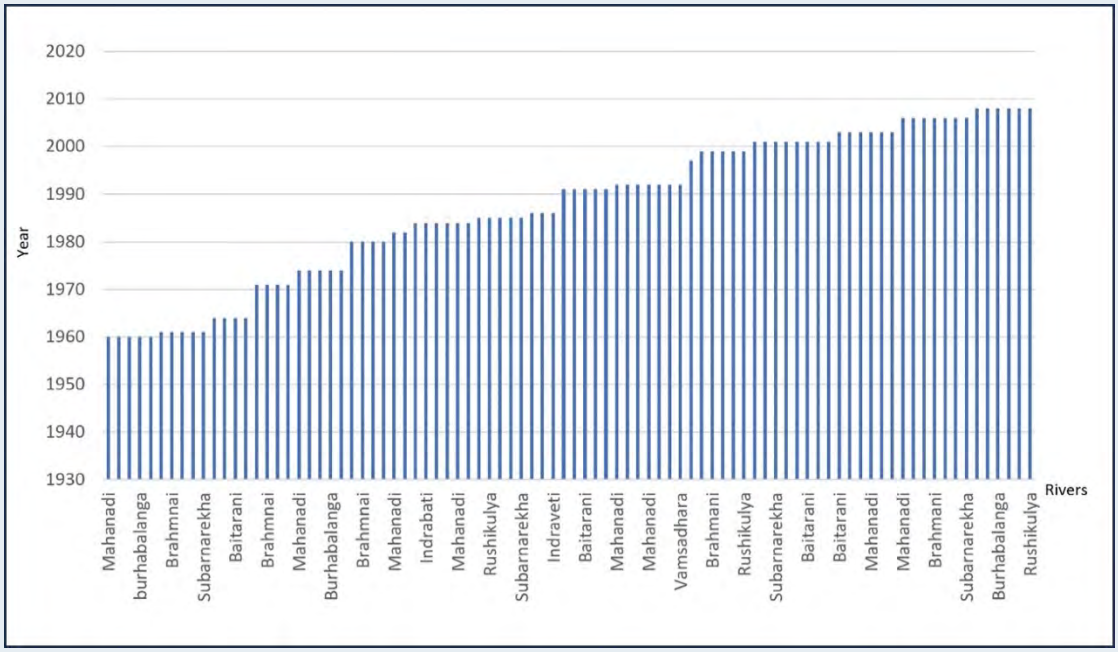
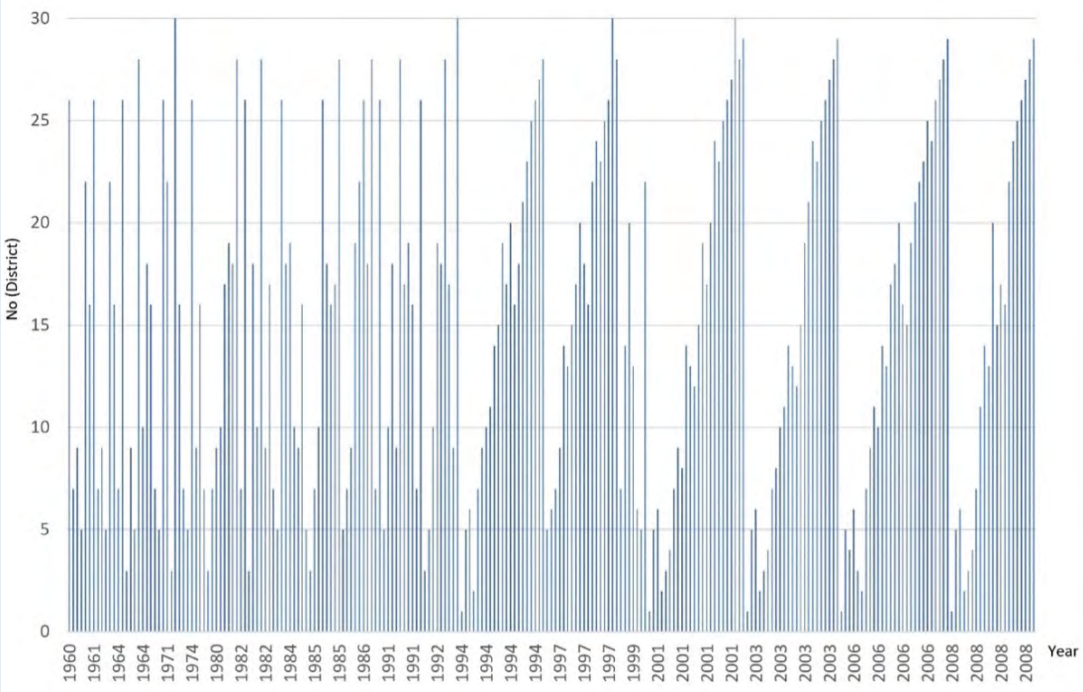


Figure 6. *List of Rivers affected by flood events that occurred in Odisha between 1960 and 2008 (source: List of Historical flood[8]).*



No	District	No	District	No	District
1	Angul	11	Gajapati	21	Malkangiri
2	Boudh	12	Jharsuguda	22	Mayurbhanj
3	Balangir	13	Jajpur	23	Nabarangpur
4	Bargarh	14	Jagatsinghapur	24	Nuapada
5	Balasore	15	Khorda	25	Nayagarh
6	Bhadrak	16	Kendujhar	26	Puri
7	Cuttack	17	Kalahandi	27	Rayagada
8	Deogarh	18	Kandhamal	28	Sambalpur
9	Dhenkanal	19	Koraput	29	Subarnapur
10	Ganjam	20	Kendrapara	30	Sundergarh

Blue: northern region ; Green : southern region; Brown: Central region

Figure 7 *Affected districts for flood events that occurred between 1960 and 2008. The table lists the numbering of the districts reported in the graphic. Districts written in blue are located in the northern region of Odisha. The green color is for the southern region and the brown in for the central region. (source: List of Historical flood[8]).*

To investigate on the impact of these two disasters in informal settlements in coastal Bengal, questionnaires for survey in Puri, Odisha District have been prepared based on the Climate Disaster Resilience Index (CDRI). The CDRI considers physical, social, economic, institutional and natural aspects [Misra, 2022]. Underlying vulnerabilities and community capacities to respond to disasters are at the core of ethical principles applied to risk reduction for preparedness and resiliency. In this context, the CDRI approach consist of 125 questions where the social dimension (population, health, education and awareness, social capital, community preparedness during disaster) in particular reflects the cohesion and the connectivity of the residents while support within the group is essential for survival [Imani et al., 2021]. The physical dimension represents mostly the built environment where the city aims to become a well-functioning one with identified parameters such as electricity, water, sanitation, accessibility of roads and housing. Questions related to the economic dimension (income, employment, household assets, finance and savings, budget and subsidy) reveals the ability to manage all financial issues related to the disaster risk management (before and after). The natural dimension reflects on parameters that characterize the natural hazards (intensity and frequency) and the ecosystem with concerns as for the land use and the environmental policies. Finally, the institutional dimension helps to answer to the resulting challenge for risk management that is the application of geoethics for decision – making and sustainable policies with parameters such as mainstreaming of disaster risk reduction, effectiveness of crisis management, knowledge dissemination, institutional collaboration and good governance. [Imani et al., 2021].

4. Results

4.1 Community Risk Assessment (CRA) in South Africa (Western Cape) and India (West Bengal, Odisha)

Table 3 hereafter reports data from the 5W's approach during field trips in the Western Cape in Mbekweni (south Western of South Africa) and in West Bengal, Odisha in Puri (Eastern India) for exploratory factor analysis of flooding impact in informal settlements. Pictures are also shown here for CRA in Figures 8 and 9. Hazard identification through writing observations and experience in a format A3 paper helped to develop risk and settlement maps for the community.

The 5W's applied to Risk	Who is most at risk?	Why are they at risk?	When are they most at risk?	What is increasing or decreasing the risk?	What is the outcome of the risk?	How do at-risk groups reduce and cope with risks?
Mbekweni (Western Cape, South Africa)	Women, children, colored people and migrants	Lack of primary and basic facilities: water, sanitation, pollution (plastic), marginalization in an enclosed settlement, prone to fire (mostly criminal), climate change with flash flooding and no water drainage system, location of the settlement in a marshy site regularly flooded during winter	Winter season (storm and heavy rains), while going to the public toilets (women…)	Growth of the community for a small settlement with income issues (unemployment and consequent and related security issues like social tension within the settlement with crimes), houses very poorly constructed, cracks on roof made of plastic or sheet metal, asbestos and related health risk), stagnant water within the settlement and related environmental and health issues	Property damaged, health concerns, pollution (plastic waste and others)	DIY (Do It Yourself) and very short-term makeshift repair
Informal Settlements in Puri (Odisha, India)	Fishing Communities, migrants, women, children	City prone to tropical cyclone, heavy rainfall leading to coastal floods, Medium Tsunami risk[10]	August, July, September, October most numbers of floods attributing to heavy rainfall (June to September are the rainy season)	Lack of healthcare facilities, informal settlements location along the coastline, open drains and other infrastructure inadequacies	Loss of life, property and infrastructure damaged, displaced people, cholera outbreak and health issues	Local NGO support, Self-help groups (Resilience fund), BGI integration with the help of local action groups

Table 3. *The 5W's method applied to the OR-Thambo informal settlement Mbekweni (Western Cape, South Africa) for CRA and to the Puri (West Bengal, Odisha, India) for questionnaires.*

[10] https://thinkhazard.org/en/report/17818-india-orissa-puri/TS (accessed 21 November 2023).

In Mbekweni, clear questions to guide all participants during the field trip were the following:

- How long have you been staying here?
- What are the common dangers in your area, and what are the most important ones?
- How often does these dangers occur?
- How were you affected personally?
- Why does then hazard occur and how do you cope with it?
- Could you identify and characterize role players (Importance, relationship, access to assistance)?
- How do you feel with services like police and ambulances?

These key questions guided the participants to identify the relationships between different aspects of risks by drawing a tree. Roots (cause) and effects of the priority hazards could then be highlighted thanks to problem trees drawn by members from each group, with the help of CRA facilitators (Figure 8b). The spatial mapping activity (Figure 8c) helped to debate on factors of vulnerabilities associated to risks in the informal settlement. Finally, selected members from each hazards groups presented the results of the CRA (problem trees, settlement maps) to all participants of the field trip (members from the community and facilitators) (Figure 8d).

Figure 8. *Community Risk Assessment in the Informal Settlements in Mbekweni, Western Cape, South Africa– July 2011 (Credit pictures: L. Amir / July 2011).*

Figure 9. *Risk Assessment in Puri, Odisha District, West of Bengal, India (Credit Pictures: S. Misra [2022]).*

The survey in Mbekweni showed that social factors were the main cause of vulnerabilities to hazards like floods, or fires. Tensions and insecurity felt among the community were the consequences of main concerns that were then reported and published by the Periperi ("Partners Enhancing Resilience for People Exposed to Risks") in the frame of the Disaster Mitigation for Sustainable Livelihoods Programme to help the Drakenstein Municipality find appropriate measures for risks reduction in these areas according to the capacities of these informal settlements marked by an endemic violence of life [RADAR, 2011].

Local knowledge and general understanding of the location of resources are crucial for stakeholders to propose long-term strategies and not only coping strategies to face risk in these settlements. The answers that help define the coping strategies from the question "How do at-risk groups reduce and cope with risks" raised the problem of funding and lack of an appropriate policy to prevent risks and reduce the impact of the identified hazards (fires, flood, environmental and health) to this vulnerable community.

To make the land habitable, several projects have been submitted for planning, design and implementation through proposals from civil engineering services like storm-water drainage system to eliminate the danger of flooding in winter storms (like underground concrete storm water piping).

The survey conducted in Puri included the preliminary household investigation of education level, number of family members, health risks people suffer from (Figure 9). The next stage included to understand in more depth the socio-economic status of people including the income profile, access to health care facilities, any government schemes that have provided support to them, number of days that the services like schools were closed. The survey questions also encompassed inquiries about the impact of the disaster on the respondents' livelihood options, the damages they had to face, and the status of any savings they might have had after experiencing such an extreme situation, with an eye towards the future. Peoples' perception on the challenges (factors that add to vulnerability) and what can be done (how people at most risk respond) were also inquired during the survey (Figures 9a and 9b). These survey questions aimed at holistically try to understand the depths of the 5W's with details on the available capacities of the communities. Focused group discussions were conducted with various stakeholders including special focus to women who were identified as a critical vulnerable group in the community.

Plastic roofing and sheet walls were as well noted as factors for vulnerability to floods impact in both case studies (Figures 8e, 8f, 9e, 9f).

4.2 Factors and vulnerabilities analysis

4.2.1 Social, Physical and Environmental factors for vulnerability

4.2.1.1 Mbekweni, Western Cape, South Africa

An accumulation zone for pollutants and debris nearby the farming land and in the Berg River can be observed using Google Earth software (Figure 10). These pollutants come from the informal settlements of Mbekweni [RADAR, 2011]. The analysis for the period between 2013 to 2017 showed the highest concentration of phosphate and ammonia levels is found near Mbekweni with values that exceed national and international accepted levels [Cullis et al., 2019]. These analyses also reveal fecal pollution in relation with the drainage from Mbekweni [Cullis et al., 2019]. Hence, the environmental pollution and the health risks should as well be considered as factors of vulnerability for Mbekweni. The region is heavily depending on sectors using water for agri-processing, agriculture, freshwater, and aquaculture. Barometers for benefits of water use mostly concern piped water, flush toilet, washing machine, residential use, water quality, income jobs. Consequently, inequalities in social-being are here pointed out [Cole et al., 2018].

Figure 10. *(a) and (b): Railway line in the Informal Settlements of Mbekweni (Credit Picture: L. Amir) – (c): Google Earth view (July 2021) of the limits between the Informal Settlement (railway line) and the hydrographic network that feed the Berg River with pollutants from the settlements – (d): Google Earth 3D view (July 2021) of the Farming lands and Informal Settlement of Mbekweni with sedimentary / pollutants deposits (accumulation zone) in the Berg River.*

4.2.1.2 Puri, Odisha, India

The vulnerability in Puri is due to demographic and socio- economic factors. Firstly, Figure 11a shows the population density of informal settlements in Puri. Due to the presence of slums and informal settlements, Puri town has a high population density near the coast as well as in some of its northern wards. However, because of the frequent natural geohazards that strike Puri, the population growth rate has been slow. Population density has been increasing mainly in the coastal wards of Puri town where major slums are present. But the decadal growth rate of population has been slow due to frequent striking of disasters to Puri. Population density of informal settlement is most ward number 32 where the most populated Penthakata slum (Figure 11a) is present, very close 200m from the sea. The density of the population is higher along the coast because of the concentration of informal settlements and major slums. Unfortunately, a high population density suggests a vulnerability with respect to floods. Moreover, in the 14 wards where the survey has been carried out, diarrhea, snake bite and skin diseases have been mapped in the aftermath of the Fani Cyclone in 2019 (Figure 11b).

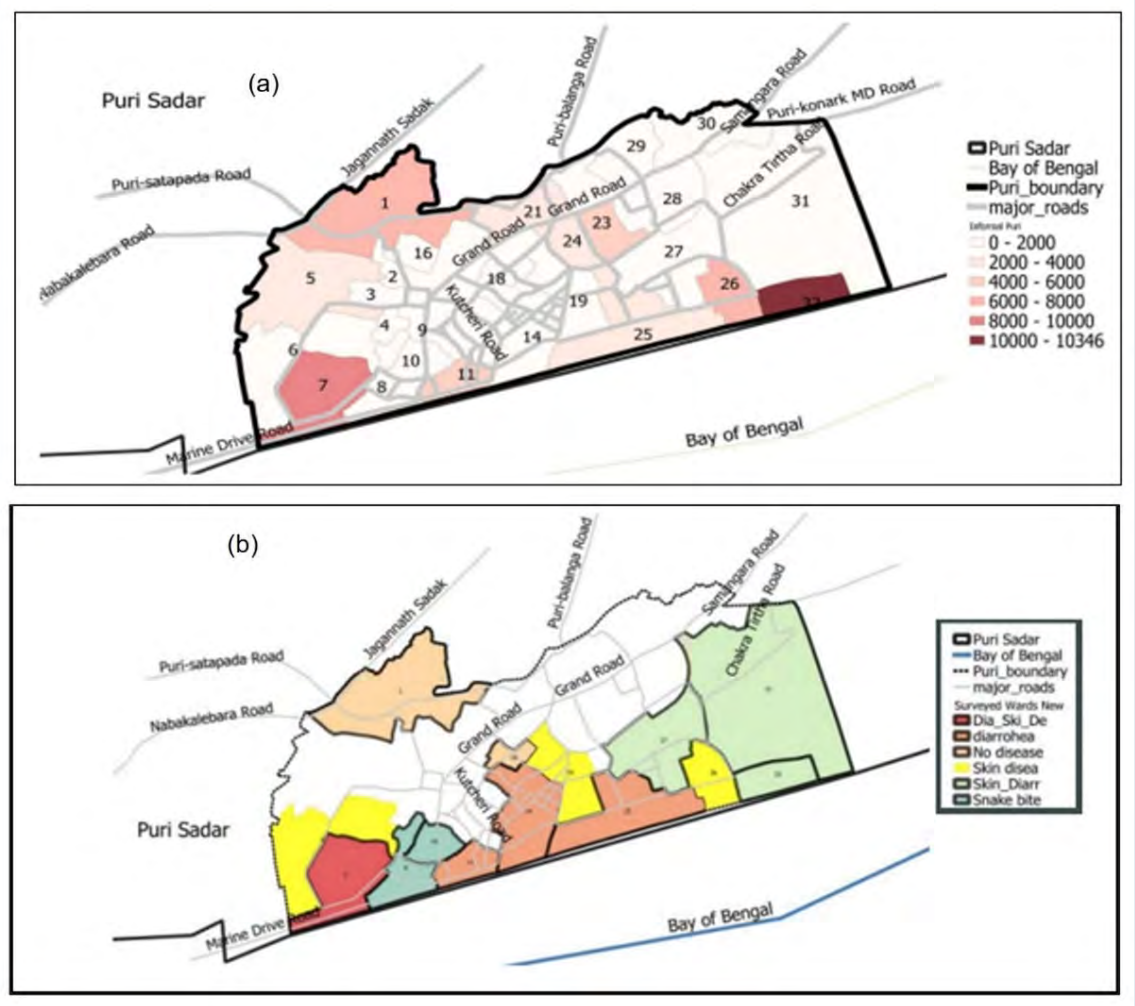


Figure 11. *(a) Population density of informal settlements and (b) health factors in wards of Puri (source: Authors – Misra S. [2022], QGIS software).*

The survey showed that the capacity and resilience was low particularly attributable to the social and economic dimensions. Limited cash transfer or assistance programs make it difficult for the community to revive easily after the disasters creating a cycle of poverty for the informal settlement due to frequent occurrence of disasters. Economic consequences of the disaster included loan from private party with higher interest rates and incapability to pay back. Low literacy rates were observed which often led to underestimating the anticipated disaster magnitude causing more damage. The survey also highlighted ethnic

segregation based on caste which raises concern on the social cohesion at the time of crisis. Housing condition as also visible through photo proof, was not prepared this adding to the vulnerability. The Penthakata slum resides Telugu speaking population with no schools with the same language option thereby making a linguistic segregation and a barrier to staining more capacity to deal with such disasters.

4.2.2 Role of geoethics in responding to risk reduction

Intergenerational ethics is a branch of ethics that developed at the beginning of the 21st century for moral obligations to integrate environmentally sustainable actions and policies for future generations [Ekeli, 2004]. Human responsibilities (personal and collective) towards nature constitute a major step to better contribute for disaster risk reduction from a geoethics perspective [Casareale et al., 2022].

Sustainable development in the Anthropocene recognizes the interconnectedness of social, economic, and environmental factors, emphasizing responsible resource use, environmental conservation, and social equity in the face of human-induced changes to the planet. Geosciences are at the service of society (energy supply, use of georesources, land management, pollution abatement, mitigation of geo-risks, climate change adaptation, ethical and social issues). Living in a planetary social ecological system as defined by Reyers et al. [2018] and Bohle and Marone [2021], tackling climate change requires sustainable practices like (1) protect and restore forests as they act as carbon sinks, (2) promote sustainable agriculture and land-use practices, (3) invest in resilient infrastructure and urban planning for example. Combating climate change requires a collective effort at local, national, and global levels, involving governments, businesses, communities, and individuals.

Research integrity statements and codes of ethics/conduct as suggested and adopted in the Cape Town Statement on Geoethics [Di Capua et al., 2017] contribute to revise controversial practices for land-use management for example. In urban geography and development, it is critical to take ethical implications—such as geoethics—into account while resolving the problems related to informal settlements. Thomson et al. [2020] stress the need of include local people in the process of defining informal settlement boundaries, emphasizing the necessity to take local views, privacy concerns, and geoethics into account. Nixon [2020] also examines the effects of informal settlements on

the environment and stresses the need to evaluate the moral standards and laws that govern conduct in these communities.

Diversity in actors, ecosystems, institutions, and social-ecological interactions as sources of resilience as emphasized by Reyers et al. [2018] is totally integrated in the Sustainable Development Goals defined by the United Nations. Ethical decision-making recognizes the interconnectedness of geological processes with human well-being and environment. Flood Risk Reduction increases awareness of responsibility in causing flood disasters and consequently leads to questioning for better ways we interact with nature [Casareale et al., 2022]. Geoethical responses here addresses the vulnerability questions for flooding risk reduction in the informal settlements of Western Cape (South Africa) and Odisha (India) where factors identified for both settlements were associated to land-use management and water pollution (Berg River catchment for South Africa, coastal for Odisha in India with plastics) and soil degradation for both cases. In fact, remote sensing studies and environmental and societal analysis of places prone to disasters revealed the need to build a bridge between geoscientists and communities at risk to find eco-friendly and socio-friendly solutions as geoethical responses, considering research integrity principles [Peppoloni and Di Capua, 2015; Peppoloni et al., 2015]. The goals defined by the United Nations for sustainability and development for the planet totally include all the dimensions (social, economic, environmental, educational) required for ethical responses to erase the discrepancies for vulnerabilities to flooding disasters in informal settlements. The discussion below develops different actions and examples found in South Africa and India.

5. Discussion

In South Africa, informal settlements of the Western Cape Province are particularly exposed to damage, environmental and health impacts from extreme weather events (rainfall, storms). In India, in western Bengal, the Odisha district and the Puri community is severely affected by tropical cyclones and related flooding like monsoons, pre-monsoons, storms, heavy rainfall, dam breaks and far-field tsunamis. Informal settlements unfortunately still lack of all facilities to face natural hazards.

Wetlands have several properties like (1) reducing the force of floodwaters and (2) cleansing the water passing through them [Brown and Maguba, 2009]. Projects to build or preserve wetlands like north of Paarl in South Africa or the

mangroves in India or improving the drainage systems could help to reduce the loss of life, infrastructure and improve the protection of biodiversity and environment with new ways to collect water to prevent for example from other geohazards related to climate change (drought,…). Forest canopies help to regulate the ecosystem functions in this particular time of the Anthropocene [Nakamura et al., 2022]. For example, evapotranspiration influences the rising of greenhouses gases between PI and PD anthropogenic climate [Connor et al., 2021]. Acting as an interface between the land and the atmosphere, forest canopies diversity leads to the development of variable microclimatic conditions (temperature, humidity) thanks to vertical stratification [Connor et al., 2021; Nakamura et al., 2022]. Finally, ecological processes are crucial for the preservation of the planet geo-ecosystem. Microhabitats provided by canopies help organisms to have greater elevational range distributions and to additionally and consequently interact with all components of their environment and the biosphere [Nakamura et al., 2022].

5.1 The Western Cape Case study (South Africa)

Several public websites indicate that an artificial wetland was to be built for the Berg River[11,12] (Figure 12). Scientific studies have shown the role of such sustainable solutions to prevent from contamination of water because of urban and peri-urban wastes and toxic elements. Unfortunately, until now, there is absolutely no information and no data on this artificial wetland that could prevent impacts from floods and pollution in the Berg River catchment.
Nevertheless, Waste Water Treatment Works (WWTW) in Paarl supports a number of waterbirds that are essential for the ecosystem (aquatic habitat, natural ponds) [Harebottle et al., 2008].

[11] https://www.capetownetc.com/news/artificial-wetland-cape/ (accessed 21 November 2023).
[12] https://www.capetalk.co.za/articles/304515/r2-5bn-fake-wetland-could-save-wc-farms (accessed 21 November 2023).

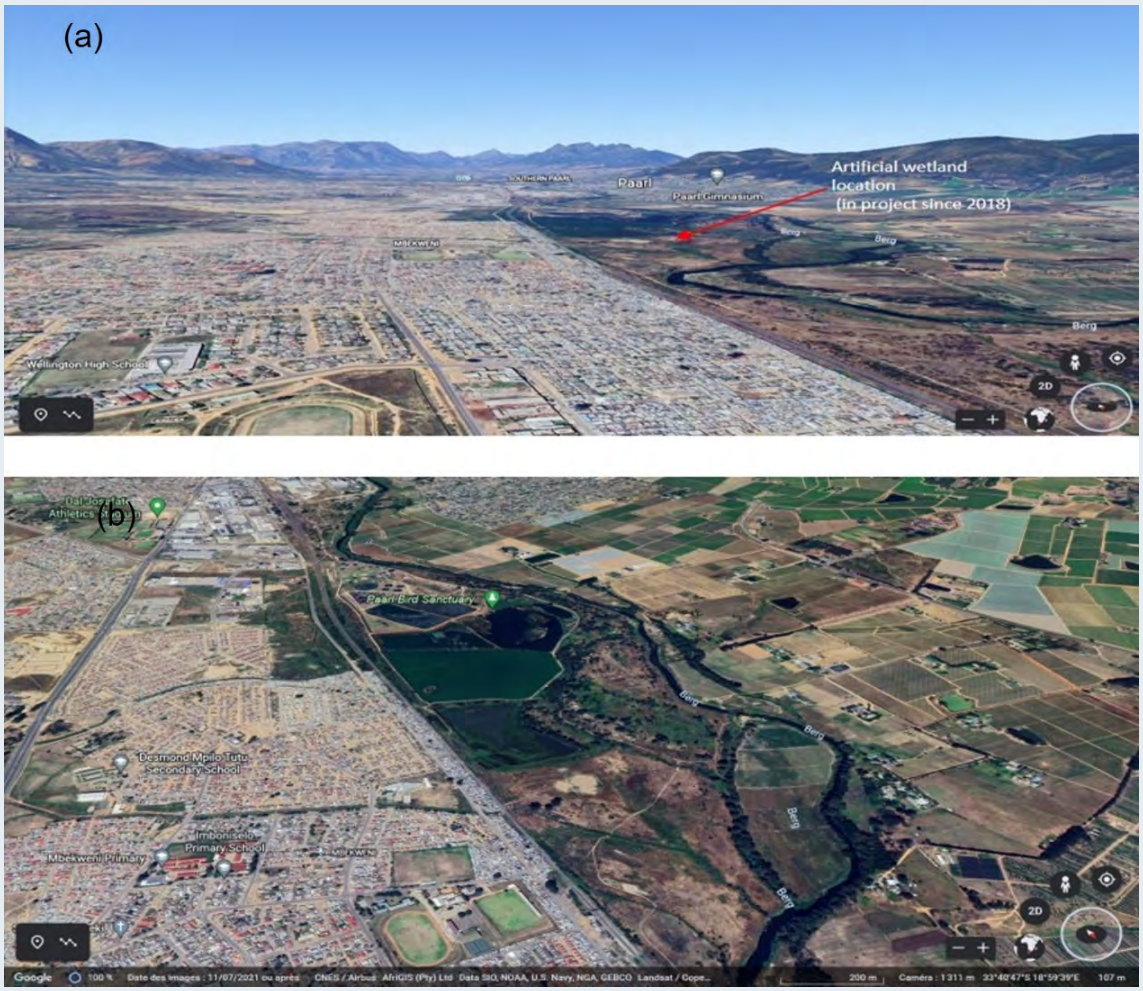


Figure 12. *(a) Google Earth 3D view with the Drakenstein Mountains from where the Berg River rises and location for the artificial wetland project near Mbekweni[12,13]; (b) Google Earth view for the location of the Paarl Bird Sanctuary, between the Informal Settlements of Mebkweni and the Berg River (source: Google Earth, July 2021).*

In 2019, citizens (volunteers) acted and created the non-profit Mbekweni Eco Club[13]. Well aware of the socio-environmental challenges they face because of climate change, this community of young citizens now depends on funds to support their green sustainable actions and programs. Located just on the banks of the Berg River Catchment, they took steps and measures for citizen initiatives at a social level like restoring biodiversity losses, and restoring nutrients back to

[13] https://www.mbekoeco.org.za/ (accessed 21 November 2023).

support sustainable healthy soil (Figure 13). These actions intend to improve the environment following the framework of the Waste Water Treatment Works (WWTW) in Paarl District.

Figure 13. *Mbekco Eco Club volunteers restoring plants, vegetations in Paarl, South of Mbewkeni (since 2021) (Source: Mbeko Eco Club[11]).*

In 2020, the Noordhoek Environmental Action Group (NEAG)[14] seriously warned and alerted the city of Cape Town after adoptions of projects for upgrading the Masiphumelele wetlands with roads and infrastructures constructions (Figure 14). Wetlands zones greatly contribute to reduce the risks to floods and storms impacts and damage. Geoethical responses include environmental sustainability through the preservation of biodiversity and natural protections from flooding

[14] https://www.groundup.org.za/article/environmental-group-say-masiphumelele-road-project-approval-flawed/ (accessed 21 November 2023).

places where the growth of townships should be prohibited due to their exposure to disasters definitively well emphasized by remote sensing and previous studies.

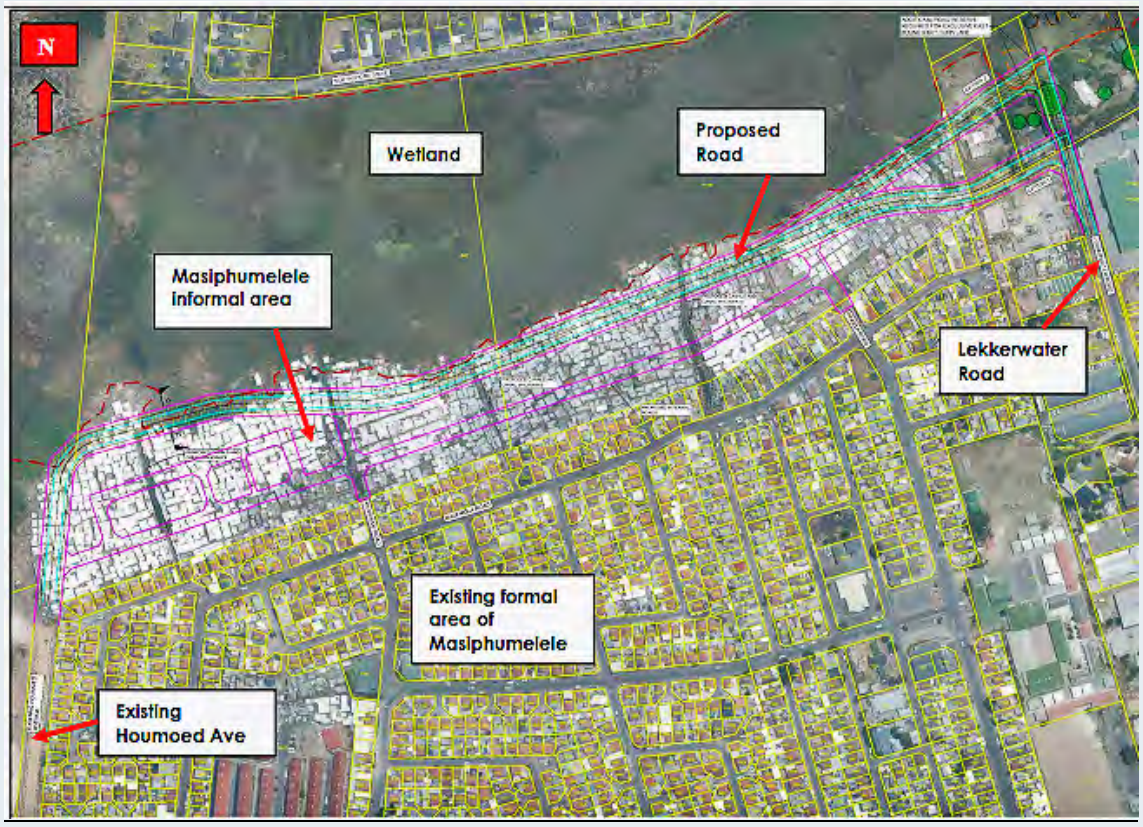


Figure 14. *Formal and Informal housing areas in the Masiphumelele Wetlands showing the proposed road between the informal settlement and the wetland (source: John Yeld[15], August 2020).*

From article 19 on Disaster management plans and strategies and article 20 on Prevention and mitigation from the Disaster Management Act [Act 57 of 2002] (Republic of South Africa 2003), there is good hope that environmental risk and the seventeen united nations 2030 agenda sustainable goals could be considered for planning actions. In particular, article 19 (a) and article 20 (b) and (c) says that "The National Center […] must give guidance to organs state […] for appropriate prevention and mitigation methodologies with development plans, programs and initiatives", with "regular review and updating of disaster management plans and strategies".

5.2 The West Bengal and the Odisha district Case Study (Eastern India)

In Odisha, Bay of Bengal, nearby the Mahanadi delta, the frequent cyclonic storms and extreme climate events impacted and damaged the mangroves [Dhyani et al., 2023]. Nevertheless, stakeholders and local inhabitants developed projects and initiatives to help restore this natural ecosystem that plays a crucial role in the regulation of water balance[15]. In fact, the local community understands the challenges they face better than anyone else.
Padhan and Madheswaran [2023] investigated on a vulnerability index, from a district-level analysis, on coastal Odisha. That index was computed from exposure, susceptibility and resilience factors, respectfully to the economic, social, physical and environmental dimensions emphasized by the CDRI and geoethics principles. This study revealed the role of the social and physical domains in Kendrapara district where the vulnerability to flood impacts is the highest (exposure, sensitivity, low adaptive capacity). The economic domain affects the response to resiliency in Bhadrack (more vulnerable) and Cuttack (one of the least vulnerable). Puri and Baleshwar are the most and least vulnerable in the environmental domain [Padhan and Madheswaran, 2023].

Geoethics response for reducing flooding risks in the Odisha community find echoes in citizen actions and initiatives proposed and launched by the vulnerable residents who are well aware of the challenge to balance between the economy, the environment and the social dimensions in their daily life. These initiatives and actions contribute to meet the sustainable goals defined in the United Nations' 2030 Agenda.

Panigrahi [2014] emphasized the role of stakeholders to include the fishermen communities affected by cyclones in rehabilitation programs. Increasing pollution in the river streams is also a major concern in west Bengal where ecological degradation is observed and reported [Panigrahi, 2014]. In the aftermath of Cyclone Fani in 2019, a women's Self-Help Group (SHG) in the Penthakota slum (population of 45000 migrant fishing community) initiated a Resilience Fund- a community fund that is used primarily to enhance the basic amenities in the settlement. The Penthakota settlement is located only 200-300

[15] https://timesofindia.indiatimes.com/city/bhubaneswar/govt-undp-join-hands-to-protect-states-mangroves/articleshow/93245143.cms (accessed 21 November 2023).

meters from the coast and is the focus of work since it is exposed to coastal damage from tropical cyclones, and other extreme weather events (Figure 15).

Figure 15. *Location of the Penthakota village (Informal Settlement), Puri (source: Google Earth – 2023).*

The SHG also took on itself to clean water drains in order to keep the settlement from getting infected with diseases[16]. It is worthy to note that the settlement has poorly ventilated houses, narrow streets, and a lack of tapped water supply. The community relies on the municipal public water taps or tapping groundwater from unregulated sources. The settlement also deals with open drains, stagnant wastewater, mosquito breeding and contamination of groundwater. Solutions involving blue-green infrastructure were introduced in the community to increase resilience and reduce flood risk vulnerability in the community[17]. Some of the key strategies adopted in the settlement are (1) WASH (Water, Sanitation and Hygiene) related projects, (2) directing wastewater from the open drain to a soak

[16] https://behanbox.com/2020/05/14/a-resilience-fund-by-women-in-coastal-odisha-is-helping-them-cope-with-covid-19-story-of-women-of-penthakata-urban-slum-in-puri/ (accessed 21 November 2023).
[17] https://storymaps.arcgis.com/stories/547d29edad8e4816bc7a5e74549fbdb5 (accessed 21 December 2023).

pit covered by seacoast weeds, thereby avoiding direct discharge into the sea, (3) treatment using blue-green filtration system, (4) promoting climate resilience through coastal vegetation and (5) safe and vibrant public spaces to promote community cohesion.

In conclusion, there is hope that stakeholders, committed to policy and laws, might consider a sustainable strategy based on the analysis presented here. Such a strategy would aim at preparedness and response during crises on the ground, involving communities, such as the Western Cape Disaster Management Center (Cape Town) and/or the center located in Stellenbosch for the Cape Winelands district[18].

6. Conclusion

Factors associated with flooding in informal settlements are numerous and the analysis to evaluate the vulnerability of exposed population and territories include social, historical, geographical, geological and meteorological (climate survey) aspects. In this paper, we presented two case studies in Western Cape (South Africa) and West Bengal (Odisha, Eastern India) where past flooding due to heavy rains, tropical cyclones severely hit slums where isolated communities are living (segregation, poverty, income issues with inequalities for descent livelihood conditions, lack of basic facilities like access to clean water).

Urban growth and extensions of informal settlements on physical vulnerable spaces were observed in locations exposed to floods and storms. In this context, an approach for geo-ethical considerations in the aftermath of disasters like flooding is necessary to solve the very complex equations of how to balance between the United Nations' 2030 agenda for goals for peace and prosperity for the people and the planet and the climate emergency all continents now face to deal with.

To this aim, very simple short- and long-term planning could go beyond the notion of coping strategies through environmental actions (e.g. preserving or restoring wetlands and mangroves) and to support local communities with funds for citizen initiatives like those either developed or planned in Western Cape (South Africa) or in Odisha (Eastern India).

[18] https://www.capewinelands.gov.za/disaster-management/ (accessed 21 December 2023).

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