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Article

# Impact of Coastal Disasters on Women in Urban Slums: A New Index

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**Abstract:** Coastal hazards, particularly cyclones, floods, erosion and storm surges, are emerging as a cause for major concern in the coastal regions of Vijayawada, Andhra Pradesh, India. Serious coastal disaster events have become more common in recent decades, triggering substantial destruction to the low-lying coastal areas and a high death toll. Further, women living in informal and slum housing along the Vijayawada coastline of Andhra Pradesh (CAP), India, suffer from multiple social, cultural and economic inequalities as well. These conditions accelerate and worsen women's vulnerability among this coastal population. The existing literature demonstrates these communities' susceptibility to diverse coastal disasters but fails to offer gender-specific vulnerability in urban informal housing in the Vijayawada area. Accordingly, the current study developed a novel gender-specific Women's Coastal Vulnerability Index (WCVI) to assess the impact of coastal disasters on women and their preparedness in Vijayawada. Field data was collected from over 300 women through surveys (2) and workshops (2) between November 2018 and June 2019, and Arc-GIS tools were used to generate vulnerability maps. Results show that women are more vulnerable than men, with a higher death rate during coastal disaster strikes. The current study also found that gender-specific traditional wear is one of the main factors for this specific vulnerability in this area. Furthermore, the majority of the women tend to be located at home to care for the elders and children, and this is associated with more fatalities during disaster events. Homes, particularly for the urban poor, are typically very small and located in narrow and restricted sites, which are a barrier for women to escape from unsafe residential areas during disasters. Overall, the research reveals that most of the coastal disaster events had a disproportionately negative impact on women. The results from this present study offer valuable information to aid evidence-based policy- and decision-makers to improve existing or generate innovative policies to save women's lives and improve their livelihood in coastal areas.

**Keywords:** coastal disasters; gender inequality; coastal Andhra Pradesh; sustainable development goals; novel vulnerability index; urban slum

## 1. Introduction

Coastal regions, particularly in lower-income countries, are highly vulnerable to natural hazards such as cyclones, climate change and seasonal changes [1–4]. In low and middle-income countries, vulnerability is also studied in terms of the power facets of gender

inequality and manifested in the marginalisation of women in socio-economic, political and cultural aspects [4–7]. The United Nations (UN) Sustainable Development Goal (SDG) 5, ‘Gender Equality’, has reiterated this as an international agenda for sustainable development [8]. The major threat to women along coastal regions is linked to gender inequality, gender-based violence, behavioural restrictions, socio-economic status and poor access to information during any hazard [9]. This acknowledgement and the studies thus far have been addressed only after the official acceptance of the link between gender inequality and climate change by the United Nations Human Rights Council (UNHRC) in March 2008. Climate change with global warming is exacerbating extreme events and a gradual increase in sea level, leading to more frequent and larger-scale catastrophes [10–12]. Climatic changes and disaster risks are interlinked and are highly likely to raise the quantity and gage of disasters with further extreme weather events [13–15]. According to the Centre for Research on the Epidemiology of Disasters [16], 85% of the deaths occurring during disasters in India are women and children. This is due to the fact that vulnerability to natural disasters is linked to poverty, unemployment, cultural traditions, illiteracy, population density and economy. In particular, the coastal belt of India is dominated by agriculture; therefore, a natural disaster could exacerbate socio-economic vulnerability. Climate policies, particularly those in South Asia, should not be considered gender-neutral for a variety of reasons. Sultana [17] explored how crises arise from social and economic inequalities that are based on patriarchal norms. In a male-dominated society, the capacities and vulnerabilities of men and women differ because of their unequal social status and the different roles they play [5,18,19]. Arora-Jonsson [20] noted that gender roles, norms and vulnerabilities should be analysed in terms of a gender-based framework, as the role of women in any society differs from nation to nation, community to community and area to area.

The coastal area of India is bound by the Bay of Bengal to the east and the Arabian sea to the west. Andhra Pradesh, the state that runs along the east coast, is highly vulnerable to tropical cyclones and associated disasters [21,22]. The livelihoods of the coastal population of Andhra Pradesh are highly dependent on agriculture and the natural ecosystem. Notably, tropical cyclones two decades earlier had higher mortality rates than that of a very severe cyclonic storm that occurred this decade [23,24]. The lower death toll was due to more accurate weather forecasting and better disaster management practices [25–27]. However, the intensity of the economic loss and social impact was not much better, and this was particularly true for women, but such a fact is often seen as not worthy of consideration. The focus of the present study is to identify the gender-specific vulnerabilities of coastal areas and suggest region-specific coping mechanisms and strategies for women in particular. Urban cities in coastal areas often face several hazards, including floods, cyclones and other extreme weather events. To generate efficient mitigation approaches, it is vital that we evaluate the vulnerability of these areas through the lens of gender. Accordingly, the study seeks to establish a new index to assess the impact of coastal disasters on women by conducting field observations, surveys, and a review of the literature.

## 2. Literature

### *Disasters and Women in Urban Areas*

More than half of the global population (which is approximately 4 billion people) live in slum areas [28], and the urban population will grow more rapidly by 2050 [29]. Among the urban female population, it is observed that unequal gender relations combined with socio-economic disadvantages are significant elements for their susceptibility and inadequate resilience in a post-disaster context [30]. The major impacts of a disaster are influenced by the gender dynamics of a society and hence lead to differences in mortality rates. A severe natural disaster significantly reduces women’s life expectancy, and the higher the women’s socio-economic status, the weaker the gender gap is in life expectancy [31]. Resources and structural constraints play a key role in this disproportional effect on women [32]. Similarly, after a disaster, their role in relief, response and

recovery stages are overemphasised at a household/family level whereas the role in organisational decision-making and disaster risk governance is too limited or neglected. Partly due to these factors, the majority of post-disaster humanitarian benefits are not reaching women [33].

Any natural disaster that occurs during the COVID-19 pandemic could have catastrophic and cascading consequences [34]. The co-occurrence of destructive natural (cyclones) and biological (COVID-19) events causes extreme crisis conditions and tests society's and systems' resilience [35]. By weakening the human body's immune system, the cyclonic effect causes a change in seasonal phenomena and increases susceptibility to cough, cold and fever [36], generating symptoms comparable to COVID-19 infections [37,38]. Furthermore, during evacuation to a safe zone, there is a risk of compromising the necessary physical distancing measures, increasing the possibility of COVID-19 infections [39]. Current socio-economic changes may modify COVID-19 epidemiological dynamics and enhance future risks related to natural catastrophes and COVID-19 interactions. COVID-19 exposure risks and vulnerabilities may be elevated due to evacuees gathering in communal areas and intensified need on medical, monetary and infrastructure capacity due to natural disaster impacts. COVID-19 epidemiology conditions could influence the nature of emergency and humanitarian responses during natural hazards [35].

Women's pre-existing symptoms play an important role in determining post-disaster mental-health conditions [40]. Violence against women in post-disaster events tremendously increases, and this also exacerbates their mental stress and overall vulnerability [35]. It is worth noting that not all women are helpless after a disaster; the outcomes are not due to biological differences but to social constructions of gender roles and relations, and these power inequalities play a crucial role in their vulnerability [41]. The efforts to advance individual productivity and competencies through education or the use of technology and local resources, as well as monetary access to economic improvement help urban women, develop their adaptive capacity post-disaster [41]. Akinsemolu et al. [42] investigated the coastal vulnerability of women due to climate change in Nigeria in the Ilaje community. This study focused on the qualitative analyses of multiple environmental, economic and social perspective factors. Hasan et al. [43] studied female vulnerability along coastal Bangladesh and mentioned that social parameters, availability of resources and environmental conditions are major issues for vulnerability. Further, due to a lack of education, development and cultural beliefs, women (especially in Asian countries) are vulnerable to multiple disasters [44].

Coastal vulnerability to women has been studied through many perspectives.

Vulnerability is also associated with poverty in several ways. Low and medium-income families are usually not capable of recovering easily after a disaster strikes. Secondly, disaster events can rapidly drive communities into poorer conditions [45]. Women are especially exposed to urban poverty and its interlinked risks [46]. Rapid urbanisation and unplanned settlements exacerbate poverty disproportionately; many unauthorised houses are located in dangerously narrow and congested streets. Some of these houses are unsafe, urban slum contexts and sites of vulnerability [47]. Existing literature reveals that women have lower managing abilities compared to men when disasters strike [48] as is evident from the 1991 cyclone disaster in Bangladesh, where 90% of deaths were women [31,49]. Additionally, during the 2004 Indian Ocean Tsunami event, the majority of victims were women and children [50]. Population growth and urbanisation in many cities across the globe often increase low-income populations in risky urban areas where cyclones, floods, storm surges and other environmental hazards often hit [51,52].

In Vijayawada's slum areas, the stress is further multiplied by the socio-economic conditions of the communities. There are several densely populated and informal slum areas in Andhra Pradesh, as shown in Figure 1. The focal point of this region is highly populated with the triggering effect of natural disasters like floods and inundations every year. Here, we represent a new assessment technique to understand the vulnerability

of women in coastal cities. This kind of work will be useful for the stakeholders to take necessary actions and avoid the risks.



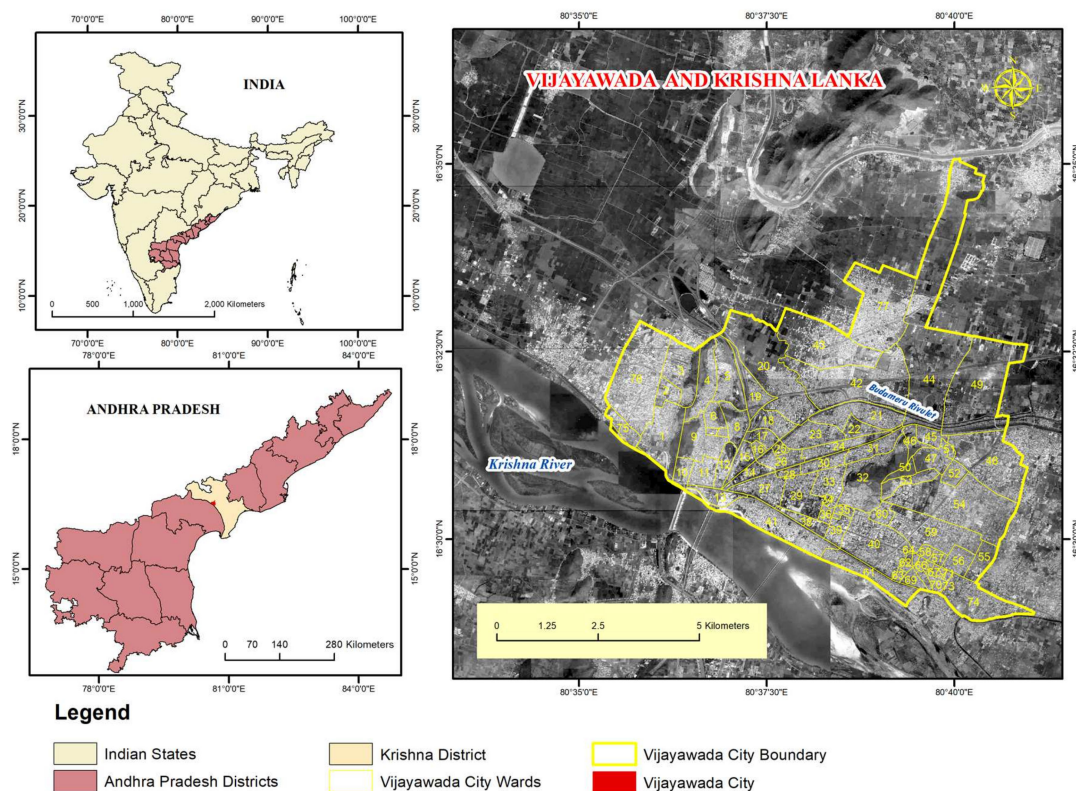
**Figure 1.** Urban slum in Vijayawada in 2019, coastal Andhra Pradesh, India.

### 3. Study Area

Vijayawada City, positioned on the banks of the Krishna River (Figure 1), is a vast urban area located in the Coastal Andhra Pradesh (CAP) with latitude— $16.5062^{\circ}$  N and longitude— $80.6480^{\circ}$  E, and has been selected as the case study area for the current study. It is the second-largest city in Andhra Pradesh (AP) and one of the 35 metropolitan cities in India [53]. The total city has an area of  $181 \text{ km}^2$  and it has 390 (as per 2020 figures) slums [54]. More than 25% of the Vijayawada population is living in slums and most of these areas are densely populated which means considerable numbers of these slums are located on the banks of the River Krishna and its canal system [55]. The city is the unofficial agricultural and commercial capital of Andhra Pradesh. It has 350,000 residential properties with a population in excess of 1 million which is 3.9% of the entire urban population of Andhra Pradesh state [56]. This city has very unique geographical characteristics such as two rivers, the Krishan and Budameru, and Vijayawada is the only city in the world that consists of two rivers [57]. The climate of Vijayawada is very much interlinked with geographical characteristics and the two river directions of flow. There are hills on the west side of the city called Indrakeeladri and the north-western and south-western parts of the city are also covered by different hills. The Budameru River is on the north side and the Krishna River runs through the city (Figure 1). Furthermore, the city climate is generally tropical with extremely hot summers and heavily humid and mild winters. The city gets a moderate to good volume of rainfall from monsoons.

The city is not seismically safe because it is categorised in earthquake zone III and the city is vulnerable to diverse natural and anthropogenic disasters mainly due to climate change and its natural geographical location [58]. However, the study focuses on slums located around the Krishna Lanka area at the coastal/riverine frontage (Figure 2).





**Figure 2.** Map of the study area.

#### 4. Methodology

Diverse vulnerability assessments and conceptual frameworks vary in the range of parameters and theoretical focus. There is no general and simple model to fulfil all potential needs in the combination of coastal urban areas and gender vulnerability. Existing methodologies to assess coastal vulnerability have often been established either at local or regional or national magnitudes and centralised on a specific subject but not on the gender vulnerability to a sufficient degree. To fulfil this research gap, the current study established a novel gender-specific Women's Coastal Vulnerability Index (WCVI).

##### 4.1. Data

The field data were collected through surveys and workshops. Accordingly, two surveys and two workshops were conducted in the case study area between November 2018 and June 2019. Additionally, census (2011) data have been used for gender statistics. While pro basic maps were used to create the vulnerability maps based upon the results and ArcGIS (Geographical Information Systems).

##### 4.2. Parameters

In total, six parameters, consisting of new and existing parameters (Table 1), have been considered for this study. The rationale behind using these parameters is the study region. The slum area is particularly vulnerable due to the higher population, literacy rate and lack of awareness for disaster preparedness. Every year, the region is flooded during monsoon season, and tropical cyclone-induced storm surges and inundations occur during pre-monsoon/post-monsoon seasons due to its location. Conservative mindsets and cultural clothing also prevent the women in that location from acting proximately during a disaster. Though there are multiple dimensions to coastal vulnerability, this study has been carried out with a focus on women and their vulnerability due to primary social parameters at a regional level. The use of these parameters for a single study is unique, and this is the only study that has used this combination of parameters, such as women/girl population,

literacy rates, past disasters, traditional dress, preparedness, awareness, survival rates and their interlinkages, to evaluate women's vulnerability to disasters.

**Table 1.** Parameters are used to evaluate the vulnerability.

| No. | Parameter                            | Type    | Symbol |
|-----|--------------------------------------|---------|--------|
| 1   | Women/girl population per household  | Numbers | $W_a$  |
| 2   | Literacy rate (ep)                   | %       | $L_b$  |
| 3   | Disasters in the last ten years (np) | Numbers | $D_c$  |
| 4   | Traditional dress (np)               | %       | $C_d$  |
| 5   | Preparedness and awareness (ep)      | %       | $P_e$  |
| 6   | Survival rate (ep)                   | %       | $S^f$  |

Note: ep: existing parameter; np: new parameter.

#### 4.2.1. Women Population

Women are one of the most important gender parameters in vulnerability studies. Female population estimates are usually based upon the census population. However, the current study has taken the concept of World Bank [59] to estimate the female population in the case study area. In this process, the study did not find any significant errors as 99% of the population in this case study does not usually migrate or move to different areas in the recent past. However, these statistics slightly differ from the Indian census data probably because of a more recent population count. During the survey period, any people who were located outside of their home for work or for any other reasons were also counted. Accordingly, for this parameter, the study considered average percentages based on the cumulative houses located in a single cell. Each house consists of 6–10 people with an average of 7 people per household in the case study area. Some households had higher proportions of men whilst other households had higher proportions of women; few households have a balanced gender ratio.

#### 4.2.2. Literacy Rate

In India, more than 68% of women are illiterate [60]. The current study adopted the UNESCO [61] methodology to measure literacy rates per household in the case study area. This is through self-reporting by the head of the household. The project team visited Krishna Lanka (case study area) in two intervals between November 2018 and June 2019 and visited more than 150 households.

#### 4.2.3. Disasters in the Last Ten Years

Deprived people living in low-lying urban slums are at greater risk from the effects of climate change and natural disasters [62,63]. Typically, these areas are not suitable to live in, partly due to the lack of basic facilities; nonetheless, poor people inhabit these areas due to affordability. In these disadvantaged conditions, natural disasters, especially floods and cyclones, damage these urban slums heavily. Disasters such as cyclones and cyclone-related floods which occur in Krishna Lanka, Andhra Pradesh have been considered as one of the parameters i.e., disasters in the last ten years. More than 10 cyclones occur in the pre-monsoon season every year on average. Due to heavy rainfall during these cyclonic events, several coastal districts (counties); namely Nellore, East Godavari, Krishna, are highly destructive. Based on these scenarios the Krishna Lanka area was assessed for disaster impact, this parameter was measured based on each household of a particular cell.

#### 4.2.4. Traditional Dress

Women and girls are more vulnerable during disasters at different magnitudes (Centre for Disaster Philanthropy 2020). Women's exposure to disasters and their vulnerability

will be more severe when they belong to lower socio-economic groups [64]. In the case study area, women tend to wear traditional dresses such as sarees, churidar and salwar (long fabric costumes). Traditional dress is more strictly adhered to by women due to family restrictions and cultural traditions. Traditional dress is one of the main barriers to escape from danger during disaster strikes as these outfits make mobility difficult in disaster conditions. Based on this reason, the current study considered traditional dress as one of the new parameters. The study then measured this parameter in % i.e., how many people (women) commonly wear traditional dress.

#### 4.2.5. Preparedness and Awareness

Andhra Pradesh is one of the cyclone and flood-prone states in India [65]. Every year thousands of people are affected by cyclones, floods and associated hazards. Almost every year people lose their temporary houses, other properties and family members despite receiving early warnings from the government. Accordingly, preparedness and awareness has been selected as one of the parameters. The parameter was measured per single household i.e., how much of the population has the preparedness and awareness towards the disasters.

#### 4.2.6. Survival Rate

In the last fifty years, weather-related disasters increased [66], however, the death toll is not even across the world. Furthermore, it is too difficult to measure the death and survival rates during various disaster strikes, especially in South Asian urban slums. Only very limited accurate information is available for Vijayawada urban slums. To fill this gap, the survival rate has been selected as one of the parameters for this study. Accordingly, the study measured the household data and asked the house owner about this survival rate, particularly for women's survival and then this data has been analysed.

### 4.3. Whole Measurement of Parameters

#### Index Development

For the development of the index, the concept of the equivalent weights of Kantamaneni et al. [67] has been adopted for this study. Kantamaneni et al. [67] developed the combined physical and coastal vulnerability indices to assess the United Kingdom's coastal vulnerability utilising both new and existing fiscal and physical parameters. The index-based approach is a stable method to understand the vulnerability rate using multiple parameters. There are several authors who used different parameters and different techniques to study the vulnerability ranking spatially. The coastal vulnerability index method was initially formulated by Gornitz in 1990 for physical variables such as erosion, geomorphology, slope, sea level, etc. However, multiple studies were forwarded, with multiple index formulas and varying localised physical/social/economic parameters. For example, Rao et al. [68] used a summing of variables, with a weightage given to each variable.

The present study used the six parameters with a combination of new and existing parameters to assess the impact of coastal disasters on women and their preparedness in Vijayawada City. Therefore, transect lines were sketched perpendicularly to the coast at 100 m × 100 m cells (Figure 3).





Figure 3. Coastline/riverine with 100 m cell.

Table 2 offers information about the parameters and ranking details between 1 (very low) and 5 (very high). Each cell was evaluated based upon the particular parameters. Therefore, WCVI was established by assigning scores between 1 and 5. All measurements were compared with Table 2 and offered a ranking score between 1 and 5 to assess women's vulnerability. After that, these values were totalised for each cell to give relative CVI scores by using the following equation:

$$\text{WCVI} = \text{Wa} + \text{Lb} + \text{Dc} + \text{Cd} + \text{Pe} + \text{Sf} \quad (1)$$

Table 2. Indicators threshold for gender-specific Women's Coastal Vulnerability Index (WCVI).

| WCVI Indicators                     | Parameters Threshold |         |              |          |               |
|-------------------------------------|----------------------|---------|--------------|----------|---------------|
|                                     | Very Low (1)         | Low (2) | Moderate (3) | High (4) | Very High (5) |
| Women/girl population per household | 0                    | 1       | 2            | 3        | >3            |
| Literacy rate per household (%)     | 100%                 | 100–80% | 70–60%       | 59–40%   | <40%          |
| Disasters in the last ten years     | 0                    | 1       | 1–2          | 3–4      | >4            |
| Traditional dress (%)               | <10%                 | 10–<30% | 30–<40%      | 40–<50%  | 50%           |
| Preparedness and awareness (%)      | 99–<80%              | 80–<70% | 70–<60%      | 60–<50%  | 50%           |
| Survival rate (%)                   | 90–<80%              | 80–<70% | 70–<60%      | 60–<50%  | 50%           |

The parameters were given a threshold to define the rate of vulnerability. Finally, the sum of all these parameters was taken for the final spatial ranking of the location. Such a method can give the details about the severity of the location by studying the indicators for better preparedness before the disaster occurrence. We believe that all these parameters may be weighed equally for the location, so no further weightage has been given individually. The WCVI value lies between a minimum value of 5 (if all the parameters record the lowest score) and a maximum of 30 (if all parameters score the maximum), as shown in Table 3.

Furthermore, all these scores were classified for the ratings in order to categorise the level of WCVI for Krishna Lanka.

**Table 3.** Rating of level of relative vulnerability. Modified from Kantamaneni et al. [67].

| Relative Vulnerability Score | Category of Vulnerability |
|------------------------------|---------------------------|
| <12                          | Low                       |
| 12–15                        | Very Low                  |
| 16–18                        | Moderate                  |
| 19–23                        | High                      |
| 24–30                        | Very High                 |

## 5. Results

In total, 2.2 km of coastline was considered for the evaluation. However, 0.2 km was eliminated from the evaluation because the middle of the coastal frontage has a bridge and also the starting and ending points are covered with different man-made structures. Finally, in total, 2 km of coastline or riverine frontage has been selected for the assessment. Accordingly, the 2 km coastline was divided into 20 cells and each cell is 100 m<sup>2</sup> as shown in Figure 2. Comprehensive measurements based upon each parameter were recorded within each identified cell.

### 5.1. Gender-Specific Women's Coastal Vulnerability Index (WCVI) Analysis

There are significant variations between all the cells in the terms of the WCVI index values. Every individual parameter recorded diverse WCVI scores, as shown in Figure 4a–f when evaluated on a cell score basis. The average value of the women/girl population is 4.1. The maximum value is 5 scored at 6 cells, and the minimum is 3, which is scored at 3 cells (Figure 4a). The parameter literacy rate maximum value is 5 scored by 10 cells. The minimum value is 2, scored by 5 cells. The average value for this parameter is 3.95 (Figure 4b). The maximum value of the parameter 'disasters in the last 10 years' is 4.1, and the maximum value is 5, which is scored by 11 cells. The minimum value is 1, scored by 2 cells (Figure 4c). For the culture clothing, the average value is 4.6, and the maximum is 5, which is scored by 12 cells. The minimum value is 4, scored by 4 cells (Figure 4d). The average value for preparedness and awareness is 3.4, with a maximum value of 5 and a minimum of 1. The maximum value scored 4 cells, and the minimum value scored only 1 cell (Figure 4e). The survival rate parameter average score is 2.8. The maximum value is 5, scored by 1 cell, and the minimum value is 1, scored by 4 cells (Figure 4f).

However, the most significant vulnerability parameter is traditional clothing, which had the highest CVI score (5) at 12 cells. The remaining 8 cells recorded the second-highest vulnerability score (4). The women and girls population parameter stands in the second position by having the second-highest vulnerability scores in 16 cells which fall in between the highest to very highest categories. The survival rate parameter scored the lowest vulnerability. Fourteen cells scored between moderate and lowest vulnerability scores (Figure 4a–f). Only one cell had the highest score (5), with an average score for this parameter of 2.8, which is the very lowest average score among all parameters. The preparedness and awareness parameter also stood at the joint-second position for having the lowest or moderate CVI scores in 10 cells. The literacy rate parameter showed divergent scores ranging from lowest to highest CVI scores in various cells. Six cells had between lowest to moderate CVI scores, and fourteen cells ranged from very low to the highest vulnerability CVI scores.

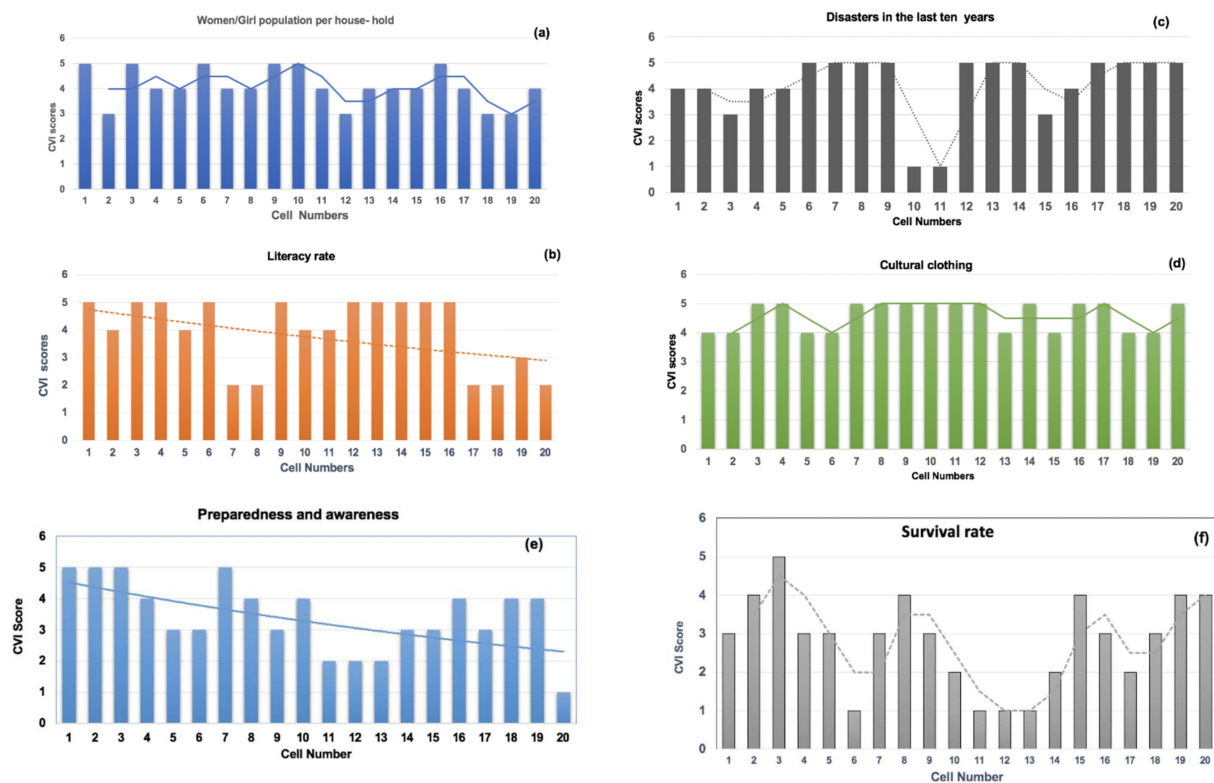


Figure 4. (a–f) Score distribution for all six parameters for WCVI.

### 5.2. Cumulative WCVI Scores

All WCVI scores for the parameters were summed based on the formula (Equation (1)), for each cell. All WCVI scores show diverse trends as shown in Figures 5 and 6. Among the 20 cells, the third cell scored the highest cumulative CV score (i.e., 28) and the lowest (11) was scored by the eleventh cell. The second-highest vulnerability score (26) was scored by three cells which are the first, ninth and sixteenth cells. The second-lowest score (21) was scored by six cells. The current study analysis revealed that 95% of cells fall into the high and very vulnerable categories (Figure 5) which indicate that 1.9 km is either high or very high vulnerability as shown in Figure 6. This also identified that almost all the coastal lines and thus the Krishan Lanka people are very vulnerable (Figure 6) and almost all women are highly vulnerable to coastal disasters. In all these parameters, the traditional dress parameter is the highest vulnerability factor.

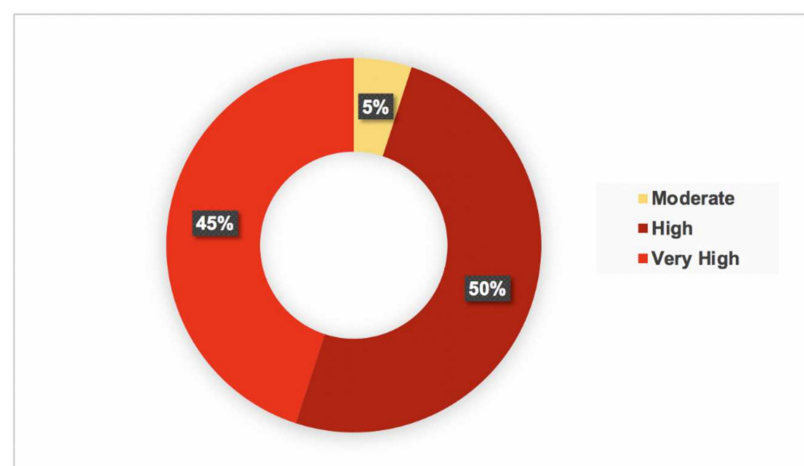


Figure 5. Cumulative WCVI scores in %.





Figure 6. Map of the coastal vulnerability of the case study area.

## 6. Discussion

In the current study, WCVI was established and applied to the urban slums of Vijayawada City by using six parameters which are the combination of new and existing factors. Parameter selection is one of the biggest challenges in this study because of several compelling factors within the urban slum coastal areas. There are 109 slums in Vijayawada of which 66 are found in and around the coastal/riverine areas [69] (Figure 7). Due to time factors and data collection limitations, the study only concentrates on slums in and around Krishna Lanka. The study starts with the urban region of Vijayawada, at a regional scale and then shifts to slums in Krishna Lanka at a local scale.

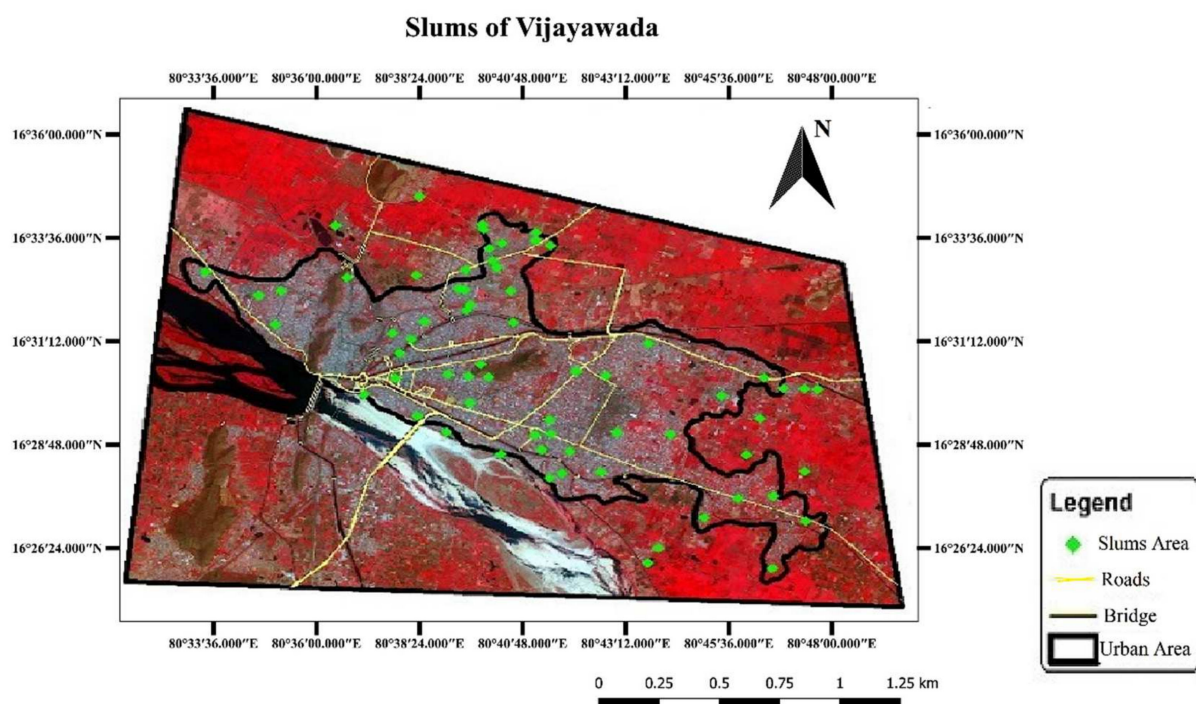
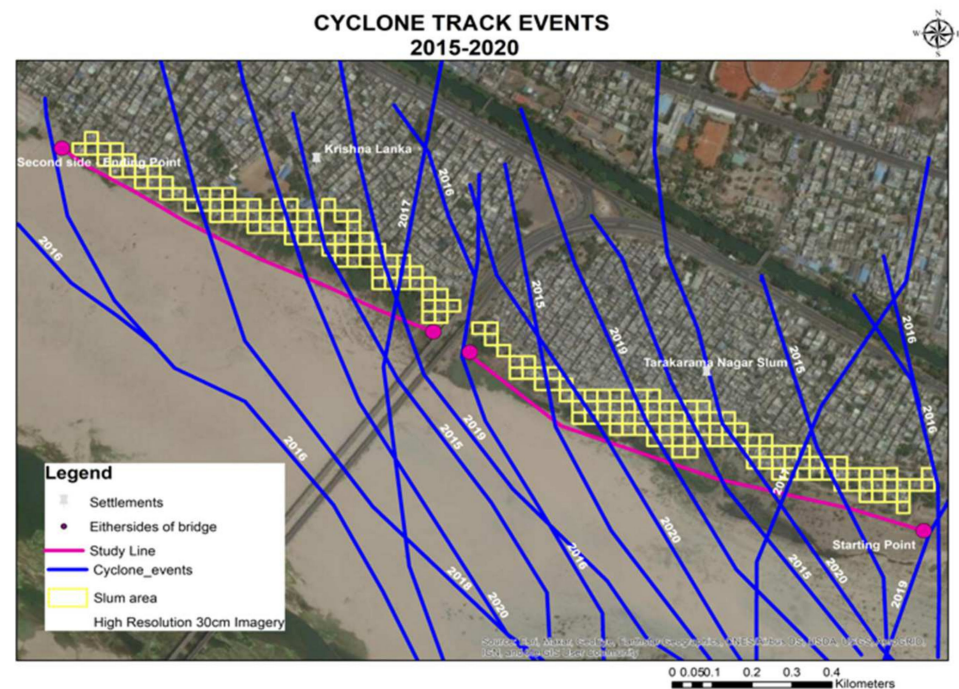


Figure 7. Slums of Vijayawada.

Significant disaster strikes affect the infrastructure across the globe, triggering enormous damage [70,71]. Collection of statistics regarding disaster damages is quite difficult

due to various reasons such as non-accessible areas to measure the immediate aftermath conditions, lack of support from the locals, etc. Here, in the study area, assessment of the disasters in coastal slum areas is complex due to the geographical location and lack of accurately recorded information regarding flooding and associated events and measurement of damage of impact in fiscal terms. Since 1990, more than 60 cyclone events have hit coastal Andhra Pradesh [72] and during these events, more than 30 cyclonic events have directly hit the Vijayawada and its neighbouring cities; the majority of cyclone events occurred between 2015 and 2020, as shown in Figure 8.



**Figure 8.** Disaster strikes in Vijayawada for the period 2015–2020.

As mentioned in the results section, traditional dress is the most significant factor and accordingly, the current study proved that traditional dress is the main reason for the death toll of women during and after the disaster events in the case study area. Therefore, traditional dress stood as the most important among all parameters. Men's and women's susceptibility to disasters are different and women's death rate is higher than men's after a severe disaster event. Rather than physical or biological traits, this is due more to cultural and socio-economic conditions, especially in low- to middle-income countries. However, the risk of magnitude depends on various factors [73]. The highest score for the cumulative WCVI was recorded in the 3rd cell and the lowest was scored in the 11th cell. This indicates that (except for the 11th cell) the remaining coastal segments are very vulnerable to various factors such as coastal disasters (floods) and socio-economic conditions. Even though urbanisation is necessary, it should not destroy natural landscapes and traditional land-use patterns. The primary conflict from rapid urban growth is altering land-use patterns. In the case study area, there are several unauthorised residential properties were identified and these houses were flooded several times, as shown in Figure 9.

The overall WCVI scores of different segments along the coastline of Krishna Lanka offer the opportunity for the coastal management in Vijayawada to take the action either to improve or generate new strategies to offer a better life to the people who are living in the urban slums in Vijayawada City.





**Figure 9.** Flooded home in Krishna Lanka slum in 2019.

## 7. Research Limitations and Scope for Future Work

Though the current study offered interesting and good results, there are some challenges that can be focused on in this particular field. The most important challenge which was encountered in this research was the availability of accurate and consistent data on coastal disasters for the case study area. Due to this missing data, significant time has been taken to finalise the parameters and other data sets. Additionally, significant social, economic, cultural, caste and political (parties) differences mean additional time was required to conduct the household survey and 300 data sets. Initially, several girls and women were not allowed by the head of their household to participate in the study because of gender barriers and cultural traditions. In the case study area, many male members lead the households and offer relatively limited opportunities and freedom to women and girls. These incidents delayed the data collection process. However, sufficient data were collected within a slightly extended data collection period. The secondary limitation is the study period. The study was done within a limited time. The years 2020 and 2021 might have affected the region further due to the COVID-19 pandemic. The government lockdown policies and virus mutations limited the study period to 2019. Future work will cover the pandemic's impact on the study area, further adding road networks and transportation procedures for mobility during the disaster.

The current study can be extended and improved by increasing the study area length within the state or other states such as Orissa and Tamil Nadu. Additionally, spatial data and survey data could be amalgamated for a better assessment of gender vulnerability. Additionally, policy reports, updated and global grey literature could be added to investigate elaborately coastal disaster's impact on gender from multiple perspectives.

## 8. Conclusions

Assessment of the coastal vulnerability of a specific gender in urban slums is a very challenging task. The present study evaluated natural disasters' impact on women in urban slums located in Krishna Lanka, Vijayawada, Andhra Pradesh, India. The WCVI was established by using six parameters combining existing and new parameters. The overall results explored that almost the entire 1.9 (95%) km coastline showed high to very high coastal vulnerability. Women are more vulnerable to coastal disasters because of traditional dress, and this is the most significant parameter in this study. At the same time,

the women or girl population is the second significant vulnerable factor. The survival rate is the least vulnerable parameter. However, most of the population, particularly women, are very vulnerable to various coastal disasters due to the cumulative impacts of various parameters discussed in detail in this study. Based on these results, a vulnerability map has been developed and will be helpful to easily understand the intensity of susceptibility. The study points out that women are particularly vulnerable to disasters in the Vijayawada slums and the observed indicators are the primary social parameters influencing the region. The index-based approach used in the current study can show the cumulative impact of effective disaster preparedness. Although such studies can always be improved in the future by adding other important indicators, the current study focuses on primary social barriers and implications. These results assist policy and decision-makers, local housing and cultural authorities to revise or generate strategies to improve the lives of the female population in urban slums in the Krishna Lanka area. Furthermore, the methodology established in the study can be implemented in any geographical study based on suitable parameters.

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