SRI LANKA

Area-Based Risk Assessment in Mahaoya Divisional Secretariat Division

Ampara District

May 2024

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IMPACT Initiatives is a leading Geneva-based think-and-do tank which aims to improve the impact of humanitarian, stabilisation and development action through data, partnerships and capacity building programmes. The work of IMPACT is done through its three initiatives: REACH, AGORA and PANDA.

About CEFE NET

CEFE NET Sri Lanka is an association of CEFE facilitators in Sri Lanka founded in 2001. Our Mission is to facilitate competency based economies through formation of enterprise and enabling the creation of a conducive environment for entrepreneurship development in Sri Lanka. We are a member of CEFE International in Germany, the network of CEFE global community.

About ACTED

ACTED (Agency for Technical Cooperation and Development) is a non-governmental organization with headquarters in Paris, founded in 1993. ACTED's vocation is to support vulnerable populations affected by wars, disasters and/or economic and social crises, and to accompany them in building a better future.

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SUMMARY

Sri Lanka's high temperatures throughout the year, unique and complex hydrological regime, and exposure to extreme climate events make it highly vulnerable to climate change. Increased extreme events and natural hazards due to climate change will considerably threaten the economy and human health. In recent years, Sri Lanka has experienced a series of major crises, including the 2019 Easter Attacks and the global COVID-19 pandemic[1], followed by the 2022 economic crisis. These crises have affected marginalized communities' capacity to withstand the impacts of even minor external shocks[2].

According to authorities' data, Sri Lanka's eastern provinces are highly susceptible to floods, drought, and human-animal conflict hazards. They experience high vulnerability due to the high share of low-income families, dependency on agriculture and fisheries, and few protection measures in place. Within this context, IMPACT Initiatives, in partnership with Acted, conducted an Area-based Risk Assessment (ABRA) in Mahaoya Divisional Secretary's Divisions (DSD) in Ampara district, Eastern Province, funded by the US Bureau for Humanitarian Assistance (BHA).

The study is anchored on the Sri Lanka Disaster Management Plan 2018-2030 and the National Action Plan for Climate Change Adaptation 2016-2025. The objective is to analyse the main hazards threatening communities within the target DSD, identifying the Grama Nilahadari Divisions (GNDs) most at risk for multiple hazards. The findings intend to assist Acted, the national Government, local authorities, humanitarian partners, and affected communities to predict better, prepare for, and respond to existing and future events through resilience and adaptation initiatives targeting the most exposed and vulnerable territories and communities.

Through local consultations, IMPACT Initiatives identified the eight most recurrent hazards in the eastern and northern provinces of Sri Lanka: drought, flood, human/animal conflict, cyclones, storms, water supply failure, explosives remnants of war (ERW), and land degradation. Local authorities and communities reported during the preliminary consultations in Mahaoya that floods, droughts, and human-elephant conflict (HEC) are the most prominent. Therefore they were selected to calculate the risk through an adapted World Risk Index Methodology, by which the risk is a multiplication of hazard, exposure, and vulnerability (including susceptibility and lack of coping capacity) of all GNDs in Mahaoya.

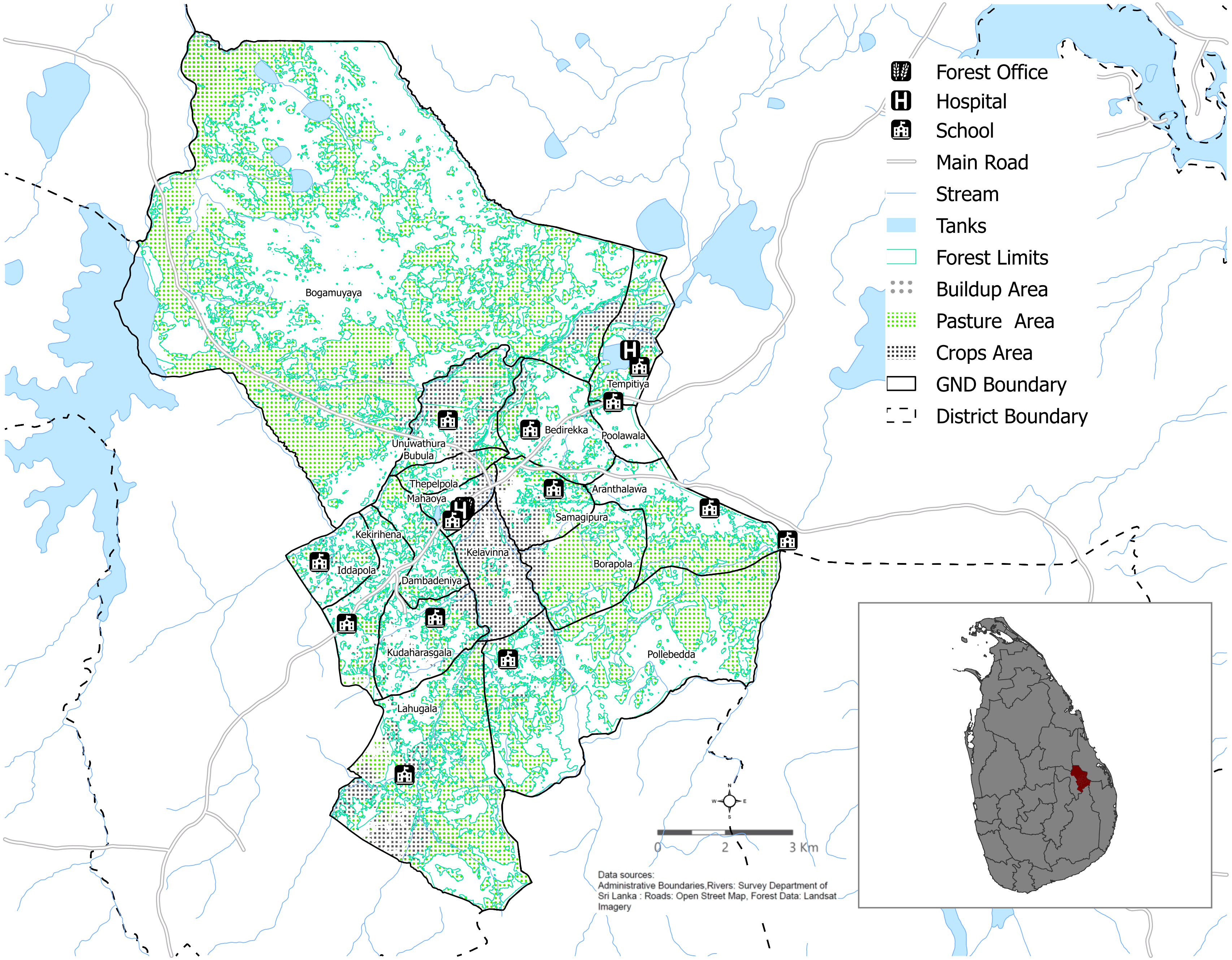
Through the study, IMPACT identified three GNDs, namely Pollebedda, Aranthalawa, and Unuwathura Bubula as the most at risk for multiple hazards. Pollebedda presents the highest risk across all assessed hazards, Aranthalawa has a high flood risk, and Unuwathura Bubula has a medium-high risk on all three. Pollebedda and Unuwathura Bubula present higher dependency on agriculture and inland fisheries, a large share of female-headed households, and over 50% of families with daily wages between 2000 and 3000 LKR. Aranthalawa and Pollebedda present the highest flood exposure, with large affected population density and crops, built-up areas, and roads in flood-prone areas.

In Poolawala, the population has the highest level of vulnerability regarding social dependency, with the highest shares of children and older people density and high female-headed households. Social dependency is when an individual or group relies on another individual or group for resources, support, or guidance. The GND also has the largest share of low-income families and unemployed people. The unemployment and low-income rates are social insecurity indicators for low financial capacity to prepare and recover from hazards.

Mahaoya, Iddapola, and Bogamuyaya are the least at risk of the combination of droughts, floods, and elephant attacks. Their territories have smaller flood-affected areas, and Mahaoya and Iddapola present almost no drought area. Mahaoya GND families are the least dependent on agriculture and inland fishery and present the best economic situation.

Overall, the study's findings underscore the importance of a local approach to understanding risk and informing disaster risk reduction strategies. The specific risk profile of each GND must guide how to prioritise and customise preparedness interventions for drought management, flood control, and HEC. Stakeholders can use this assessment as a valuable tool to design targeted interventions to enhance the resilience of communities and territories in Mahaoya against single and multi-hazard scenarios.

Map 1. Overview map of Mahaoya DSD



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Senalfernando. (2019). Sri Lankan Elephant. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Sri_Lankan_Elephant.jpg

BACKGROUND

Located in the Eastern province, Ampara district, Mahaoya DSD covers an area of 667 km². The total population is 20,828 individuals, 49% of whom are female. The average population density is 31.23/ km², living across 17 Grama Nilhadari Divisions (GNDs). The estimated dependency ratio is 35%, which is the population below 15 and above 60 years old[3].

The terrain in Mahaoya is diverse with flat plains and some hilly terrain. Additionally, several lagoons and water bodies in the region contribute to agriculture, livestock and fishing activities. Mahaoya's vegetation comprises palm trees, together with forests, marshes, and agricultural lands. Mahaoya experiences a tropical climate with distinct dry and wet seasons, significant rainfall during the northeast monsoon (Maha season) from November to February, while the southwest monsoon (Yala season) from May to September is relatively drier. Out of 681.93 km² of the area, 176.35 km² is used for agriculture. Paddy cultivation stands out as the predominant agricultural activity and the average yield of the paddy was 22,000 MT in Mahaoya in both seasons. The farmers primarily engage in highland crop cultivation apart from paddy cultivation in this region, according to the Mahaoya Divisional Secretariat Division Office.

Overall, Mahaoya's geography significantly shapes its economy, with livelihood activities primarily revolving around agriculture, addition to the agricultural sector, 3,202,746 litres of milk are produced each year by the livestock sector, which is the secondary contributor to the division's economy. According to local authorities, 183 families work in inland fishing activities.

During heavy monsoon rains, low-lying areas in Mahaoya may be prone to flooding, leading to property damage and disruption of livelihood activities, especially agriculture. Periods of drought can affect water availability for agricultural purposes, impacting crop yields and livestock health.
Mahaoya is also vulnerable to the influence of cyclones and tropical storms in the Bay of Bengal which can significantly impact weather patterns in Sri Lanka. The intense rainfall leads to an elevated risk of flooding, damage to infrastructure, and displacement of communities. Mahaoya's natural environment, surrounded by forest and in the migration path of elephants, may result in human-elephant conflict, loss of lives, and damage to infrastructure and agricultural land.

Mahaoya was also a battle area during the 26-year Sri Lankan civil war, causing large civilian displacement, deaths, and damage to housing and infrastructure.

The ABRA measured the risk in the 17 GNDs in Mahaoya, covering its entire area. By gathering and analysing secondary data including global and regional geospatial datasets and socio-economic statistics shared by local authorities it was possible to calculate hazard exposure and vulnerability in each GND. The contribution and support of local authorities by providing relevant vulnerability and hazard data for each GND during IMPACT's data collection phase was key to achieving the results presented in this document. By providing a tailored risk assessment of Mahaoya that considers specific local environmental, social, and economic factors, the study is intended to address a data gap and contribute to inform initiatives aimed at enhancing the resilience of communities and territories to stand with external shocks.

Why an ABRA?

- It provides localized analysis of risks, working as a strategic tool to contribute to operational and programmatic purposes of local authorities and other relevant stakeholders.
- The findings will inform Acted's implementation work with communities, addressing the most affected areas while improving livelihoods and the humanitarian and development community.
- It utilizes remote sensing and GIS technologies to identify and visualise hazards and exposure and helps triangulate scientific data with available knowledge.

METHODOLOGY

The ABRA methodology was adapted by IMPACT based on the World Risk Index (WRI), using a multi-hazard risk equation. The concept of the WRI, including its modular structure, was developed by the Bündnis Entwicklung Hilft with the United Nations University's Institute for Environment and Human Security (UNU-EHS)[4]. In this assessment, IMPACT analysed key hazards, exposure, vulnerability and risks across the DSD, based on the following definitions:

- **Hazard:** A process, phenomenon, or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation (UNGA, 2016[5]).
- **Exposure:** The situation of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas (UNGA, 2016).
- **Vulnerability**: The conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (UNGA, 2016).
- **Disaster risk:** The potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity (UNGA, 2016).

Through the ABRA, IMPACT collected, processed, and analysed existing openly available geospatial data on hazard exposure, and secondary data, mainly provided by local authorities, on vulnerability to assess risks in the target areas. The secondary data review included an analysis of several published disaster and climate risk assessments' data and projects' key findings conducted at the national and regional levels.

The remotely sensed data was processed to represent the spatial distribution and other characteristics of the hazards and determine the exposure to the population and agricultural lands. The vulnerability index was calculated based on identified indices of susceptibility, and lack of coping capacities, the adaptive capacity was excluded from the calculation due to lack of data. The risk calculation was based on the formula Risk=Hazard x Exposure x Vulnerability.

The results present the GNDs most at risk in Mahaoya, according to the multi-hazard risk index (detailed methodology for multi-hazard risk index calculation in Annex 2). In consultation with local authorities and communities, these results supported Acted in the selection of areas of intervention for resilience-building activities. It is important to highlight that the objective was to assess the risk of the main hazards primarily identified by communities during the consultation process. However, it is not inclusive nor exhaustive of all natural hazards in Mahaoya.

HAZARD EXPOSURE

The exposure of communities to these multiple hazards needs to be better understood at the local level with proper response and contingency plans in place. This analysis hopes to raise awareness of hazard exposure at the local level.

Natural hazards:

Drought

The drought severity index was calculated by equally weighting the long-term Vegetation Condition Index[6] (VCI) spanning from 2003 to 2023, the Vegetation Health Index (VHI) during the drought period in 2023, and the 12-month Standardized Precipitation Index (SPI) of 2023. The Vegetation Condition Index (VCI) highlights the impacts of drought on vegetation health (greenness) by detecting the areas prone to drought based on a 20-year anomaly of satellite-derived vegetation index (MODIS EVI[7]). MODIS Normalized differentiated vegetation index (NDVI[8]) and MODIS Land Surface Temperature (LST[9]) data are used to calculate the VHI during the drought period to highlight the drought manifestation and impact in the last drought event. The SPI index reflects the precipitation anomalies during 2023 compared to long-term observations based on CHIRPS datasets[10]. The analysis covered agricultural, croplands, and rangelands to reflect the drought exposure.

Hazard indicator 1.1: Drought area (ha)

Exposure indicator 2.1: Population density

Exposure indicator 2.2: Crop area prone to drought (%)

Exposure indicator 2.3: Pasture land prone to drought (%)

Exposure indicator 2.4: Share of affected fisheries families

Flood

The assessment used images from Sentinel-1 to delineate historic floods from 2018 to 2022. The chosen timeframe encompassed pre and post-flood acquisitions, facilitating change detection and monitoring flood evolution. The GEE script from the UN-Spider methodology[11] guided the extraction of the flood-prone zones.

Hazard-Exposure indicator 3.1: Affected population density index

Population density in flooded afected areas

Hazard-Exposure indicator 3.2: Crop area within a flood zone (%)

Hazard-Exposure indicator 3.3: Build up area within a flood zone (%)

Hazard-Exposure indicator 3.4: Road length and railways within a flood zone (km)

Human-elephant conflict

This method identifies and examines forest fragmentation patterns, where deforestation causes disruptions to elephant habitat and elephant migration corridors, leading to human-wildlife conflict. Local authorities provided secondary data on reported human deaths due to elephant attacks.

Hazard indicator 4.1: Human deaths reported due to elephant attacks

Hazard indicator 4.2: Forest area

Hazard indicator 4.3: Forest distrubances

Deforestation area during last 5 years

Exposure indicator 5.1: Population density

SUSCEPTIBILITY

Population groups that are more susceptible to a hazard have increased vulnerability. Several components drive susceptibility, livelihood dependency, social dependency, and economic situation were used to define the indicators.

Livelihood dependency:

Indicator 6.1: Share of families engaged in agricultural activities (paddy, chena)

Indicator 6.2: Share of families engaged in inland fishery activities

Indicator 6.3: Share of families engaged in marine fishery activities

The high dependence on reliable weather patterns and natural resources and usual location in flood-prone areas makes these families more susceptible. Hazards like drought and flood can reduce access to farming and fishing resources.

Social dependency:

Indicator 7.1: Share of female headed households

These households are more affected by disasters and susceptible to hazard shocks due to limited opportunities to diversify livelihoods, restricted access to land, assets, credit, social networks, risk-sharing, and insurance. They also face the dual burden of income generation and domestic work.

Indicator 7.2: Share of families with members with a disability

Apart from the potential physical inability to evacuate during a disaster, their reliance on others to ensure evacuation to safety may involve reliance on public services.

Indicator 7.3: Children density (0-18)

Children are more susceptible to hazards due to their dependency on others and inability to protect themselves or evacuate. Their developing systems also make them particularly sensitive to extreme heat and cold, limiting their ability to adapt to climate changes.

Indicator 7.4: Elderly density (60+)

Elders are more susceptible to hazards as they depend more on others and may be unable to protect themselves or evacuate if necessary.

Economic situation:

Indicator 8.1: Share of families earning a daily income between 2,000 and 3,000 LKR

Indicator 8.2: Share of families earning a monthly income from 1,000 to 20,000 LKR

Indicator 8.3: Share of unemployed individuals

Low income and unemployment limit the capacity to prepare for and cope during and after the shock of the hazard.

COPING CAPACITY

The ability of a population to cope after a hazard occurs is crucial in reducing negative consequences and influences one's vulnerability and risk level to a hazard. These are the measured factors that drive coping capacity.

Indicator 9.1: Number of evacuation centers

Indicator 9.2: Number of boats available for evacuation, logistics, and transportation purposes

Indicator 9.3: Number of fences built to protect from elephants

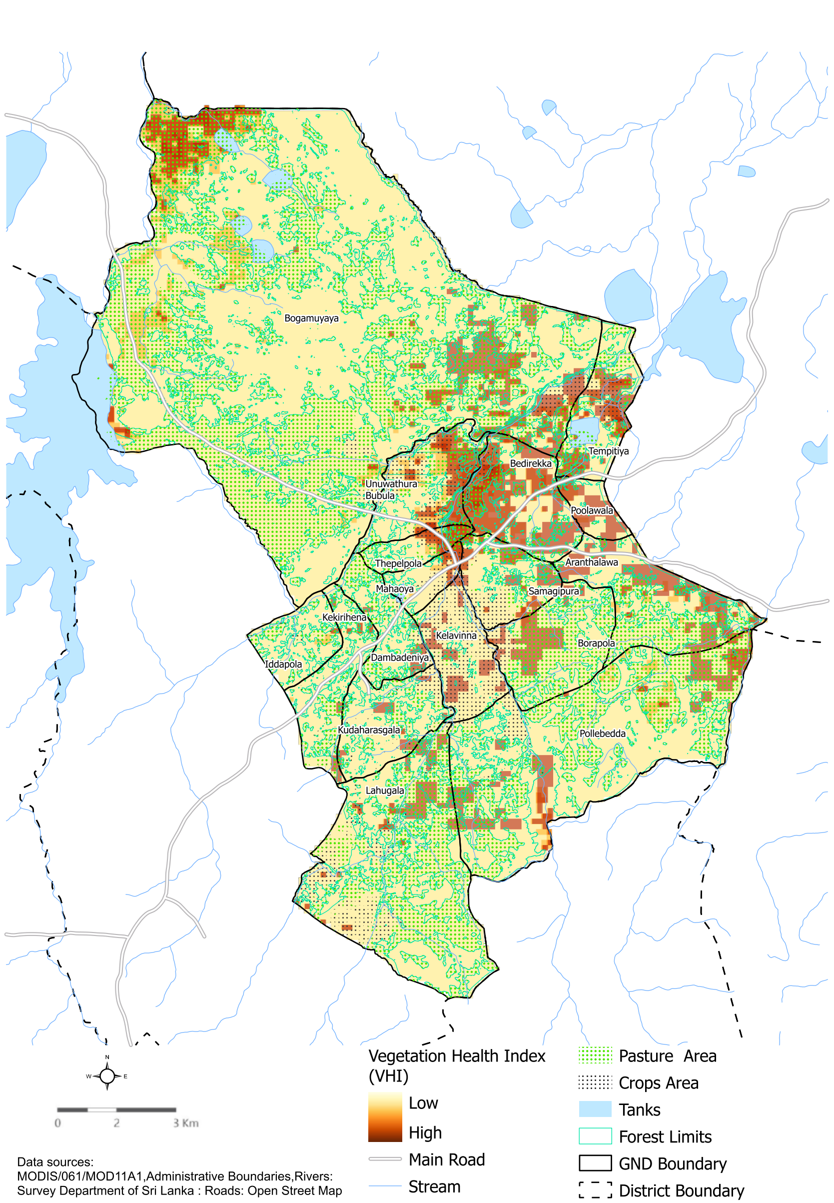
DROUGHT

Drought in Sri Lanka has been a recurring problem, impacting agriculture, water availability, and the livelihoods of people dependent on farming and inland fishery. During the last El Niño in 2016 and 2017, Sri Lanka suffered its worst drought in 40 years, and its rice output fell by nearly 50 per cent year on year to 2.4 million metric tonnes over both harvests. In 2023, according to the National Disaster Relief Service Centre (NDRSC), nearly 150,000 people lacked safe drinking water.

According to the drought severity analysis in Mahaoya (Map 2), the exposure index is moderate across the DSD with 15% of the total area and an average of 31% of cropland affected by drought and 30% of pasture land. In total terms, Bogamuyaya presents the largest drought area, 2434 ha, covering almost 8% of its territory and accounting for 25% of Mahaoya's drought area, the GND has 12% of its pasture land affected. Bedirekka follows with 2191 ha of drought affected area, affecting 70% of the GND and 18% of agriculture and 81% of pasture lands. The DSD has five GNDs with over 40% of agriculture land affected by drought, Kelavinna and Mahaoya percentage reaches almost 90%. Other 5 GNDs have over 40% of pasture land affected by drought.

Pollebedda is the GND most at risk of drought, caused by the combination of

Map 2. Drought exposure



high exposure indexes, largest affected population density, 67% of families engaged in agriculture, 36% in inland fishery, 50% of female-headed households.

High drought exposure leads Unuwathura Bubula and Bedirekka to high risk, both GNDs has large affected areas. Unuwathura Bubula has the largest share of families engaged in agriculture, female-headed households and families earning daily wages between 2000 and 3000 LKR. GNDs characterized by high population density, such as Pollebedda, Samagipura, Thepalpola, and Unuwathura Bubula might encounter intensified pressure on resources and heightened vulnerability due to the impact of drought on their livelihoods.

The exposure analysis was run for agricultural, croplands, and rangelands to calculate population density, percentage of crop area, and pasture land prone to drought and share of affected fishery families. The analysis suggests a risk of severe agricultural and livestock production decline in Mahaoya.

The data presented in Figure 1 relates the extension of drought over crop and pastureland with the economic dependency on farming activities. The share of families engaged in agriculture was provided by local authorities during the consultation phase. The increasing drought exposure, if not faced with sustainable water resources management and climate-smart agriculture, will result in more livelihood and food security challenges.

Figure 1. Percentage of drought-affected areas and agricultural families[13]

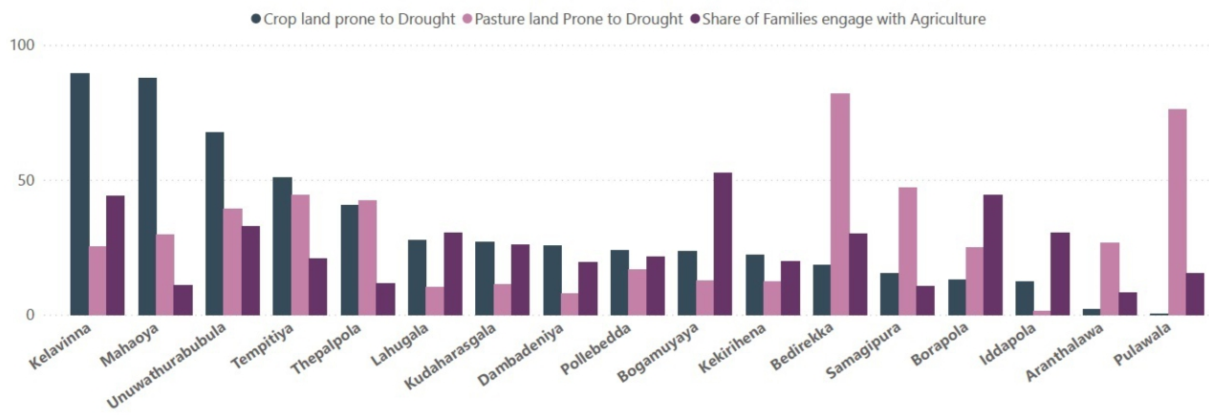


Figure 2. Drought area (ha) per GND[12]

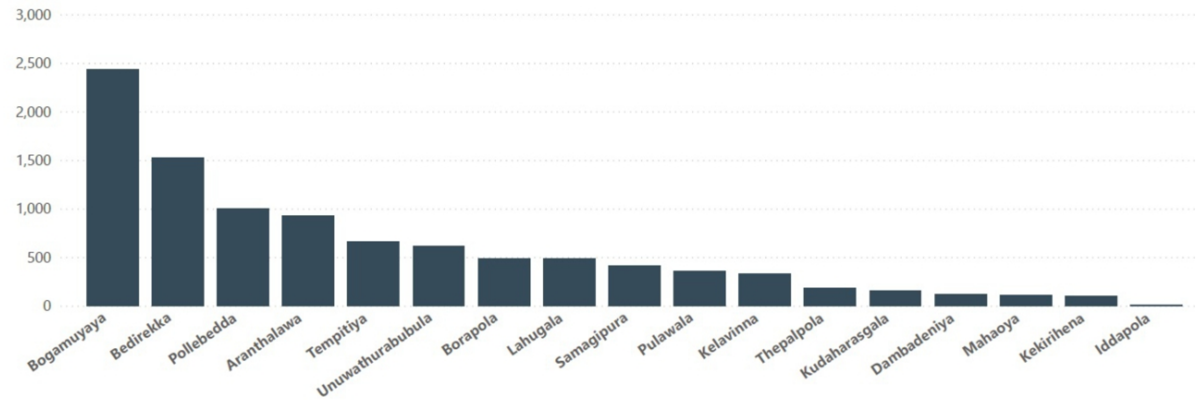


Table 1. Drought risk index

GND	Hazard	Exposure	Vulnerability	Risk
Pollebedda	**0.41**	**0.48**	**0.53**	**0.106**
Unuwathura Bubula	**0.25**	**0.66**	**0.49**	**0.082**
Bedirekka	**0.62**	**0.46**	**0.14**	**0.040**
Samagipura	0.17	0.53	0.40	0.035
Tempitiya	0.27	0.51	0.22	0.030
Poolawala	0.14	0.37	0.43	0.023
Kelavinna	0.13	0.63	0.27	0.022
Aranthalawa	0.38	0.31	0.12	0.015
Bogamuyaya	1.00	0.13	0.11	0.015
Lahugala	0.20	0.29	0.16	0.009
Borapola	0.20	0.24	0.17	0.008
Thepalpola	0.07	0.57	0.19	0.008
Kekirihena	0.04	0.35	0.40	0.005
Dambadeniya	0.04	0.35	0.26	0.004
Kudaharasgala	0.06	0.36	0.18	0.004
Mahaoya	0.04	0.55	0.05	0.001
Iddapola	0.00	0.16	0.15	0.000

Hazard, exposure and vulnerability values were calculated as a relative indicator (for more details please see the Annex 2)

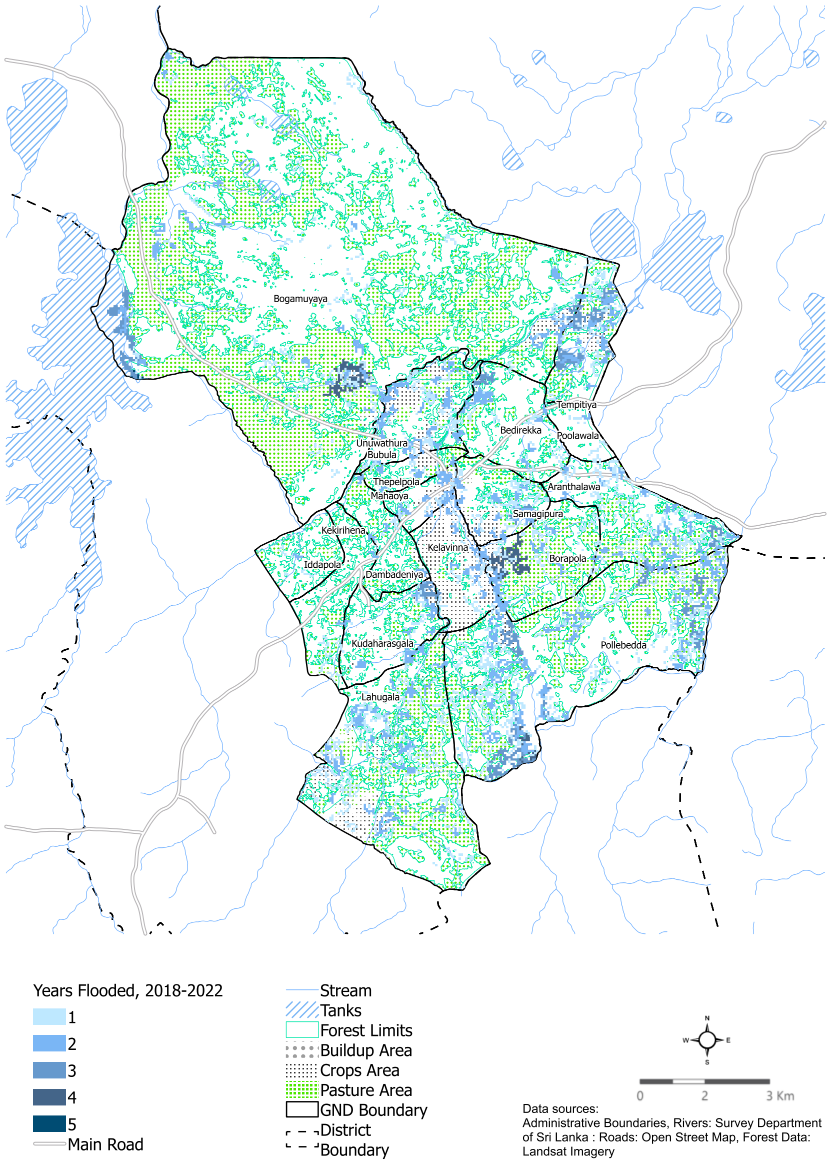
FLOODS

The rainy season in Mahaoya is from September to February, with most floods typically happening from November to January (Map 3), caused by heavy rainfall, improper drainage systems, land use changes, and unplanned cultivation. Paddy seasons in Mahaoya go from mid-September to January (Maha season) and from April to mid-July and rely heavily on rainfall patterns.

Between 2018 and 2020, satellite images showed that 7252 hectares of Mahaoya were flooded. Pollebedda was the most affected area, accounting for 25% of the total flooded area in Mahaoya and covering 21% of its territory. Tempitiya had 30% of flooded land, and other 4 GNDs had over 20%. The exposure indicators assessed included the affected population density, the percentage of crop area and built-up area, and the lengths of roads within flooded zones.

Table 2 indicates that Pollebedda is at the highest risk due to its high exposure and vulnerability. It has the second largest affected population density, with 43% of flood-affected cropland, and the largest length of flood-affected roads. The GND presents relevant vulnerability indexes, such as 21% of families engaged in agriculture and nearly 54% of its families earning daily wages between 2,000 and 3,000 LKR.

Map 3. Flood exposure



Aranthalawa follows with the largest affected population density, 46% of build-up area within flood zones, and 48% of affected cropland. Tempitiya presents the third highest risk due to having 26% of female-headed households, 21% of families engaged in agriculture, and 27% of unemployed individuals, according to data provided by local authorities.

Borapola presents the largest crop area affected by floods, 53%. Mahaoya has 8 GNDs with over 30% of crop-affected area, demonstrating a great impact on local livelihoods, considering that the average dependency on agriculture is 25%. Unuwathura Bubula, Samagipura, and Kelavinna had over 500 displaced families due to floods, according to local authorities.

In contrast, Mahaoya, Kekirihena, and Iddapola have the lowest risk. They have low exposure indexes and presented little flooded areas during the assessed period, and low affected population density. Mahaoya has a low family dependency on agriculture and inland fisheries and a small share of low-income families and unemployment.

Table 2. Flood risk index

GND	Hazard-Exposure	Vulnerability	Risk
Pollebedda	**0.63**	**0.70**	**0.443**
Aranthalawa	**0.77**	**0.57**	**0.441**
Tempitiya	**0.42**	**0.68**	**0.288**
Unuwathura Bubula	0.43	0.67	0.286
Borapola	0.35	0.73	0.259
Samagipura	0.55	0.39	0.217
Lahugala	0.27	0.62	0.165
Kelavinna	0.38	0.42	0.160
Bedirekka	0.20	0.65	0.130
Thepalpola	0.17	0.61	0.101
Kudaharasgala	0.16	0.64	0.101
Pulawala	0.12	0.80	0.096
Dambadeniya	0.11	0.63	0.069
Bogamuyaya	0.23	0.22	0.050
Iddapola	0.06	0.66	0.042
Kekirihena	0.05	0.65	0.033
Mahaoya	0.22	0.07	0.016

Hazard, exposure and vulnerability values were calculated as a relative indicator (for more details please see the Annex 2)

Figure 4. Crop area, flood area, and flooded crop area per GND[15]

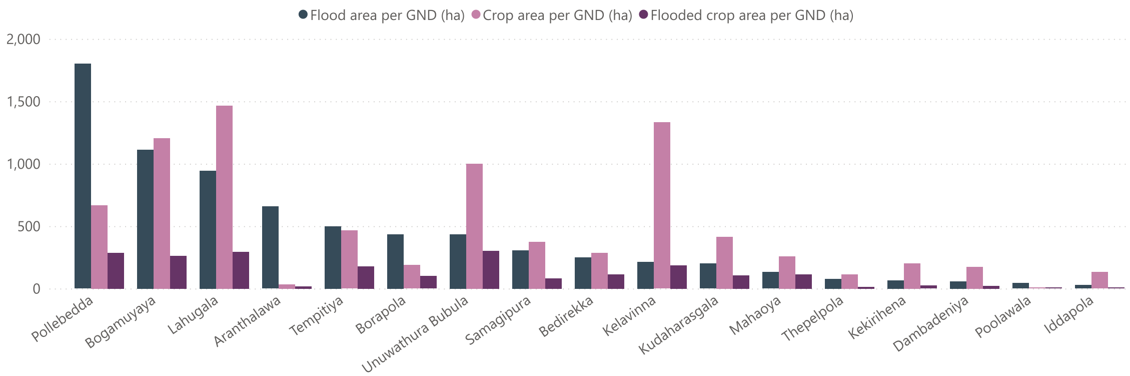


Figure 5. Annual rainfall in Mahaoya (mm)[16]

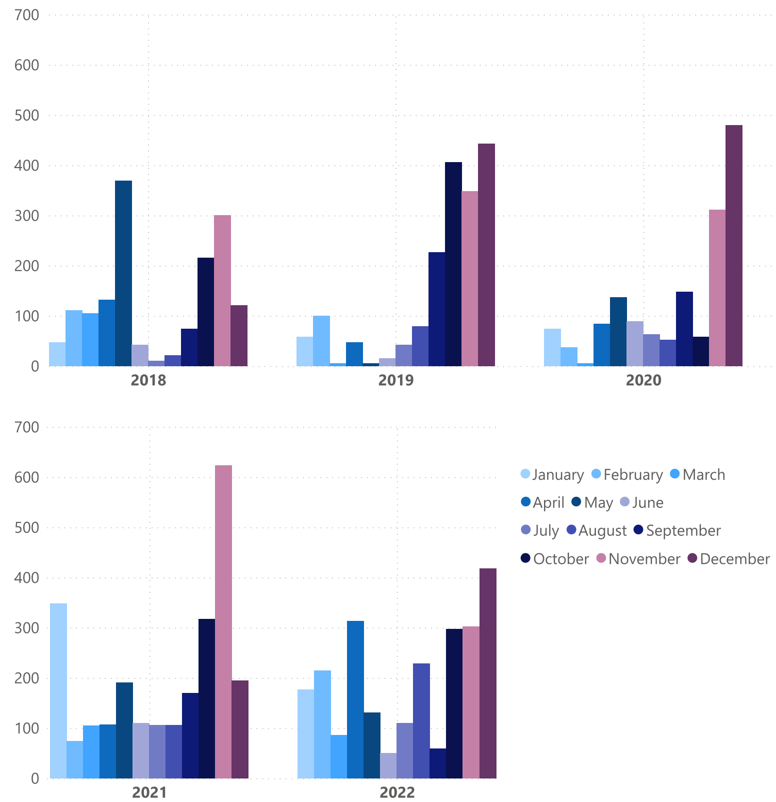
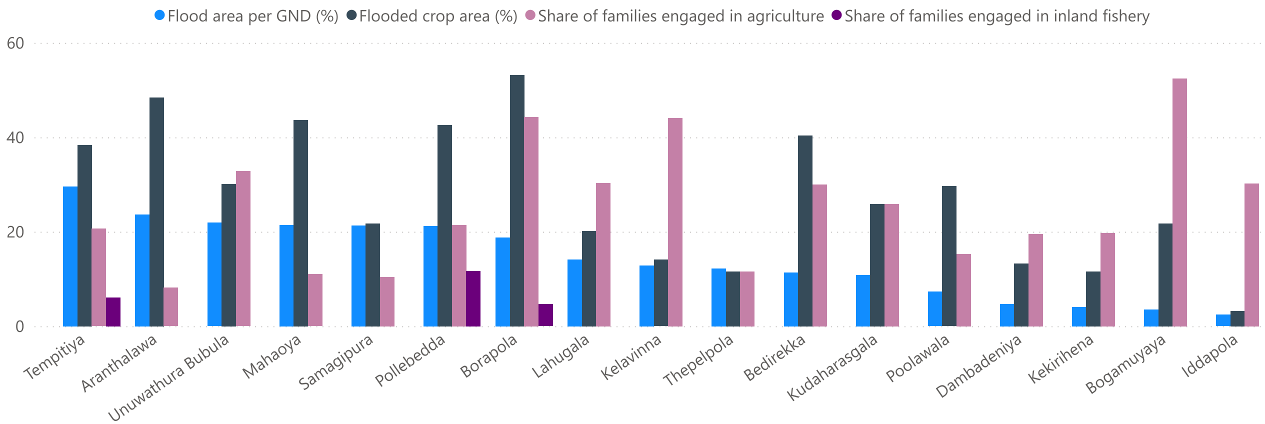


Figure 3. Flood-affected areas and inland fishery and agricultural families[14]



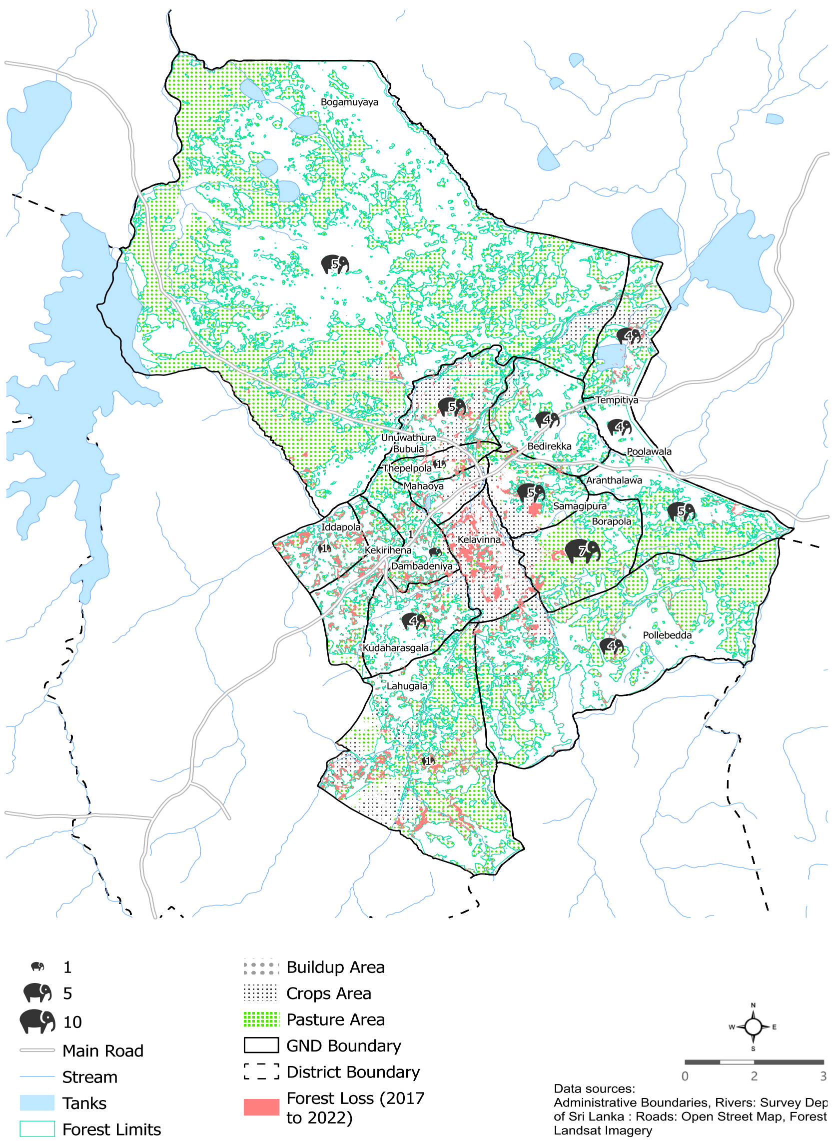
HUMAN-ELEPHANT CONFLICT

Human-elephant conflict emerged as a significant socio-economic and conservation challenge in Sri Lanka. The country has the highest annual elephant deaths globally and the second-highest human deaths attributed to such conflicts. This issue stems from competition for essential natural resources, as urban and agricultural expansion encroach upon elephant's natural habitats. Sri Lanka has the highest density of Asian elephants, with 10–20% of the global population and less than 2% of the global area they inhabit[17].

Deforestation leads to the loss and fragmentation of natural habitats and wildlife corridors used for migration, resulting in a decline in available food and water sources. This often drives elephants to raid croplands and urban areas, leading farmers to view elephants as threats to their livelihoods, increasing the likelihood of retaliatory measures. Between 2015 and 2021, 54% of incidences in Sri Lanka happened in open forests, while 62% occurred within 2 km of the forest edge[18]. GNDs with high human populations and activities coupled with increased forest disturbances, may exacerbate conflicts over resource access between humans and elephants.

Table 3 shows Pollebedda as the GND most at risk with four registered elephant attacks. The high risk is driven by having

Map 4. Human-elephant conflict exposure



the highest affected population density, share of families engaged in inland fisheries (27%), share of female-headed households (37%), and families with members with a disability (12%). The GND has the second largest share of families earning daily wages between 2000 and 3000 LKR and 50% of families depend on agriculture.

Unuwathura Bubula, the second most at risk, has 45% of families engaged in agriculture, and the second largest shares of female-headed households and families with members with a disability. The GND has 36% of unemployed individuals. Kelavinna follows with the second largest forest disturbance, and 87% of families are engaged in agriculture.

According to local authorities' data, Borapola registered seven elephant attacks and Unuwathura Bubula, Samagipura, Aranthalawa, and, Bogamuyaya had five attacks. Bedirekka, Bogamuyaya, and Mahaoya have the lowest HEC risk. Despite Bogamuyaya having the highest hazard index, its low population density results in low exposure index and low risk.

The impact of deforestation is evident across Mahaoya, where nine GNDs lost over 100 ha of forest cover over the last five years. Lahugala presents the largest loss, with an area of 419 ha. A combination of factors contributes to the observed variability in degraded forest areas, including geographic location, land use patterns, conservation initiatives, and human activities.

Table 3. HEC risk index

GND	Hazard	Exposure	Vulnerability	Risk
Pollebedda	**0.33**	**1.00**	**0.40**	**0.132**
Unuwathura Bubula	**0.33**	**0.75**	**0.33**	**0.082**
Borapola	**0.49**	**0.30**	**0.46**	**0.068**
Samagipura	0.25	0.86	0.29	0.063
Kudaharasgala	0.32	0.66	0.28	0.058
Lahugala	0.44	0.47	0.24	0.050
Kelavinna	0.24	0.59	0.35	0.049
Tempitiya	0.29	0.42	0.36	0.044
Kekirihena	0.19	0.68	0.29	0.038
Aranthalawa	0.38	0.61	0.15	0.034
Dambadeniya	0.16	0.70	0.26	0.029
Poolawala	0.20	0.19	0.60	0.023
Iddapola	0.15	0.34	0.31	0.016
Bedirekka	0.26	0.18	0.30	0.014
Thepalpola	0.08	0.76	0.22	0.014
Bogamuyaya	0.63	0.00	0.44	0.000
Mahaoya	0.00	0.33	0.15	0.000

Hazard, exposure and vulnerability values were calculated as a relative indicator (for more details please see the Annex 2)

Figure 6. Human and elephant deaths in Sri Lanka[21]

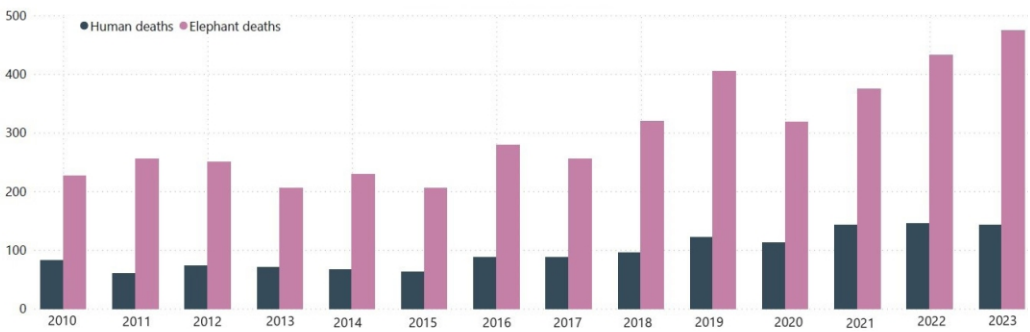


Figure 7. Forest disturbance in the last 5 years[19]

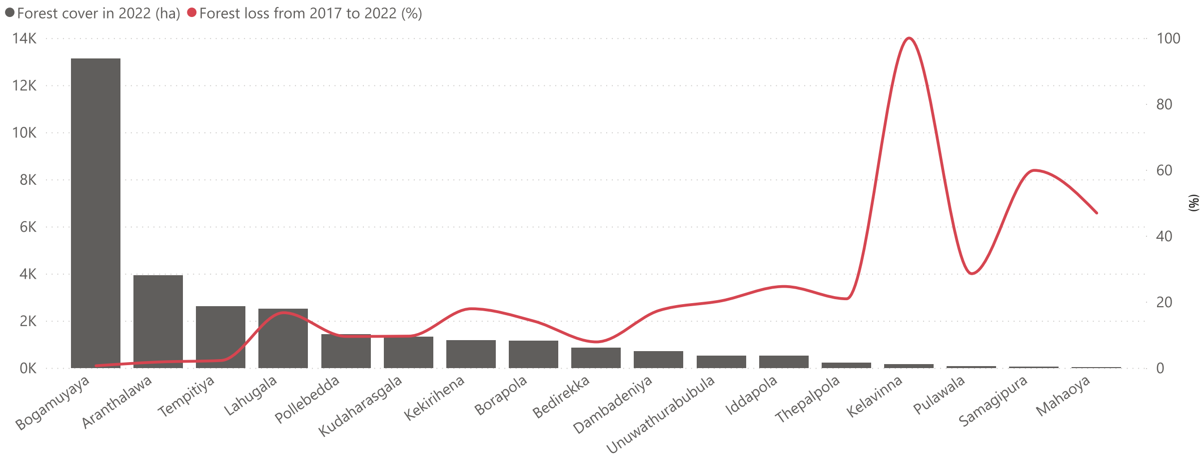
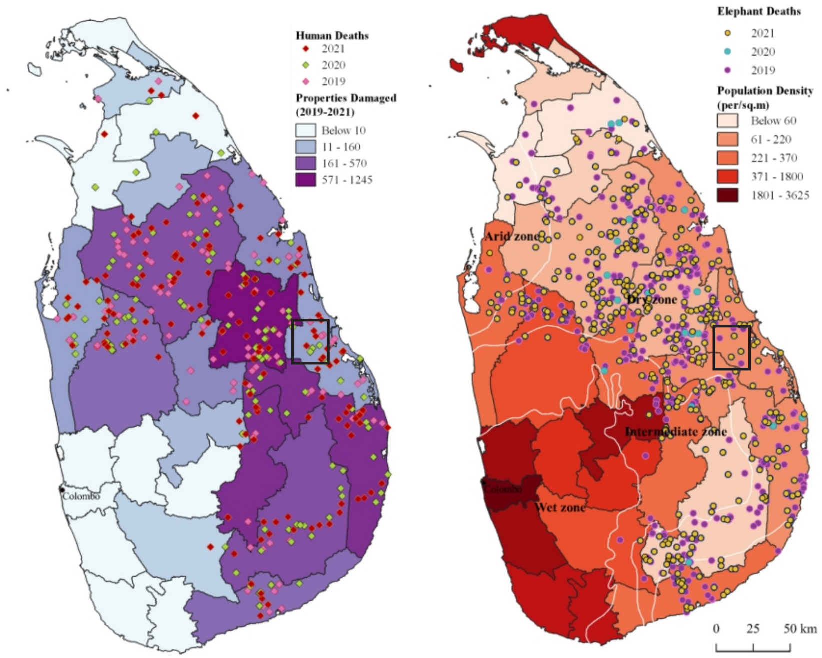


Figure 8. Human death and property damage caused by elephants/elephant death and human density[20]



AGORA

MULTI-HAZARD RISK

Mahaoya's multi-hazard risk analysis, presented in Table 4 and Map 5, was calculated based on the three assessed risks: flood, drought, and HEC. The GNDs with very high risk (≥0.20 out of 1) in Mahaoya is Pollebedda and with high risk (>=0,15 out of 1) are Aranthalawa and Unuwathura Bubula.

Pollebedda presents the highest risks in all three hazards. Aranthalawa has the second highest flood risk, followed by Unuwathura Bubula, with the fourth highest flood risk and second highest drought and HEC risks. The higher exposure to natural hazards and the socio-economic vulnerability of the population in the three GNDs, particularly in Pollebedda and Unuwathura Bubula, increases the risk to communities highly dependent on natural resources for their livelihoods. This further impacts their ability to prepare for, respond to, and recover from shocks. The high percentage of families earning daily wages between 2,000 and 3,000 LKR and unemployement raging between 18% and 36% demonstrates their low coping capacity.

In Pollebedda and Unuwathura Bubula, the multi-hazard risk is increased due to the lack of livelihood diversification, with 21% and 33% of families engaged in agriculture, respectively. Pollebedda has the highest share of families engaged in inland fishery.

It is important to look at other GND individual risks and define targeted actions, as some GNDs may present a low multi-hazard risk despite having a single prominent risk.

Mahaoya, Iddapola and Bogamuyaya present the lowest multi-hazard risk, having low risk across the three hazards. Mahaoya has the lowest flood and HEC risks and second last drought risk due to low exposure and dependency on agriculture and fishery, and a good economic situation. Iddapola and Bogamuyaya's low vulnerability index contributes to their low risk.

The multi-hazard risk analysis conducted with this study can inform both disaster risk reduction and social protection programmes, as the GNDs most at risk in Mahaoya present opportunities for a multi-pronged approach to mitigating disaster risks and their impact on communities.

Map 5. Multi-hazard map

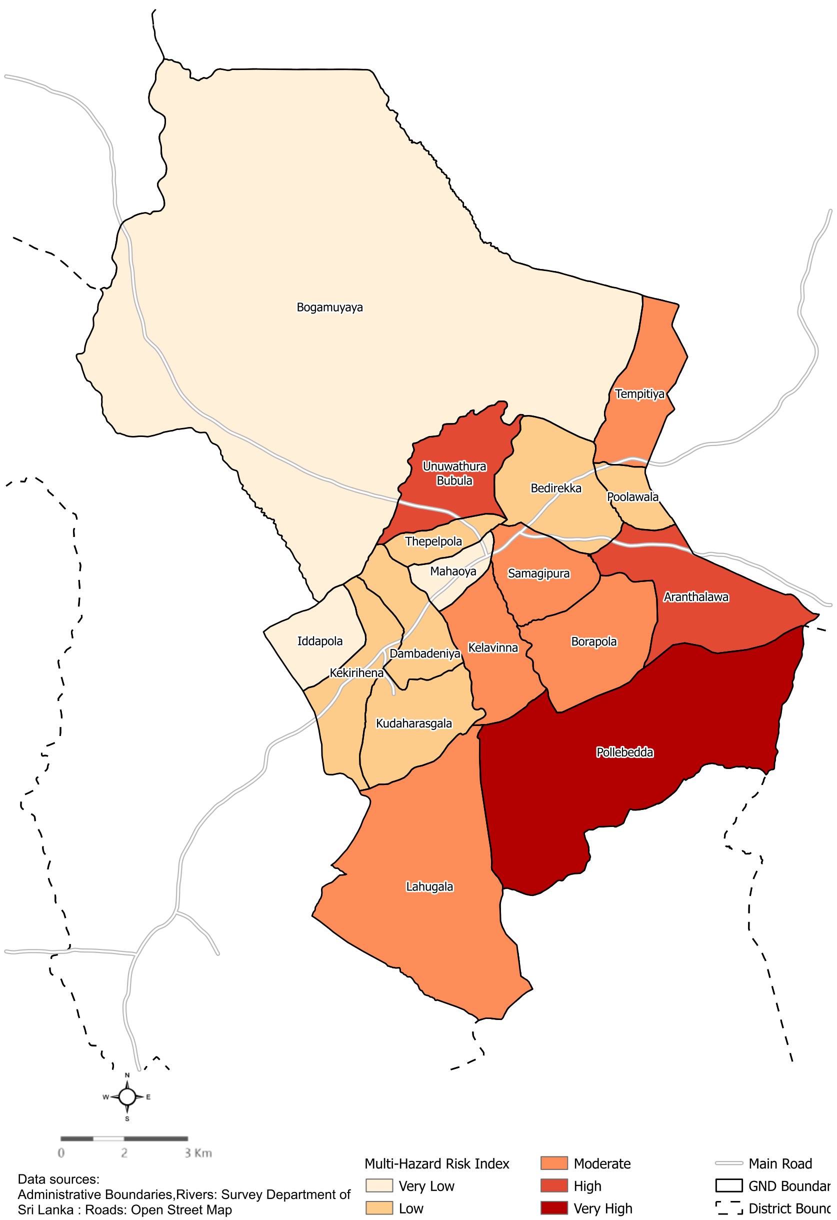


Table 4. Multi-hazard risk index

GND	Flood	Drought	HEC	Multi-hazard risk
Pollebedda	**0.44**	**0.11**	**0.19**	**0.248**
Aranthalawa	**0.44**	**0.01**	**0.02**	**0.159**
Unuwathura Bubula	**0.29**	**0.08**	**0.09**	**0.151**
Tempitiya	0.29	0.03	0.02	0.111
Borapola	0.26	0.01	0.04	0.101
Samagipura	0.22	0.04	0.04	0.098
Kelavinna	0.16	0.02	0.06	0.080
Lahugala	0.17	0.01	0.03	0.069
Bedirekka	0.13	0.04	0.00	0.058
Kudaharasgala	0.10	0.00	0.04	0.047
Poolawala	0.10	0.02	0.01	0.044
Thepelpola	0.10	0.01	0.01	0.039
Dambadeniya	0.07	0.00	0.02	0.032
Kekirihena	0.03	0.01	0.05	0.031
Bogamuyaya	0.05	0.01	0.00	0.022
Iddapola	0.04	0.00	0.01	0.016
Mahaoya	0.02	0.00	0.00	0.006

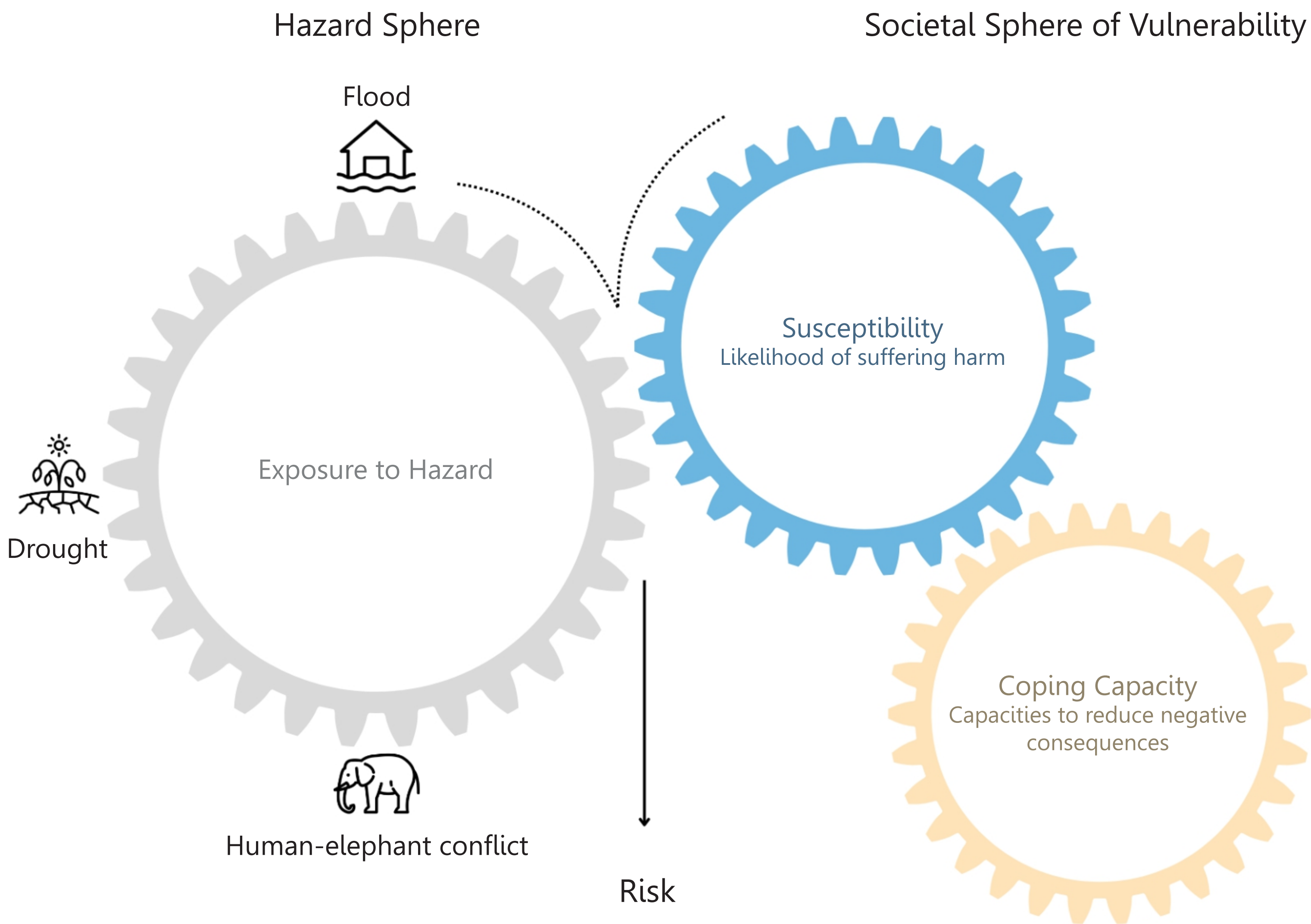
OTHER POTENTIAL HAZARDS

Other hazards also affect the population in Mahaoya, a combination of **land degradation**, **epidemics**, and **water scarcity** significantly impact livelihood resilience activities, posing additional challenges to the local communities. Firstly, land degradation reduces agricultural productivity and drains land's natural resources, causing reduced yields and economic losses. Additionally, disease outbreaks and pandemics disrupt livelihood activities and reduce access to markets and resources. These health crises worsen vulnerabilities, particularly in communities reliant on sectors like tourism or healthcare services.

Moreover, water scarcity intensifies these challenges, as it restricts access to clean water for drinking, sanitation, and irrigation. In regions facing prolonged drought or inadequate water infrastructure, livelihoods dependent on water-intensive activities suffer, leading to increased food insecurity and economic instability. Collectively addressing these interconnected challenges requires holistic approaches that promote sustainable land management, disease prevention, and equitable access to water resources, bolstering the resilience of livelihood activities and enhancing community well-being in the face of adversity.

ANNEX 1

Graph 1. Multi-hazard risk concept



ANNEX 2

Hazard, exposure and vulnerability index calculations

The risk calculation, for each GND, was done following these steps:
1. Define hazard, exposure, and vulnerability indicators.
2. Collect data for the indicators. Hazard and exposure are explained in the tables below, vulnerability was provided by local authorities on request.
3. Calculate the relative number (%) of indicators when they are presented in absolute numbers for comparability .
4. Normalize all data (with a min-max approach) using formulas:

$$I = (Ix - Imin) / (Imax - Imin) \text{ - if indicator increase vulnerability (S)}$$
$$I = 1 - ((Ix - Imin) / (Imax - Imin)) \text{ - if indicator decreases vulnerability (CC)}$$

where I is an indicator, Ix - hazard, exposure or vulnerability value for the particular GND, Imin - minimal hazard/exposure or vulnerability value through all the GNDs, I max - maximum hazard/exposure or vulnerability value through all the GNDs.
5. Aggregate data calculating the average number for Hazard (H), Exposure (Ex), and Vulnerability (V) into indexes for each hazard using the formulas:

$$H = (h1+h1)/2$$
$$Ex=(ex1+ex2+ex3)/3$$
$$V=((s1+s2+s3+s4+s5)/5+(lcc1+lcc2+lcc3)/3)/2$$

where h, ex, s, and lcc are each indicators for hazard, exposure, susceptibility, and lack of coping capacity, respectively
6. Calculate the risk (R) for each hazard using the formula:

$$R = H \times Ex \times V$$

7. Calculate the multi-hazard risk index (MHRI) using the formula:

$$MHRI = (R1+R2+R3)/3$$

where R1, 2, and 3 are each of the risks calculated for drought, flood and HEC

ANNEX 2

Hazard, exposure and vulnerability index calculations

Hazard	Data source	Methodology
Drought	NASA Modis data[22] for vegetation and land-surface temperature data as well as CHIRPS rainfall datasets[23] from Earth Engine Data Catalog[24]	VCI data derived from Modis EVI[25] (2003-2023) using the UN-Spider methodology (GEE code[26]). VHI was calculated using NDVI[27] and LST[28] data based on UN-Spider methodology[29] (GEE code). The SPI[30] was calculated to highlight the rainfall anomalies in 2023, using CHIRPS rainfall data processed using the GEE code. The analysis was run for agricultural, croplands, and rangelands Copernicus land cover data[31].
Flood	European Space Agency's Sentinel-1 synthetic aperture radar (SAR) data 2019-2022 from Earth Engine Data Catalog[32]	Spider flood assessment methodology[33] for each of the years from 2018 to 2022 comparing pre-flood and post-flood acquisitions dates also related to the yearly rain season.
HEC	Landsat Satellite Imagery (1990-2022) from Earth Engine Data Catalog[34]	Forest fragmentation was detected using LandTrend methodology[35] based on Landsat satellite imagery acquired from 1990 to 2022

ANNEX 2

Hazard, exposure and vulnerability index calculations

Exposure	Data source	Methodology
Population density	Population density raster-Socioeconomic Data and Applications Center (SEDAC)	The affected population value for each GND was extracted from the global raster that indicates population density.
Percentage of crop area prone to drought	VCI data derived from MODIS EVI (2003-2023). (VHI/SPI-2023)	Using ArcGIS Pro spatial analysis tool and related statistical analysis tools, the percentage of crops susceptible to drought is determined based on the area's drought frequency.
Percentage of pasture land prone to drought	VCI data derived from MODIS EVI (2003-2023). (VHI/SPI-2023)	Using ArcGIS Pro spatial analysis tool and related statistical analysis tools, the percentage of crops susceptible to drought is determined based on the area's drought frequency.
Share of affected fisheries families	Secondary data from Local Authority.	Acted prepared and shared a questionnaire with local authorities to collect the information.
Affected population density index	Population density raster-Socioeconomic Data and Applications Center (SEDAC)	The affected population value for each GND was extracted from the global raster that indicates population density.
Percentage of crop area within a flood zone	Sentinel-1 synthetic aperture radar (SAR) data 2019-2022 -European Space Agency's Copernicus Open Access Hub and other repositories.	Using ArcGIS Pro spatial analysis tool and related statistical analysis tools, the percentage of crops susceptible to drought is determined based on the area's drought frequency.
Percentage of build up area within a flood zone	Sentinel-1 synthetic aperture radar (SAR) data 2019-2022 -European Space Agency's Copernicus Open Access Hub and other repositories.	Using ArcGIS Pro spatial analysis tool and related statistical analysis tools, the percentage of crops susceptible to drought is determined based on the area's drought frequency.
Road length and railways within a flood zone (km)	Open street map, Survey Department of Sri Lanka	Using the ArcGIS Pro spatial analysis tool and related statistical analysis tools.
Population density	Secondary data from Local Authority.	Acted prepared and shared a questionnaire with local authorities to collect the information.
Share of affected fisheries families	Secondary data from Local Authority.	Acted prepared and shared a questionnaire with local authorities to collect the information.

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