SRI LANKA

Area-Based Risk Assessment in Koralai Pattu South Divisional Secretariat Division

Batticaloa District

May 2024

Cover images: Google Earth Image 2024 CNES Airbus

Who are we?

About IMPACT
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 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.

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. A rise in extreme events and natural hazards due to climate change will considerably threaten Sri Lanka's economy and human health. In recent years, Sri Lanka has experienced a series of recurrent crises, including the 2019 Easter Attacks and the global COVID-19 pandemic[1], followed by the 2022 economic crisis. These crises have severely affected marginalized communities' capacity to withstand the impacts of even minor external shocks[2].

According to local authorities data, Sri Lanka's eastern provinces are highly susceptible to floods, drought, and human-animal conflict hazards and experience high vulnerability due to the high share of low-income families and 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 Koralai Pattu South (Kiran) Divisional Secretary's Divisions (DSD) in Batticaloa 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 better predict, 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 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. The communities and local authorities reported during the preliminary consultations, floods, droughts, and human-elephant being the most prominent hazards. 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 Koralai Pattu South.

Through the study, IMPACT identified three GNDs, Muruthanai, Perillavely, and Vahanery, as the most at risk for multiple hazards, especially droughts and floods. Muruthanai is the most at risk due to its high exposure, having the largest drought area in the DSD, and 50% of its crops within a flood zone. The large share of families relying on agriculture as their main l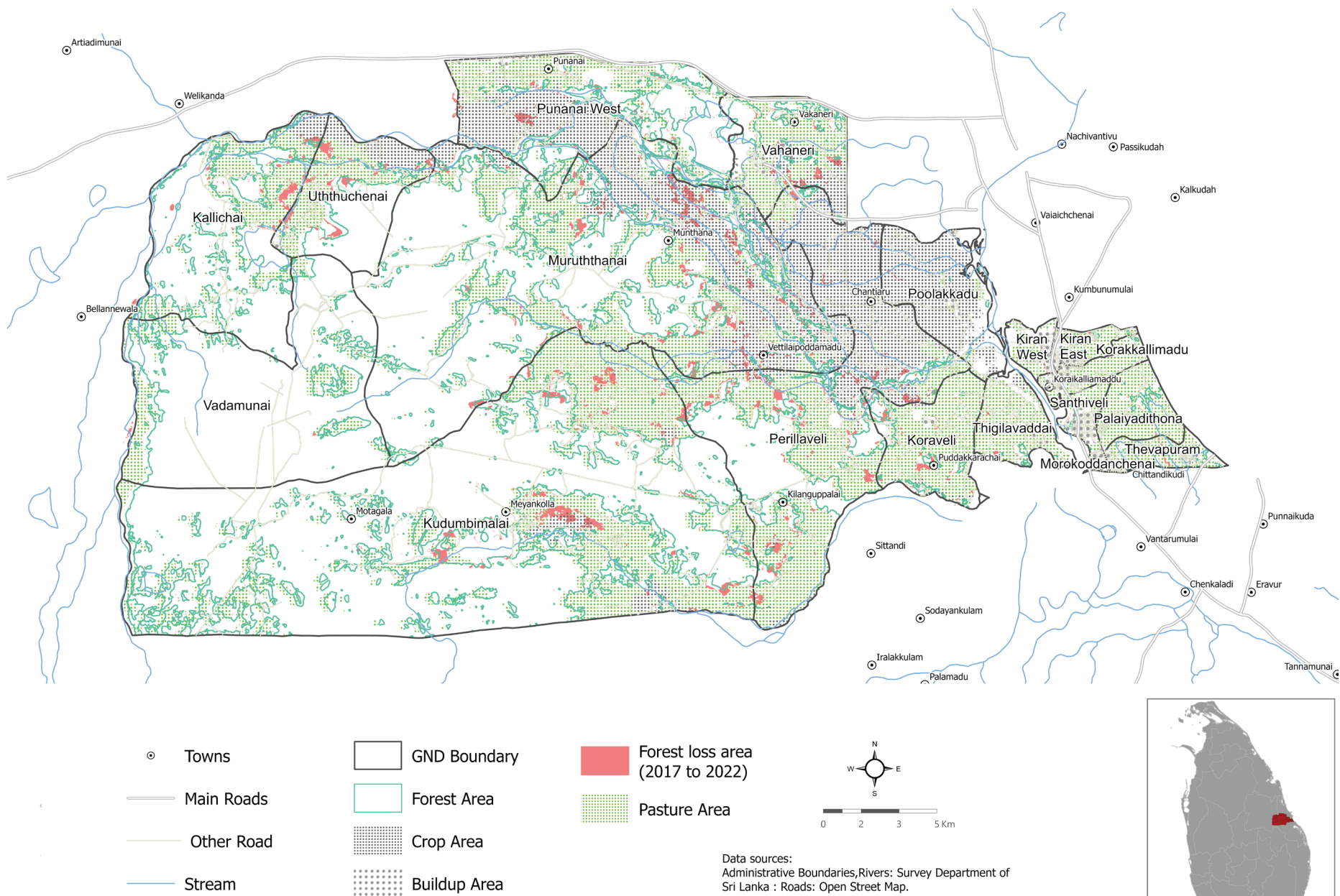ivelihood and low income level increases the vulnerability of the Muruthanai population to cope with external shocks. The large number of female-headed households exacerbates Perillavely's vulnerability to external shocks. In Vahanery, the population has the highest level of susceptibility regarding social dependency and mostly relies on agriculture and cattle-keeping livelihoods. Social dependency is when an individual or group relies on another individual or group for resources, support, or guidance.

According to the analysis, Santhiveli was identified as the most at risk of elephant attacks, along with Palayadithona and Kudimpimalai, due to a combination of deforestation, population density, and unemployment among the residents. The unemployment rate is a social insecurity indicator, that indicates the low financial capacity to prepare and recover from elephant attacks. Kiran East, Vadamunai, and Korakallimadu are the least impacted by droughts, floods, and elephant attacks. Their communities mainly rely on marine or inland fishing, and their socio-economic situation allows for higher coping capacity.

The study's findings underscore the importance of a localised approach to understanding risk and informing disaster risk reduction strategies. The specific risk profile of each GND must guide how to prioritize and customize preparedness interventions for drought management, flood control, and human-elephant conflict (HEC). Stakeholders can use this assessment as a valuable tool to design targeted interventions to enhance the resilience of communities and territories in Koralai Pattu South against single and multi-hazard scenarios.

AGORA

Map 1. Overview map of Koralai Pattu South DSD

Legend:

- ⊙ Towns
- — Main Roads
- — Other Road
- — Stream
- ▭ GND Boundary
- ▭ Forest Area
- ▦ Crop Area
- ⠿ Buildup Area
- ▮ Forest loss area (2017 to 2022)
- ▦ Pasture Area

Data sources:
Administrative Boundaries,Rivers: Survey Department of Sri Lanka : Roads: Open Street Map.

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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, Batticaloa district, Koralai Pattu South (Kiran) DSD covers an area of 656 km², with a population of 26,143 individuals, 52% out of them female and 38% children. The average population density is 49,85/ km². The terrain in Koralai Pattu South is diverse, ranging from coastal areas with sandy beaches to inland areas with flat plains and some hilly terrain. It is bordered by the Indian Ocean to the east, providing access to coastal resources and activities such as fishing. Additionally, several rivers and water bodies in the region contribute to agriculture and livelihood activities. The vegetation in Koralai Pattu South includes coastal vegetation, such as mangroves and palm trees along the shoreline, and inland vegetation consisting of forests, shrubs, and crop lands. Koralai Pattu South experiences a tropical climate with distinct wet and dry 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. Overall, Koralai Pattu South's geography significantly shapes its economy, with livelihood activities primarily revolving around agriculture and fishery. In Koralai Pattu South, paddy cultivation stands out as the predominant agricultural activity, the highest level of employment with 1521 families and 1768 farmers[3]. This highlights the dependency on rice cultivation.

During heavy monsoon rains, low-lying areas in Koralai Pattu South 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. Being located near the coast, Koralai Pattu South 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, resulting in coastal erosion, damage to infrastructure, and displacement of communities. Hilly areas within or near Koralai Pattu South Division may be susceptible to landslides, especially during heavy rainfall or seismic activity. Koralai Pattu South'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.

With 7,5 km of coastal area, Koralai Pattu South was one of the nine DS divisions severely affected by the Tsunami in 2004. Batticaloa district experienced greater inundation since the tsunami hit directly, the water levels were generally high with low terrain to a considerable distance inland (JPL-NASA, 2005[4]), causing the displacement of 63,717 families, 2,975 deaths, including 1,229 fishermen, and 346 missing people[5]. Koralai Pattu South 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 18 GNDs in Koralai Pattu South, 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 Koralai Pattu South 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 for localized hazard-exposure analysis.

AG⊙RA

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)[6]. 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[7]).

• **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 analised 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 Koralai Pattu South, 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 or exhaustive of all natural hazards in Koralai Pattu South.

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[8] (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[9]). MODIS Normalized differentiated vegetation index (NDVI[10]) and MODIS Land Surface Temperature (LST[11]) 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[12]. 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[13] 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 2000 and 3000 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 percent 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 of all GNDs in Koralai Pattu South (Map 2), the extent of drought areas varied significantly. In total terms, Muruththanai has the largest drought area, 5119 ha, covering over 40% of its territory and accounting for 28% of the total drought area. Poolakadu, Palaiyadithona, and Morokoddanchenai have over 85% of their territories prone to drought. Vadamunai recorded the lowest drought area at 22 hectares, covering 0,4% of its territory. This divergence underscores the spatial variability in drought impact across the 18 Grama Niladhari Divisions (GNDs).

The extent of drought in certain areas, exemplified by Muruththanai, leads to potential agricultural losses, and the high share of families engaged in agriculture and inland fishery and high levels of poverty contribute to Muruththanai's position as the highest drought risk index. High hazard exposure leads Perillaveli, Vahaneri, and Poolakadu to present high risks, the first and second ones also presenting high vulnerability, with many female-headed households, and low-income families, and the third with high children density,
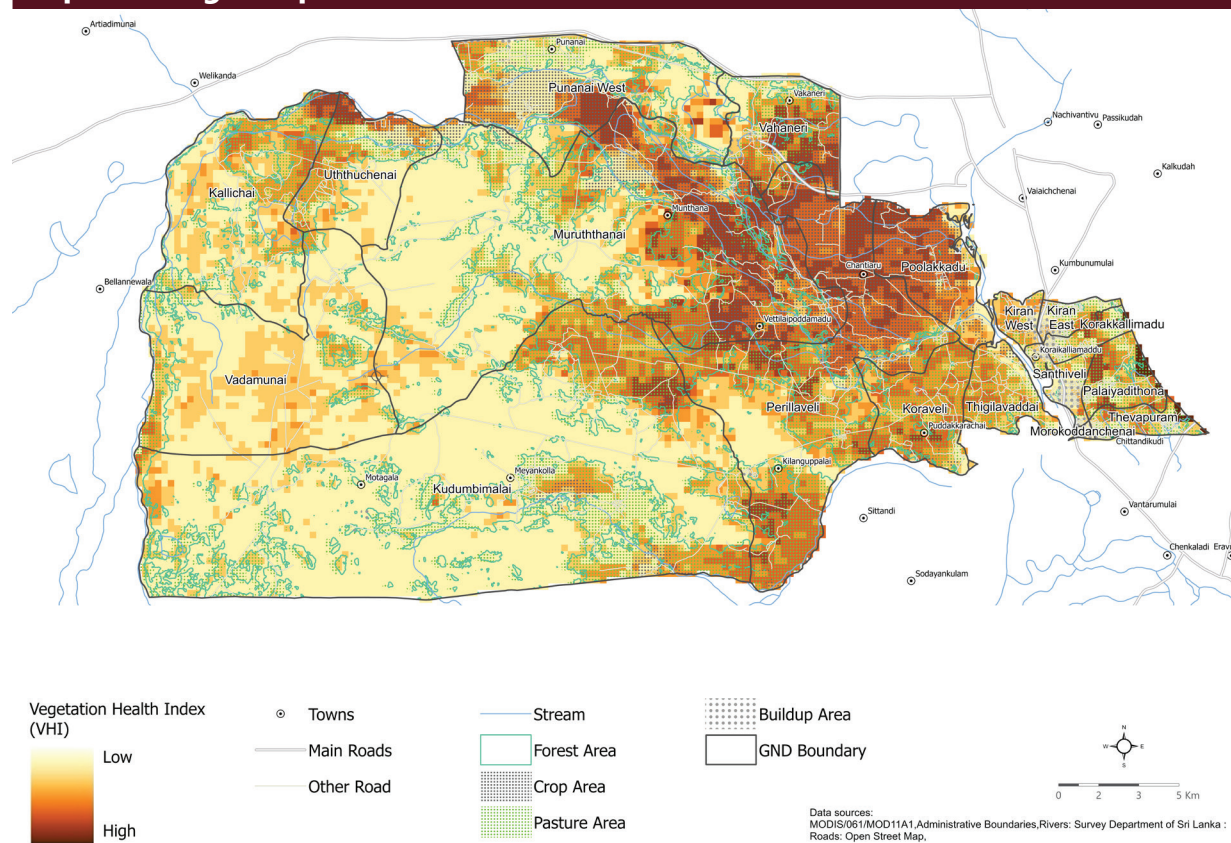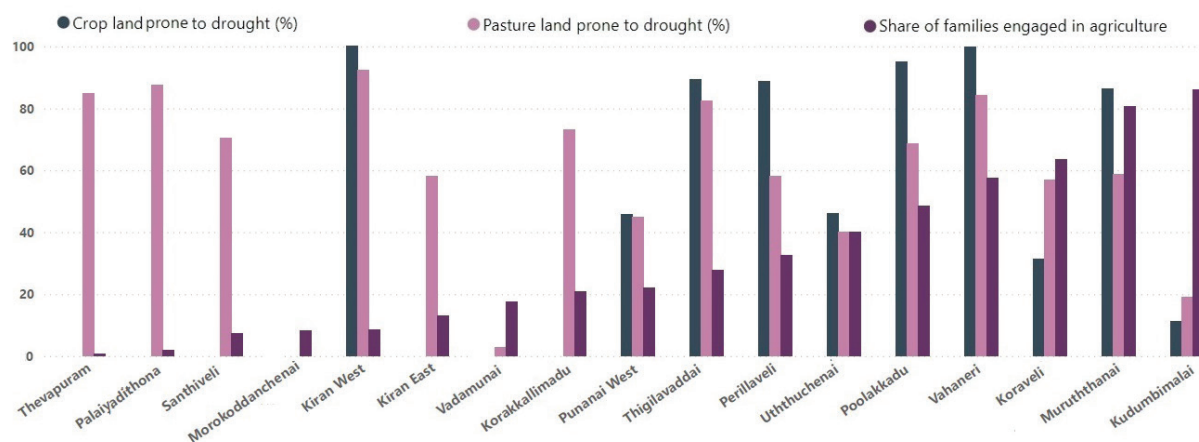
Map 2. Drought exposure

Vegetation Health Index (VHI): Low — High
Towns · Main Roads · Other Road
Stream · Forest Area · Crop Area · Pasture Area
Buildup Area · GND Boundary

Data sources:
MODIS/061/MOD11A1, Administrative Boundaries, Rivers: Survey Department of Sri Lanka : Roads: Open Street Map,

Figure 1. Percentage of drought-affected areas and agricultural families[14]

female-headed households, and unemployment rates. GNDs characterized by high population density, such as Santhiveli and Kiran East, 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. Notably, Vahanery faces a substantial risk to crop production, with 99.92% of its crop area prone to drought. The analysis suggests a risk of severe agricultural production decline in this GND. Similarly, areas with a significant percentage of pasture lands exposed to drought, exemplified by Kiran West, may grapple with challenges in the livestock farming sector (Figure 1).

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. Besides the GNDs previously mentioned, the high share of farming families in Kudumbimalai and Koraveli and large drought-prone areas in Thigilavaddi stand out as indicators of possible livelihood and economic impact.

Moreover, GNDs with a significant share of families engaged in inland fishery activities, as seen in Vadamunai and Thigilavaddi, may face grave difficulties due to the impact of drought on water resources, potentially jeopardizing family's livelihoods.
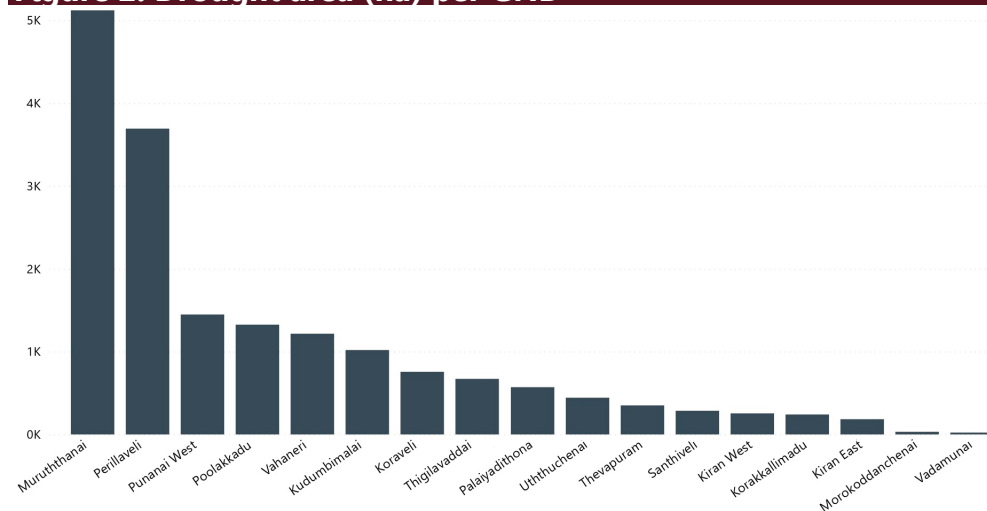

Figure 2. Drought area (ha) per GND[15]

Table 1. Drought risk index

GND	Hazard	Exposure	Vulnerability	Risk
Muruththanai	**1**	**0.44**	**0.55**	**0.24**
Perillaveli	**0.71**	**0.45**	**0.42**	**0.14**
Vahanery	**0.2**	**0.63**	**0.55**	**0.08**
Poolakadu	0.25	0.51	0.54	0.07
Punanai West	0.27	0.31	0.36	0.03
Koraveli	0.14	0.3	0.57	0.02
Kudumbimalai	0.19	0.2	0.54	0.02
Thigilavaddi	0.12	0.57	0.39	0.02
Uththuchenai	0.08	0.47	0.6	0.02
Palaiyadithona	0.1	0.38	0.31	0.01
Kiran East	0.03	0.34	0.36	0
Kiran West	0.04	0.65	0.21	0
Korakkallimadu	0.04	0.3	0.27	0
Morokoddanchenai	0	0.17	0.37	0
Santhiveli	0.05	0.47	0.26	0
Thevapuram	0.06	0.41	0.29	0
Vadamunai	0	0.03	0.29	0

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

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FLOOD

The rainy season in Koralai Pattu South 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[16].

The flooded area in Koralai Pattu South was 7852 hectares, based on satellite images from 2018 to 2020. Perillavely had the largest affected area, accounting for 32% of the total flooded area in Koralai Pattu South, covering 38% of the GND. Poolakadu and Vahanery had 69% and 38% of their area affected by floods, respectively. Kiran West, Morokoddanchenai, Punanai West, and Muruththanai also recorded moderate flooding.

The exposure indicators assessed were the affected population density, the percentage of crop area and built-up area, and roads and railways length within flooded zones. Table 2 shows Perillavely with the highest risk, due to its high exposure and susceptibility, with a large share of female-headed households, families with disabled members, and monthly income under 20 000 LKR. Followed by Vahanery, with high dependency on agriculture and the highest child density, and Muruththanai, with a large share of families engaged in agriculture and inland fishery and earning less than 20 000 LKR monthly according to data provided by Local Authorities.

Korakkallimadu, Kiran East, and Vadamunai have the lowest risk. They presented low or no flooded areas during the assessed period, low share of families engaged in agriculture, and low-income families.
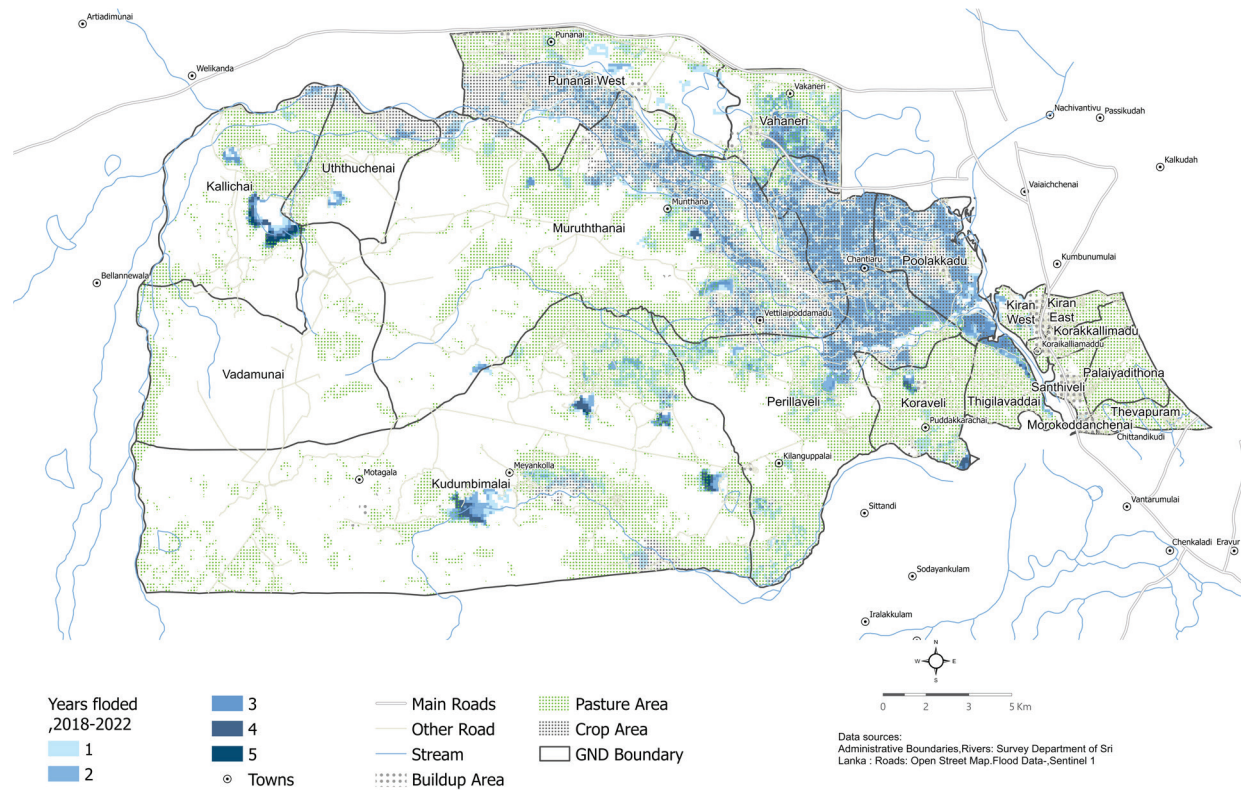
Map 3. Flood exposure

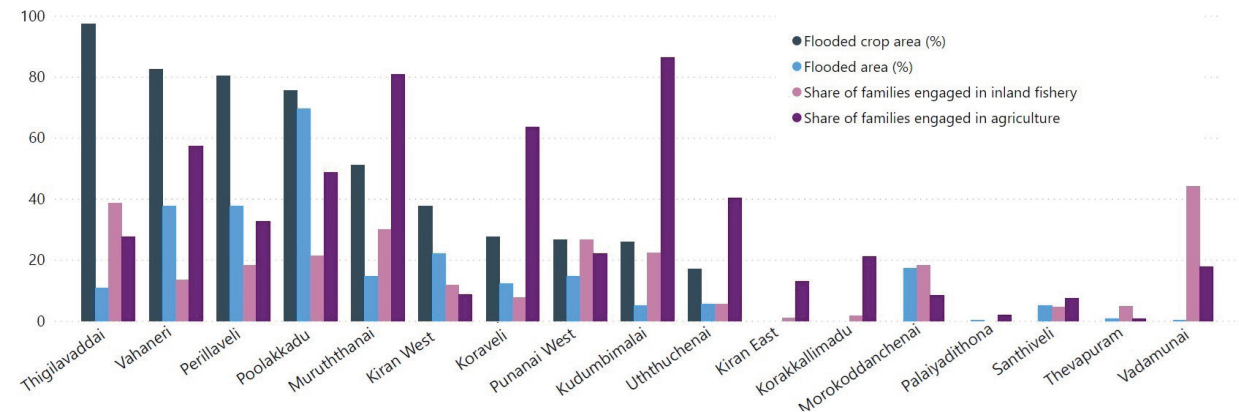## Figure 3. Flood-affected areas and inland fishery and agricultural families[18]

Table 2. Flood risk index

GND	Hazard	Exposure	Vulnerability	Risk
Perillavely	**1**	**0.57**	**0.46**	**0.26**
Vahanery	**0.75**	**0.35**	**0.48**	**0.25**
Muruththanai	**0.43**	**0.37**	**0.36**	**0.18**
Poolakadu	0.24	0.41	0.73	0.15
Thigilavaddi	0.34	0.31	0.51	0.13
Morokoddanchenai	0.22	0.26	0.65	0.11
Kiran West	0.07	0.31	0.25	0.11
Punanai West	0	0.16	0.7	0.10
Santhively	0.03	0.28	0.35	0.10
Koraveli	0	0.37	0.39	0.09
Kudumbimalai	0	0.17	0.43	0.09
Thevapuram	0	0.11	0.67	0.07
Uththuchenai	0.01	0.08	0.36	0.04
Palaiyadithona	0	0.03	0.65	0.02
Vadamunai	0.04	0.00	0.42	0.00
Kiran East	0.04	0.00	0.54	0.00
Korakkallimadu	0	0.00	0.65	0.00

* 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[19]
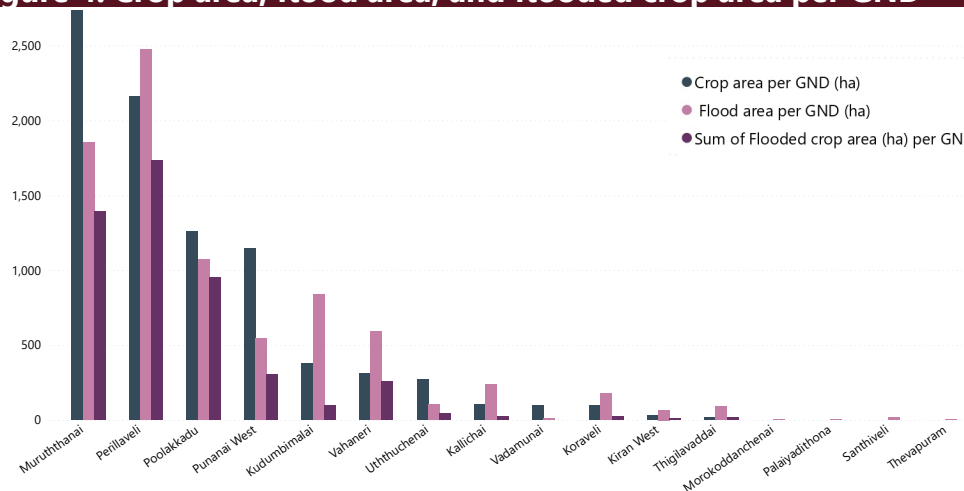
Figure 5. Annual rainfall in Koralai Pattu South[20]
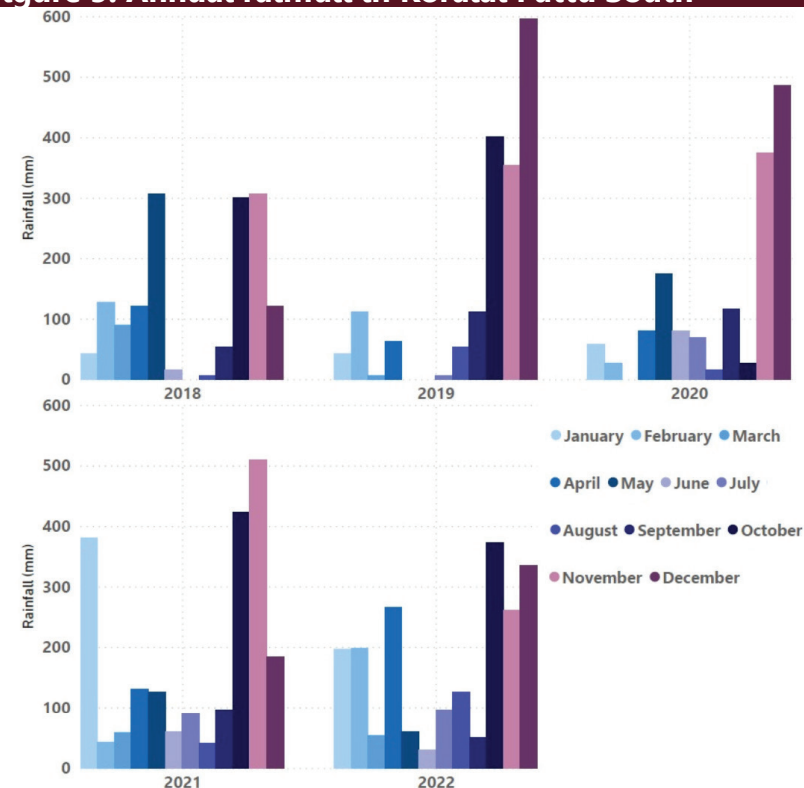
The distribution of flood risks in Koralai Pattu South shows the urgency of developing plans for flood management, especially during the agricultural seasons, to mitigate its adverse effects. This is critical for the livelihood of Koralai Pattu Souths' families and the food security of Batticaloa communities since Koralai Pattu South accounts for 21% of the paddy fields area between the 14 DSDs in the district[17]. Paddy season in Koralai Pattu South goes from October to February and relies heavily on rainfall patterns.

Thigilavaddi stands out with 97% of crop areas prone to floods, indicating a significant impact on agricultural activities. Vahaneri, Perillaveli, and Poolakadu follow with 83%, 80%, and 76% flooded crop areas, respectively. In total, Koralai Pattu South has 47% of crop area affected by flood.

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HUMAN-ELEPHANT CONFLICT

HEC has emerged as a significant socio-economic and conservation challenge in Sri Lanka, with the highest annual elephant deaths globally and the second-highest human deaths attributed to such conflicts. It is rooted in the competition for essential natural resources, with urban and agricultural expansion into the elephants' natural habitat. Sri Lanka has the highest density of Asian elephants, with 10–20% of the global population and less than 2% of the worldwide range.

Deforestation causes the loss and fragmentation of natural habitats and wildlife corridors used for migration and a decline in the availability of food and water sources. This often drives elephants to raid agricultural fields and human-occupied areas. Farmers may view elephants as threats to their livelihoods, increasing the likelihood of retaliatory measures. Between 2015 and 2021, 54% of incidents recorded in Sri Lanka happened in open forests, while 62% within 2 km of the forest edge.

The impact of deforestation is evident in Poolakadu, Kiran East, Thevapuram, and Koraveli, all with more than 40% of forest loss (Figure 7). Morokoddanchenai and Vadamunai, on the other hand, record the lowest forest loss, the latter being the third GND with the highest forest area. A combination of factors contributes to the observed variability in degraded forest areas, including geographic location, land use patterns, conservation initiatives, and human activities.

According to local authorities' data, Palaiyadithona, Vahanery, Kudumbimalai, and Vadamunai had registered human deaths caused by elephant attacks, placing the first three on the
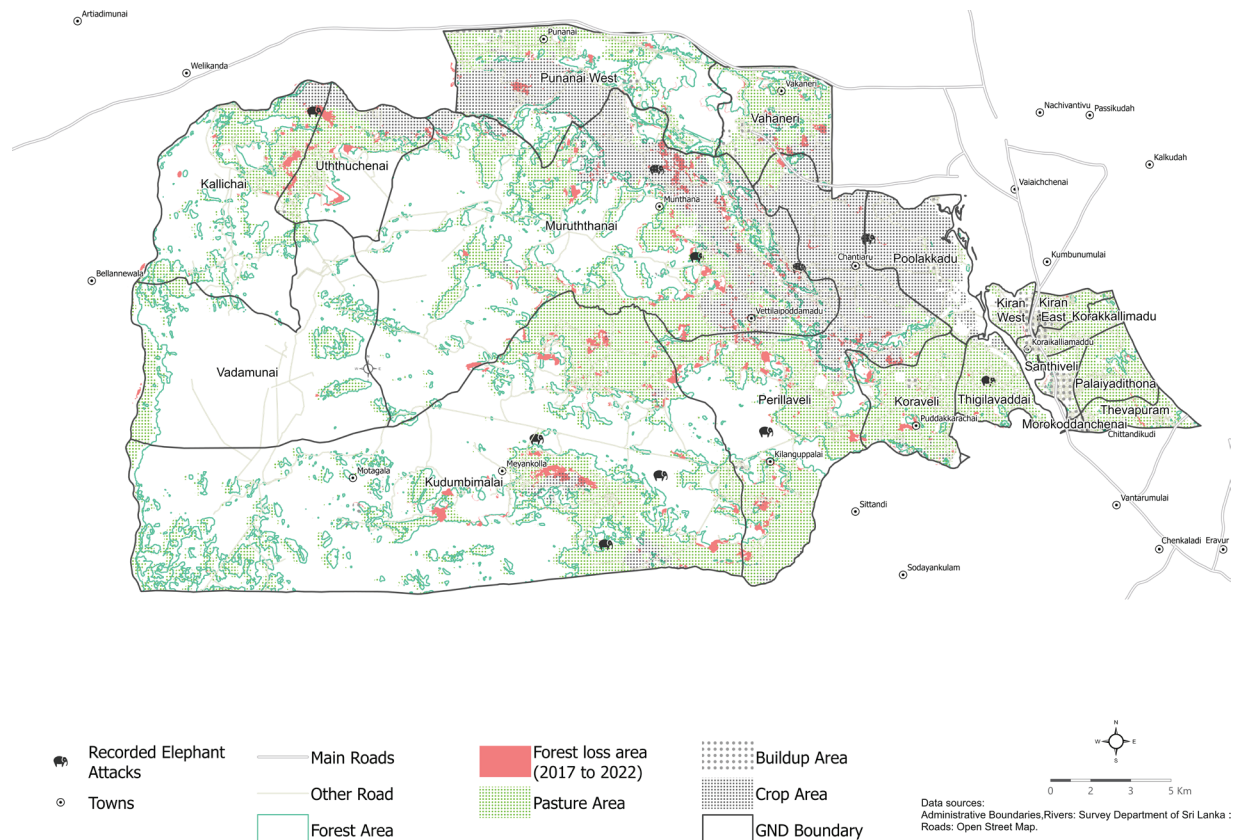
Map 4. Human-elephant conflict exposure


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

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Table 3. HEC risk index

GND	Hazard	Exposure	Vulnerability	Risk
Palaiyadithona	**0.34**	**0.48**	**0.69**	**0.11**
Vahanery	**0.4**	**0.18**	**0.77**	**0.05**
Kudumbimalai	**0.92**	**0.06**	**0.79**	**0.04**
Perillaveli	0.27	0.18	0.73	0.04
Poolakadu	0.34	0.14	0.77	0.04
Muruththanai	0.35	0.13	0.75	0.03
Koraveli	0.06	0.13	0.8	0.01
Kiran East	0	0.74	0.68	0
Kiran West	0	0.53	0.61	0
Korakkallimadu	0	0.45	0.65	0
Morokoddanchenai	0	0.43	0.68	0
Punanai West	0.1	0.18	0.15	0
Santhiveli	0	1	0.64	0
Thevapuram	0.01	0.55	0.65	0
Thigilavaddi	0.01	0.25	0.66	0
Uththuchenai	0.12	0	0.36	0
Vadamunai	0.49	0	0.63	0

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

Figure 7. Forest disturbance in the last 5 years[22]
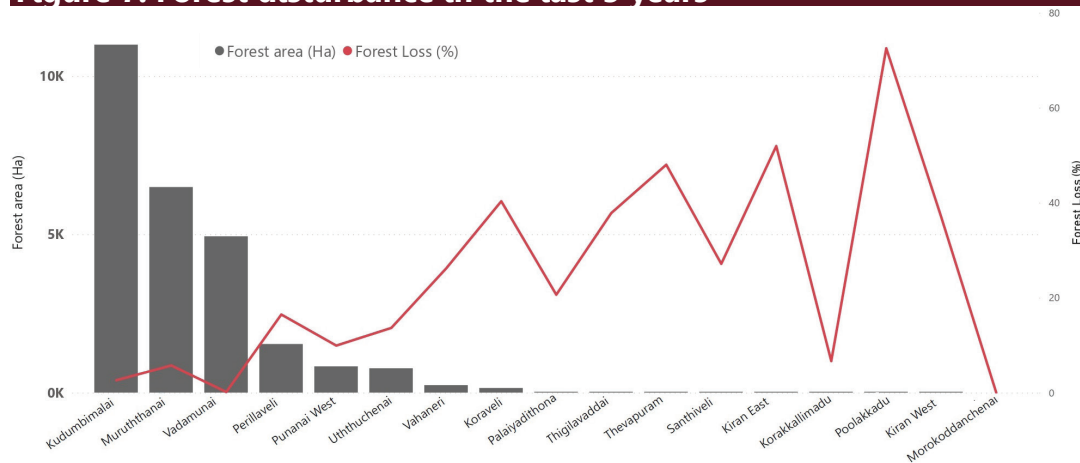
top of the risk index. Considering their low population density, Vadamunai and Uththuchenai present a low exposure index, consequently presenting lower risk. Palaiyadithona presents the highest risk due to its high population and child density, low-income families, and unemployed individuals. Vahanery presents a high share of families engaged in agriculture, female-headed households, and children and elderly density and Kudumbimalai has a high share of farmer families, low-income families, and families with members with disabilities.

Kudumbimalai, Vadamunai, and Perillaveli still exhibit vast forest areas and comparatively low forest loss. With the correct protection and conservation efforts application, these GNDs have the potential to sustainably host human and elephant populations. Uththuchenai, Morokoddanchenai, Korakkallimadu, and Kiran West present the lowest risk to HEC, the first one because of low population density and the existence of protection fences, and the final three for being more central and urbanised areas in the DSD, without forests.

Figure 8. Human death and property damage caused by elephants/Elephant death and human density[23]

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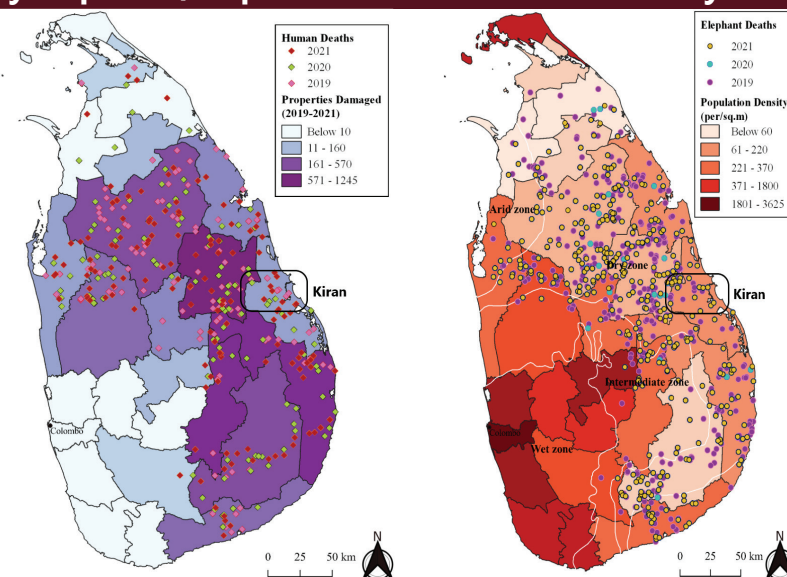
MULTI-HAZARD RISK

Koralai Pattu South's multi-hazard risk analysis is displayed in Table 4 and Map 5 and was calculated based on the three risks assessed: flood, drought, and HEC. Standing out as most at risk are Muruththanai, Perillaveli, and Vahanery, the GNDs with very high risk (>=0.15 out of 1) and high risk (>=0,13 out of 1) in Koralai Pattu South. Muruththanai presents very high drought and flood indexes, and Perillavely presents a high flood index and the second-highest drought index. Finally, the high multi-hazard risk in Vahanery is due to its high flood risk.

The three GNDs register a higher share of families engaged in agriculture and inland fishery than the average. The higher exposure to natural hazards, especially drought and flood, and the socio-economic vulnerability of the population in the three GNDs increases the risk to communities highly dependent on natural resources for their livelihoods, further impacting their capacity to prepare, respond, and recover from shocks. The high share of low-income families, particularly in Muruththanai (84% with monthly income lower than 20 000 LKR) and Perillavelly (96% with monthly income lower than 20 000 LKR) further increase their susceptibility, showcasing their low coping capacity.

In Muruththanai, the risk of drought is increased due to the lack of livelihood diversification, while in Perillaveli and Vahanery, the risk of flooding is exacerbated by the large crop areas and the significant presence of female-headed households and families with members with disabilities.

Map 5. Multi-hazard map
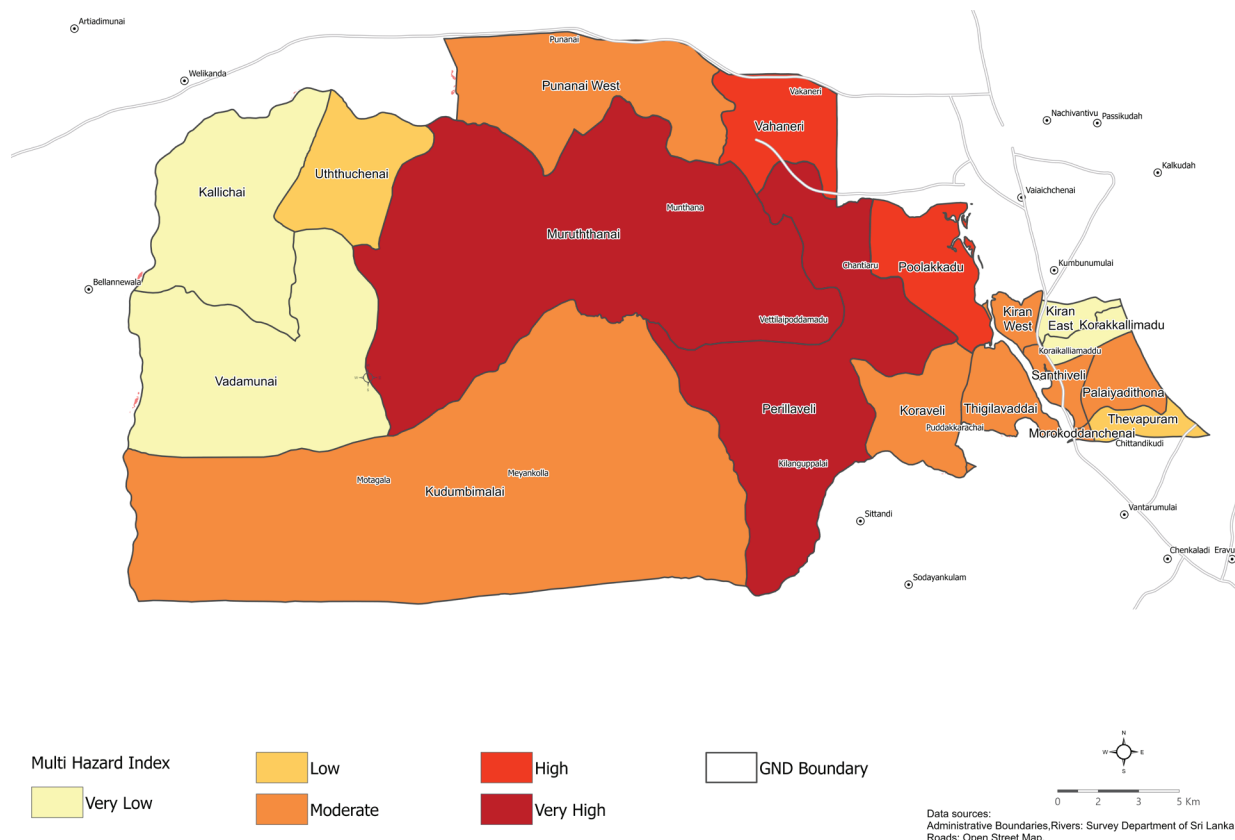
It is important to look at other GND individual risks and define targeted actions. Some GNDs may present a low multi-hazard risk despite having a single prominent risk.

Vadamunai, Korakkallimadu, and Kiran East present the lowest multi-hazard risk, the first mainly because of its low population density, reducing the exposure. The following two are more urbanised areas, with fewer flood and drought-prone areas and fewer families engaged in agriculture and farming that may experience urban-specific hazards requiring specialised analysis.

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 Koralai Pattu South present opportunities for a multi-pronged approach to mitigate disaster risks and their impact on communities.

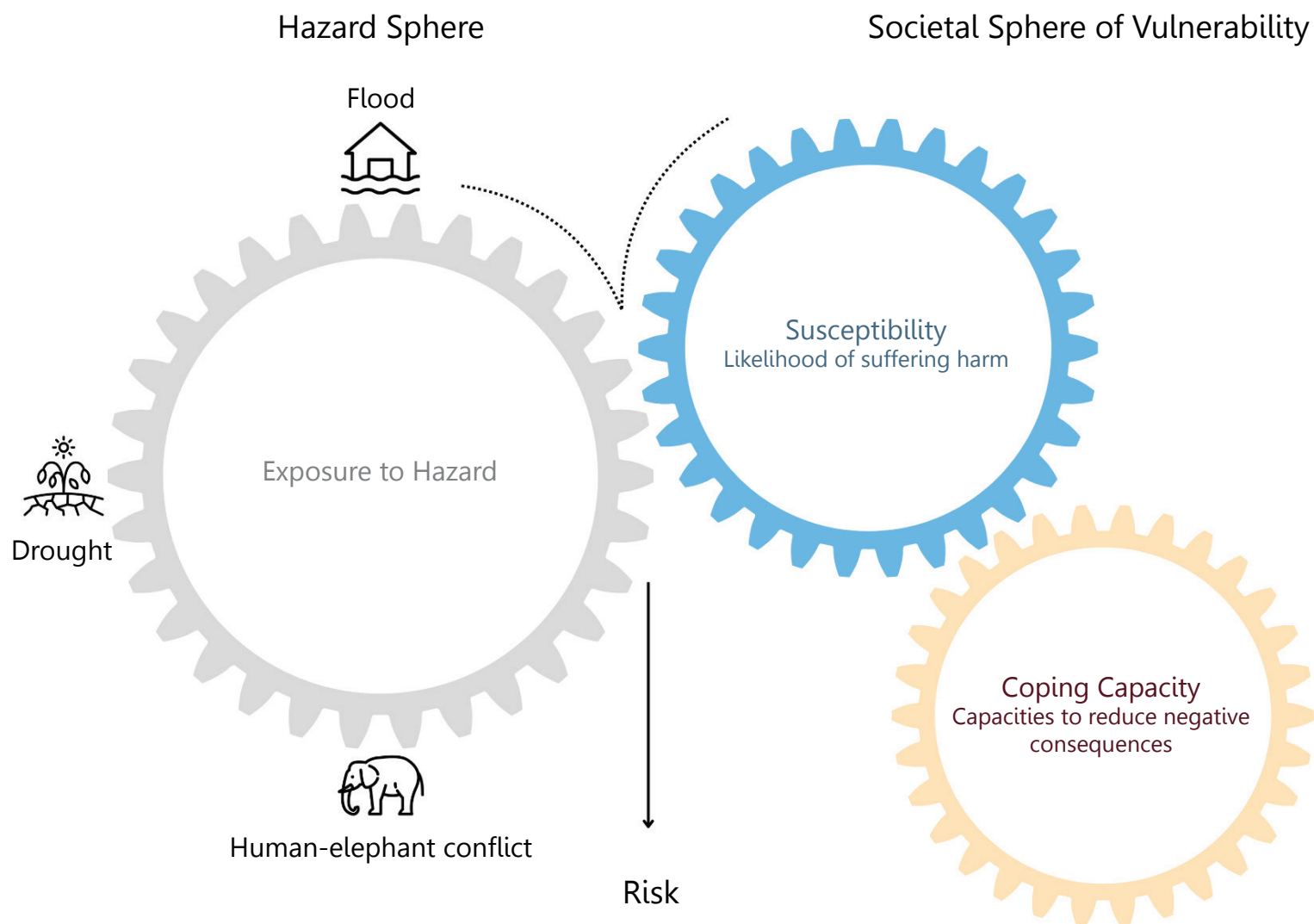| Table 4. Multi-hazard risk index				
GND	Flood risk index	Drought risk index	HEC risk index	Multi-hazard risk
Muruththanai	**0.18**	**0.25**	**0.03**	**0.15**
Perillaveli	**0.26**	**0.14**	**0.04**	**0.15**
Vahanery	**0.25**	**0.08**	**0.05**	**0.13**
Poolakadu	0.15	0.07	0	0.07
Thigilavaddi	0.13	0.03	0.06	0.07
Kudumbimalai	0.09	0.02	0.04	0.05
Palaiyadithona	0.02	0.01	0.01	0.05
Punanai West	0.1	0.03	0	0.05
Kiran West	0.11	0.01	0	0.04
Koraveli	0.09	0.02	0.01	0.04
Morokoddanchenai	0.11	0	0	0.04
Santhiveli	0.1	0.01	0	0.04
Thevapuram	0.07	0.01	0	0.03
Uththuchenai	0.04	0.02	0	0.02
Kiran East	0	0	0	0
Korakkallimadu	0	0	0	0
Vadamunai	0	0	0	0

OTHER POTENTIAL HAZARDS

Other hazards also affect the population in Koralai Pattu South, the combination of factors such as **land degradation**, **epidemics**, and **water scarcity** significantly impact livelihood resilience activities, increasing challenges to communities in Koralai Pattu South. 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.

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Graph 1. Multi-hazard risk concept

Hazard Sphere

Societal Sphere of Vulnerability

Flood

Exposure to Hazard

Drought

Human-elephant conflict

Risk

Susceptibility
Likelihood of suffering harm

Coping Capacity
Capacities to reduce negative consequences

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, Imax - 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 calclulated for drought, flood and HEC

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Hazard, exposure and vulnerability index calculations

Hazard	Data source	Methodology
Drought	NASA Modis data[24] for vegetation and land-surface temperature data as well as CHIRPS rainfall datasets[25] from Earth Engine Data Catalog[26]	VCI data derived from Modis EVI[27] (2003-2023) using the UN-Spider methodology (GEE code[28]). VHI was calculated using NDVI[29] and LST[30] data based on UN-Spider methodology[31] (GEE code). The SPI[32] 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[33].
Flood	European Space Agency's Sentinel-1 synthetic aperture radar (SAR) data 2019-2022 from Earth Engine Data Catalog[34]	Spider flood assessment methodology[35] 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[36]	Forest fragmentation was detected using LandTrend methodology[37] based on Landsat satellite imagery acquired from 1990 to 2022

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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