SRI LANKA

Area-Based Risk Assessment in Vavuniya North Divisional Secretariat Division

Vavuniya District

May 2024

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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 (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 Sri Lanka's 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 severely affected marginalized communities' capacity to withstand the impacts of even minor external shocks[2].

According to local authorities' data, Sri Lanka's northern 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 Vavuniya North Divisional Secretary's Divisions (DSD) in Vavuniya district, Northern 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 in predicting better, preparing for, and responding 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 Vavuniya North 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.

Through the study, IMPACT identified three GNDs, namely Ananthapuliyakulam, Katkulam, and Puliyankulam South as the most at risk for multiple hazards. Ananthapuliyakulam presents the highest drought risk, combined with a high flood risk. Katkulam has a combination of high flood and HEC risks and Puliyankulam South presents a combination of the three hazards.

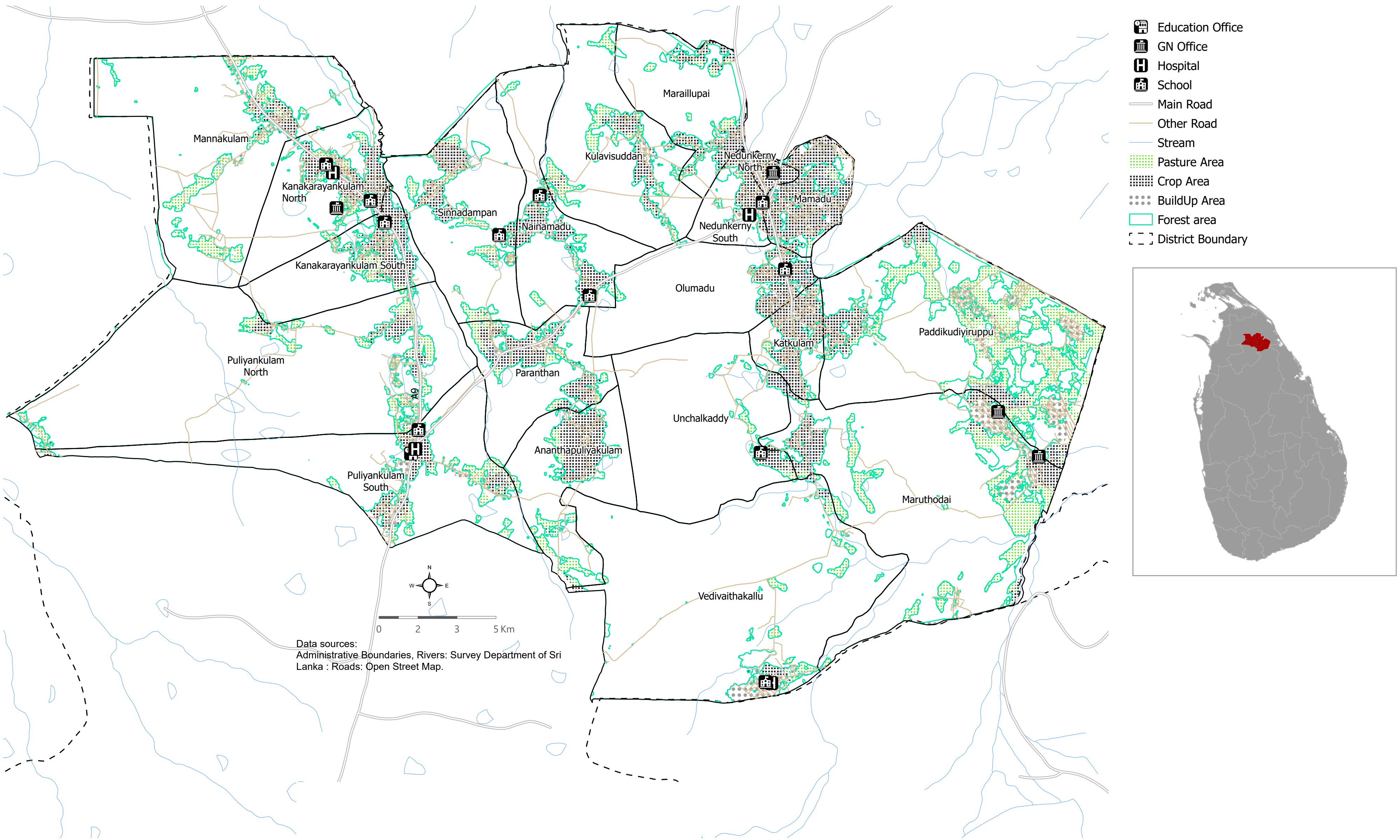
In Katkulam, the population has the highest level of vulnerability regarding social dependency, with a high share of female-headed households, families with members with a disability, as well as many children and older people. Social dependency is when an individual or group relies on another individual or group for resources, support, or guidance. Unchalkaddy presents the family's livelihood dependency on agriculture and inland fishery.

According to local authorities, 15 out of the 20 GNDs have registered elephant attacks. The DSD had 4243 ha of forest loss between 1990 and 2022, accounting for 8% of the current forest area.

Ananthapuliyakulam has the lowest economic situation, with 70% of households earning daily wages between 2000 and 3000 LKR and 42% of unemployed individuals, according to local authorities. The unemployment and low-income rates are social insecurity indicators, that present the low financial capacity to prepare and recover from hazards.

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 Vavuniya North against single and multi-hazard scenarios.

Map 1. Overview map of Vavuniya North DSD



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

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BACKGROUND

Located in the Northern province, Vavuniya district, Vavuniya North DSD covers an area of 769.6 km², almost 40% of the Vavuniya district area. The population size is 19,258 individuals, of whom 50,7% are female and 25% children living across 20 Grama Nilhadari Divisions (GNDs) and 110 villages[3]. It is estimated that the dependency ratio reaches 32%, which is the population below 15 and above 60 years old. The average population density is 25/ km².

Administratively, the division constitutes a part of Wanni Electoral District. Vavuniya North is located in the dry zone of Sri Lanka[4]. The terrain in Vavuniya North is mainly flat areas with forest land. Additionally, several ponds and water bodies in the region contribute to agriculture, livestock and fishing activities. Vavuniya North experiences a tropical climate with distinct wet and dry seasons, with 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, Vavuniya North's geography significantly shapes its economy, with livelihood activities primarily revolving around agriculture. Out of the 769.6 km², 56.45 km² are used for agriculture, 43.18 km² of those for paddy cultivation, standing out as the predominant agricultural activity and the average yield of the paddy was the region was 15,850.5 Mt in both seasons. In Vavuniya North, 3047 families have paddy cultivation as their main income source. The farmers also practice highland crop cultivation apart from paddy cultivation in the division. Beyond agriculture, livestock and milk production are the secondary contributors to the division's economy, in addition to those livelihood activities, 73 families work in freshwater fishing, which is conducted on a small scale in inland water sources[5].

During heavy monsoon rains, low-lying areas in Vavuniya North 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. Vavuniya North 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. Vavuniya North'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.

The ABRA measured the risk in the 20 GNDs in Vavuniya North, 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 Vavuniya North that considers specific local environmental, social, and economic factors, the study is intended to address a data gap and contribute to inform initiatives to enhance the resilience of communities and territories faced 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)[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 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 Vavuniya North, 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 Vavuniya North.

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 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 of all GNDs in Vavuniya North (Map 2), almost 10% of the total area is affected by drought and an average of 15% of cropland and 38% of pasture land. In total terms, Ananthapuliyakulam presents the highest hazard index, with the largest drought area, almost 1100 ha, covering 43% of the GND area, 24% of affected cropland, and 87% of pasture land.

Paranthan, Puliyankulam South, Mamadu, and Nedunkerny North have between 15% and 35% of their territory affected by drought. Mamadu has the highest shares of crop and pasture land affected by drought, 57% and 100%, respectively. Unchalkaddy

Map 2. Drought exposure

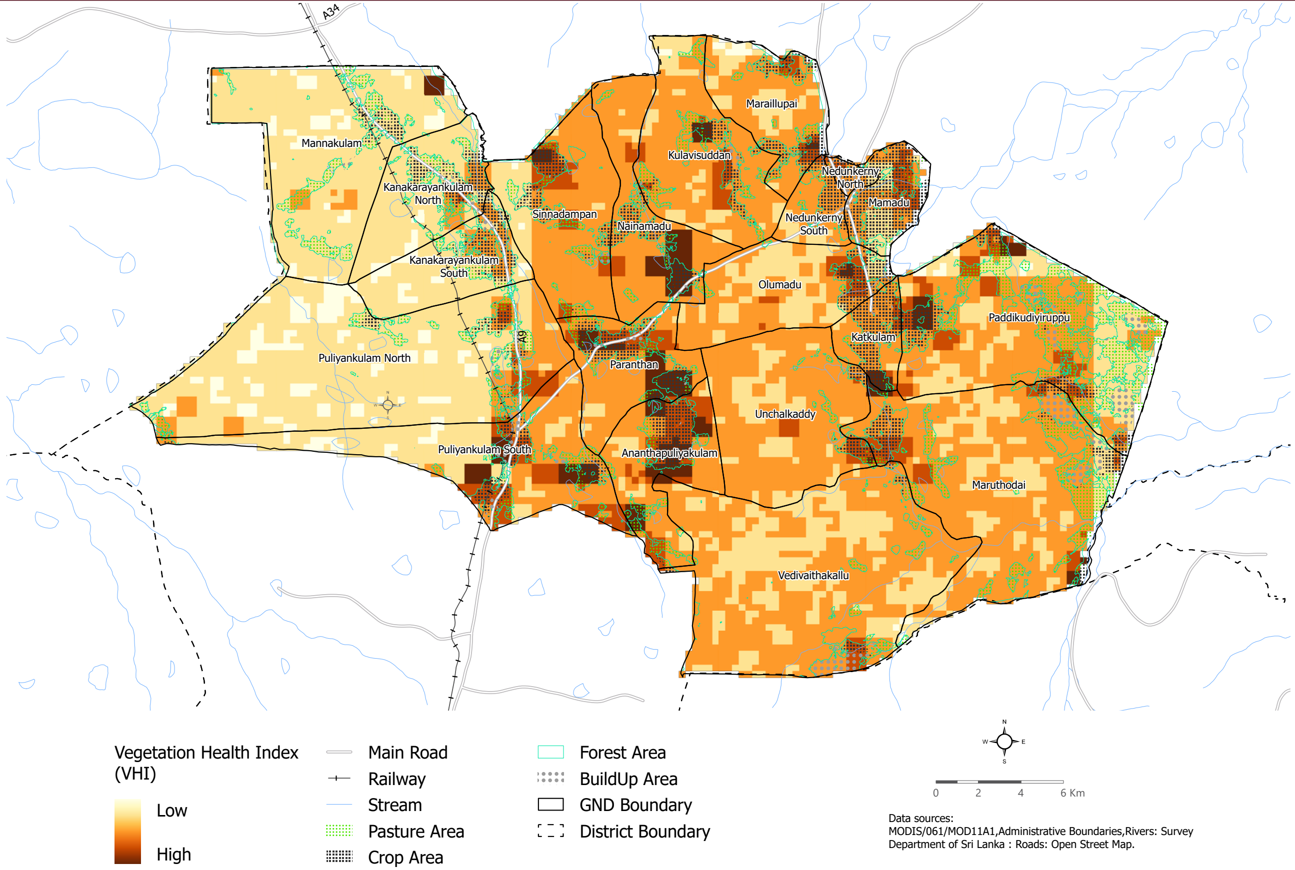


Figure 1. Percentage of drought-affected areas and agricultural families[14]

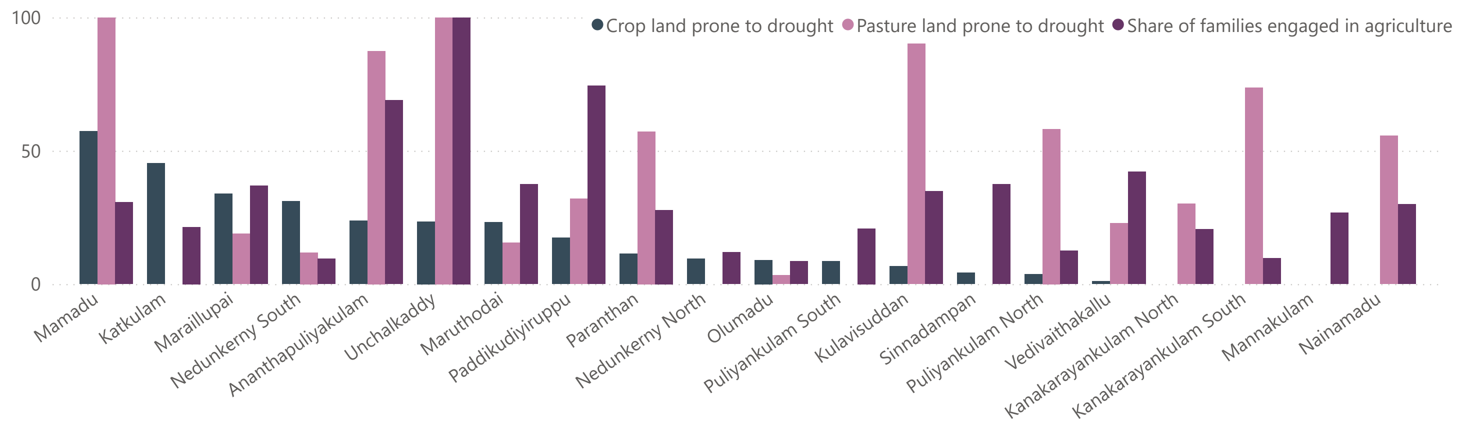


Table 1. Drought risk index

GND	Hazard	Exposure	Vulnerability	Risk
Ananthapuliyakulam	**1.00**	**0.49**	**0.68**	**0.337**
Paranthan	**0.71**	**0.44**	**0.35**	**0.110**
Puliyankulam South	**0.98**	**0.29**	**0.35**	**0.098**
Paddikudiyiruppu	0.84	0.28	0.33	0.079
Mamadu	0.20	0.83	0.37	0.062
Kulavisuddan	0.32	0.47	0.37	0.056
Unchalkaddy	0.17	0.47	0.66	0.054
Maruthodai	0.46	0.25	0.45	0.051
Nainamadu	0.35	0.35	0.39	0.049
Puliyankulam North	0.24	0.55	0.28	0.037
Katkulam	0.13	0.40	0.59	0.031
Sinnadampan	0.44	0.21	0.32	0.030
Maraillupai	0.14	0.38	0.47	0.026
Olumadu	0.25	0.31	0.32	0.026
Vedivaithakallu	0.15	0.39	0.37	0.022
Nedunkerny North	0.03	0.20	0.46	0.003
Kanakarayankulam North	0.02	0.33	0.34	0.003
Nedunkerny South	0.02	0.44	0.28	0.002
Kanakarayankulam South	0.00	0.58	0.40	0.000
Mannakulam	0.00	0.15	0.27	0.000

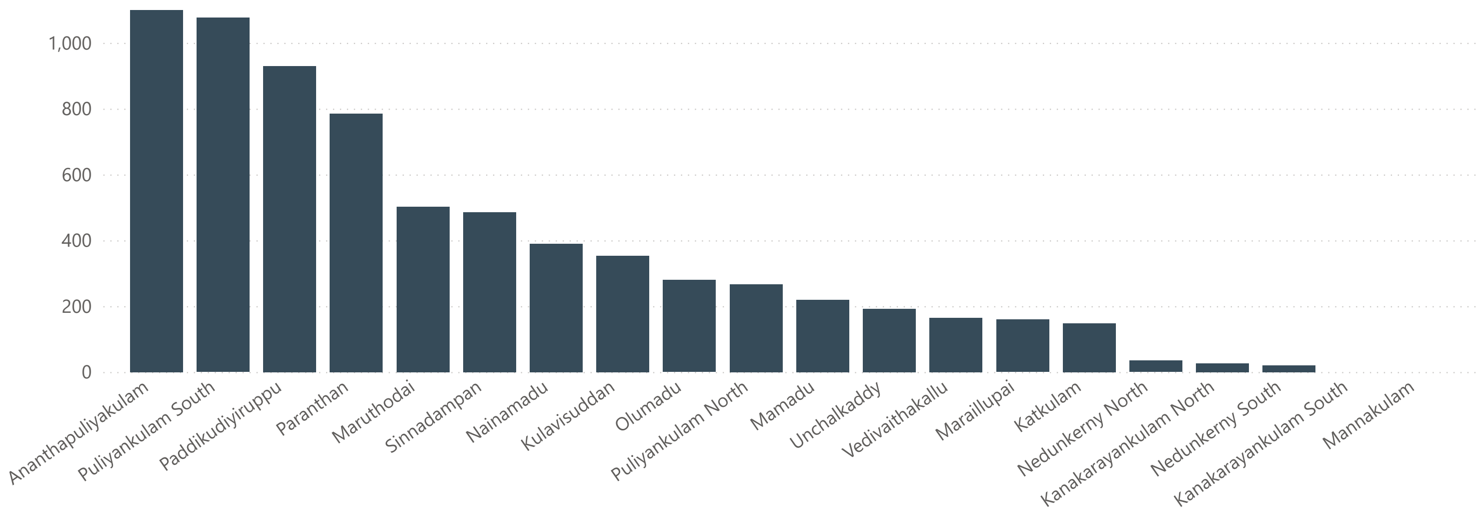
Hazard, exposure and vulnerability values were calculated as a relative indicator (for more details please see the Annex 2)

also has 100% pasture land affected, six GNDs have between 20% and 45% affected cropland, and pasture land is even more affected, with six GNDs between 55% and 90% affected areas. Beyond the high hazard and exposure indexes, Ananthapuliyakulam has almost 70% of families engaged in agriculture, 20% of female-headed households, 37% dependency ratio, and 70% of households earning daily wages between 2000 and 3000 LKR. The combination of high hazard, exposure, and vulnerability leads the GND to the highest risk of drought.

The fourth largest drought area leads Paranthan to high risk. The GND has 57% of drought prone farming land, 28% of families engaged in agriculture, and 30% of low-income families. The third GND most at risk is Puliyankulam South with almost 1080 ha of drought area, 26% child density, and 41% of low-income households.

GNDs characterized by high population density 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, pasture land prone to drought, and share of affected fishery families. The analysis suggests a risk of severe agricultural and livestock production decline in Vavuniya North. Unchalkaddy, Paddikudiyiruppu, Ananthapuliyakulam, and Vedivaithakallu have over 40% of families engaged in agriculture, the first three with around 20% of drought-affected cropland.

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



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FLOODS

The rainy season in Vavuniya North lasts from September to February, with most floods typically happening from December to February (Map 3), caused by heavy rainfall and improper maintenance of existing natural drainage systems, improper land use, and deforestation in the headwater region[17].

Between 2018 and 2020, satellite images showed that 4349 hectares of Vavuniya North were flooded. The largest flooded areas were registered in Paddikudiyiruppu and Maruthodai, with 856 ha and 834 ha. The flooded areas in the two GNDs represented over 40% of flood cover in Vavuniya North. Mamadu and Nedunkerny North had 37% and 27% of their territories affected by floods, respectively. 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 Katkulam is at the highest risk due to its high hazard exposure and vulnerability. It has the largest percentage of built-up area within a flood zone, 13%, and 26% of cropland. The GND has 21% of female-headed households, 18% of families with members with a

Map 3. Flood exposure

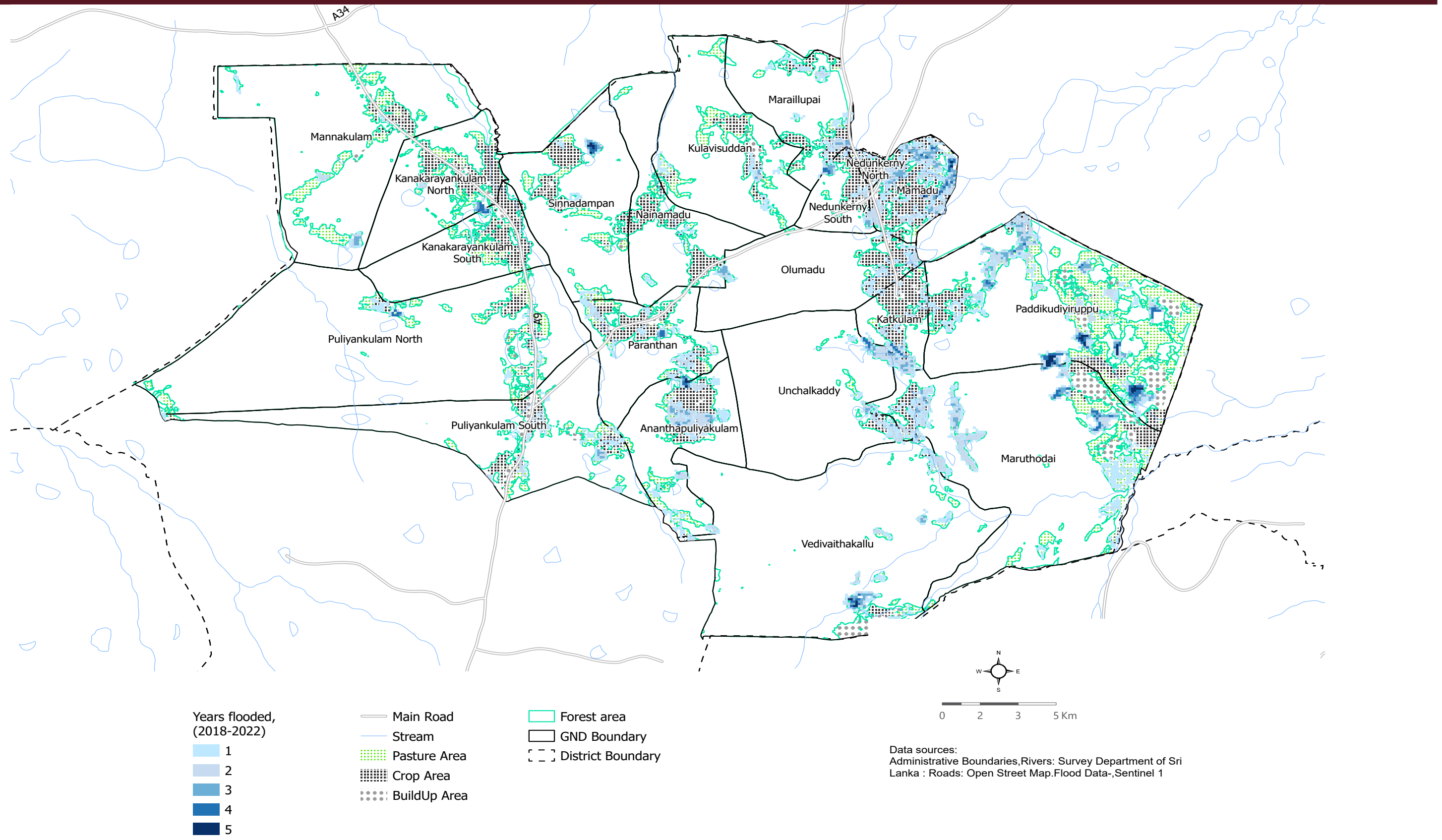


Figure 3. Flood-affected areas and inland fishery and agricultural families[16]

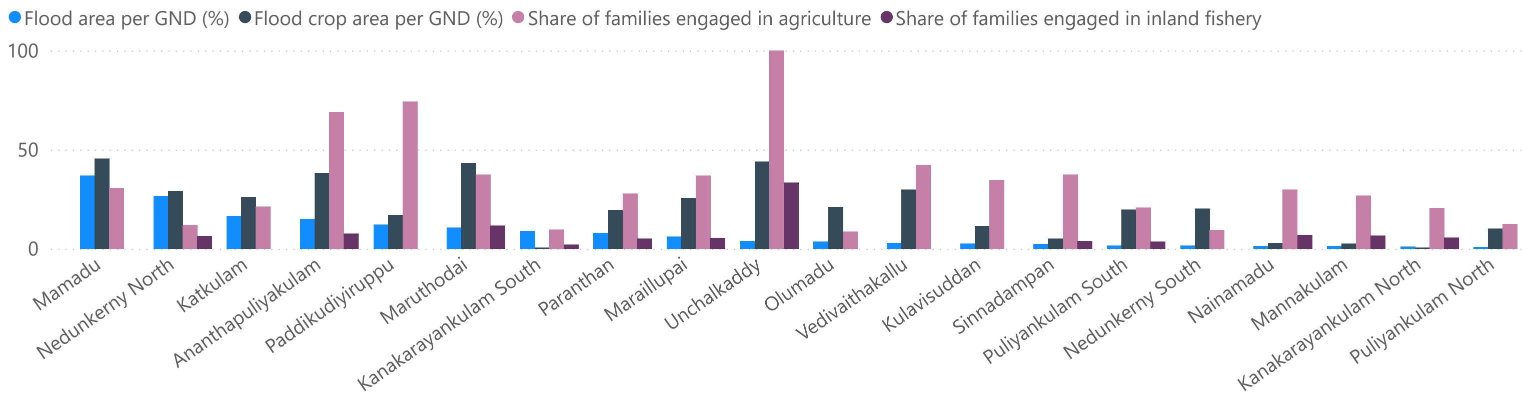


Table 2. Flood risk index

GND	Hazard-Exposure	Vulnerability	Risk
Katkulam	**0.52**	**0.30**	**0.155**
Maruthodai	**0.64**	**0.21**	**0.137**
Mamadu	**0.64**	**0.17**	**0.109**
Paddikudiyiruppu	0.42	0.20	**0.086**
Unchalkaddy	0.29	0.30	0.085
Olumadu	0.49	0.17	0.083
Vedivaithakallu	0.46	0.17	0.077
Nedunkerny North	0.36	0.21	0.077
Puliyankulam South	0.46	0.17	0.077
Ananthapuliyakulam	0.24	0.31	0.074
Maraillupai	0.20	0.22	0.043
Paranthan	0.21	0.17	0.037
Nainamadu	0.05	0.70	0.035
Puliyankulam North	0.25	0.13	0.033
Nedunkerny South	0.23	0.13	0.030
Sinnadampan	0.15	0.15	0.022
Kulavisuddan	0.10	0.17	0.018
Kanakarayankulam South	0.09	0.19	0.017
Kanakarayankulam North	0.02	0.17	0.003
Mannakulam	0.02	0.13	0.002

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

disability, a high dependency ratio and half of low-income households. Maruthodai and Mamadu follow with the highest hazard exposure index, around 45% of affected cropland. Maruthodai has the highest affected population density and 42% of unemployed individuals and Mamaduhas 10% of affected built-up areas and 64% of low-income households.

Mannakulam, Kanakarayankulam North, and Kanakarayankulam South have the lowest risk due to having low hazard exposure, with low flooded areas during the assessed period. All GNDs have two evacuation centres, but Nainamadu with only one, demonstrating efforts to support the community's coping capacity.

The distribution of flood risks in Vavunyia North underscores the need for flood management plans, especially during agricultural seasons, to mitigate adverse effects. Ten GNDs have between 20% and 45% of cropland within flood zones, indicating a significant impact on agricultural activities, considering that these GNDs have 45% of families engaged in agriculture, on average. Agricultural production is critical for the livelihood and food security of families.

Figure 4. Crop area, flood area, and flooded crop area per GND[18]

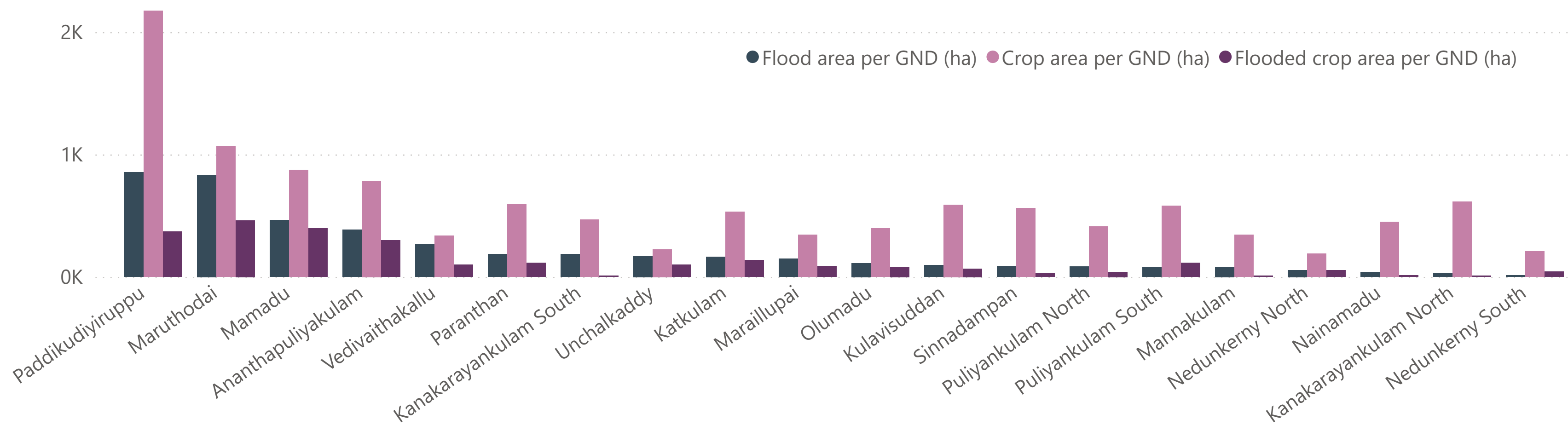
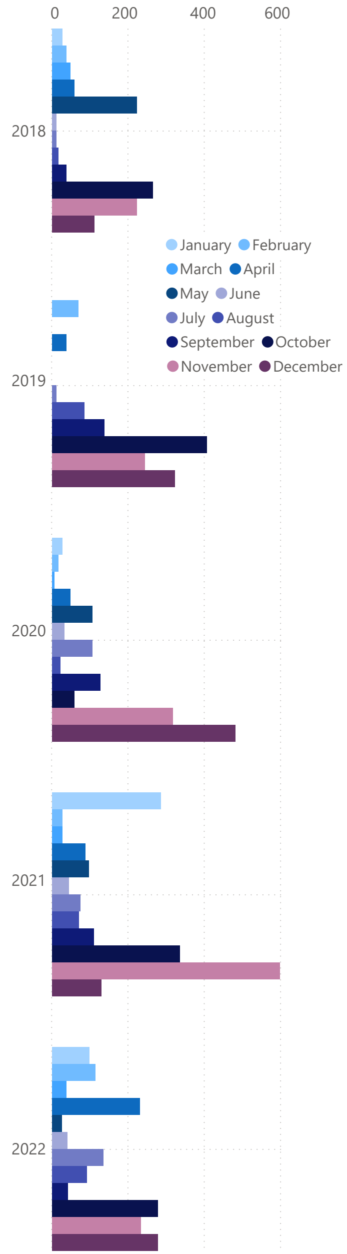


Figure 5. Annual rainfall in Vavuniya North[19]



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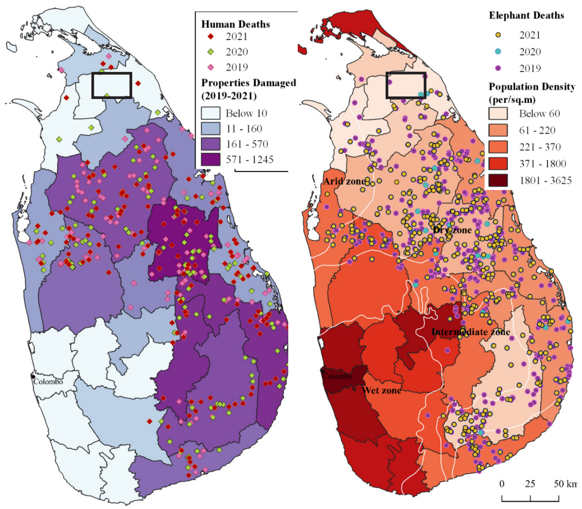
HUMAN-ELEPHANT CONFLICT

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 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[20].

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

Figure 6. Human death and property damage caused by elephants/Elephant death and human density[23]



Map 4. Human-elephant conflict exposure

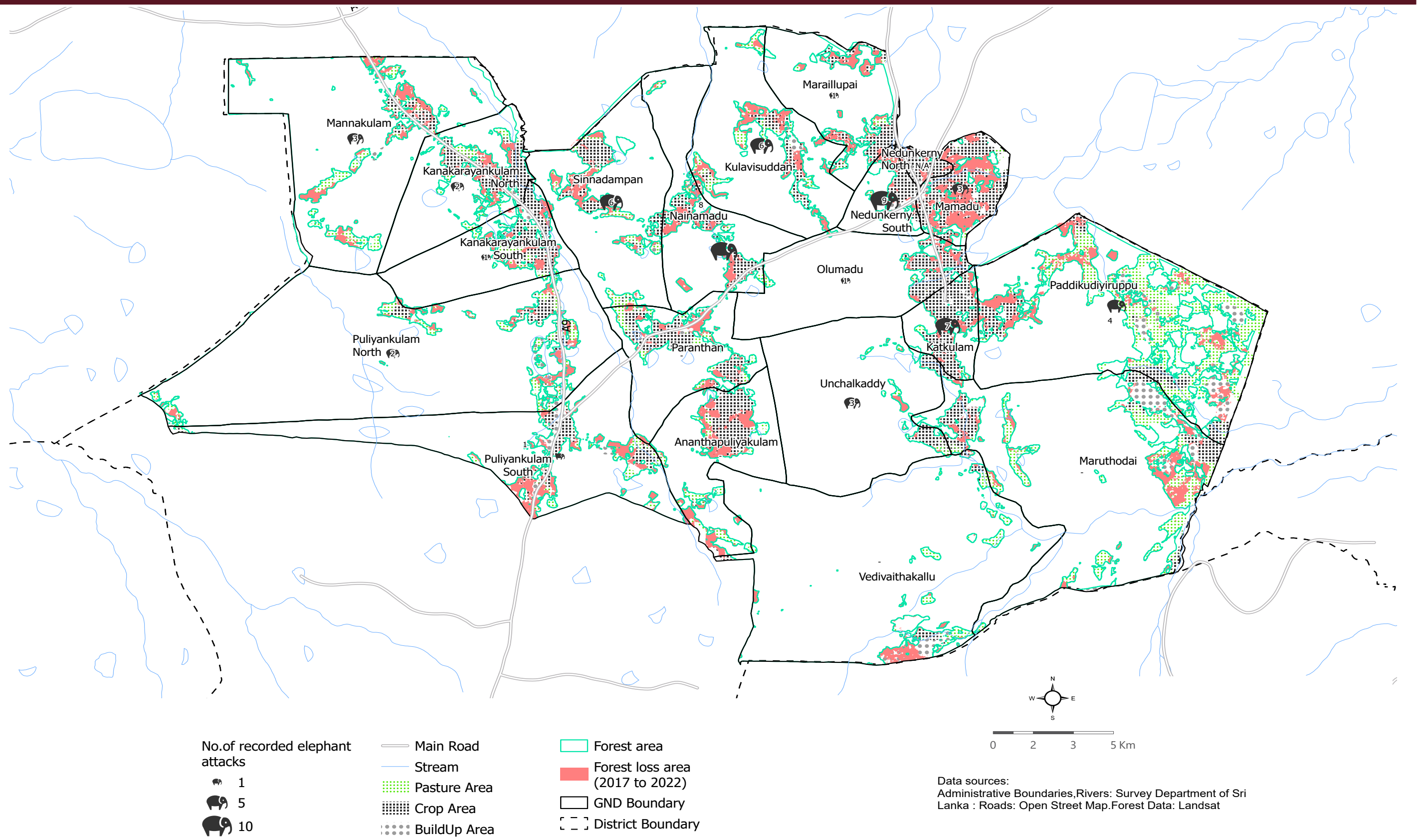


Figure 7. Human and elephant deaths in Sri Lanka[22]

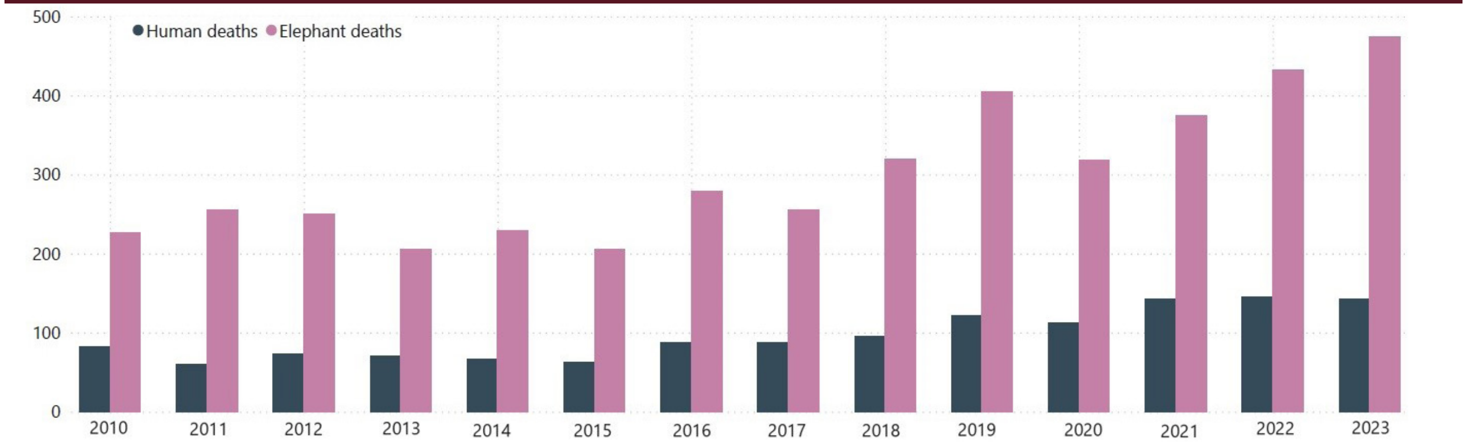


Table 3. HEC risk index

GND	Hazard	Exposure	Vulnerability	Risk
Puliyankulam North	**0.57**	**1.00**	**0.26**	**0.147**
Vedivaithakallu	**0.43**	**0.91**	**0.33**	**0.129**
Nainamadu	**0.53**	**0.51**	**0.39**	**0.105**
Puliyankulam South	0.39	0.71	0.33	0.092
Sinnadampan	0.48	0.57	0.30	0.083
Katkulam	0.33	0.40	0.60	0.081
Mamadu	0.41	0.50	0.34	0.069
Kanakarayankulam South	0.18	1.00	0.39	0.068
Nedunkerny South	0.39	0.67	0.26	0.067
Mannakulam	0.51	0.44	0.26	0.058
Paddikudiyiruppu	0.63	0.23	0.40	0.057
Kanakarayankulam North	0.24	0.68	0.33	0.055
Olumadu	0.20	0.75	0.34	0.050
Maraillupai	0.24	0.37	0.44	0.039
Maruthodai	0.49	0.18	0.43	0.038
Paranthan	0.18	0.54	0.35	0.034
Kulavisuddan	0.22	0.39	0.34	0.030
Ananthapuliyakulam	0.20	0.19	0.62	0.023
Nedunkerny North	0.01	0.43	0.42	0.002
Unchalkaddy	0.30	0.00	0.59	0.000

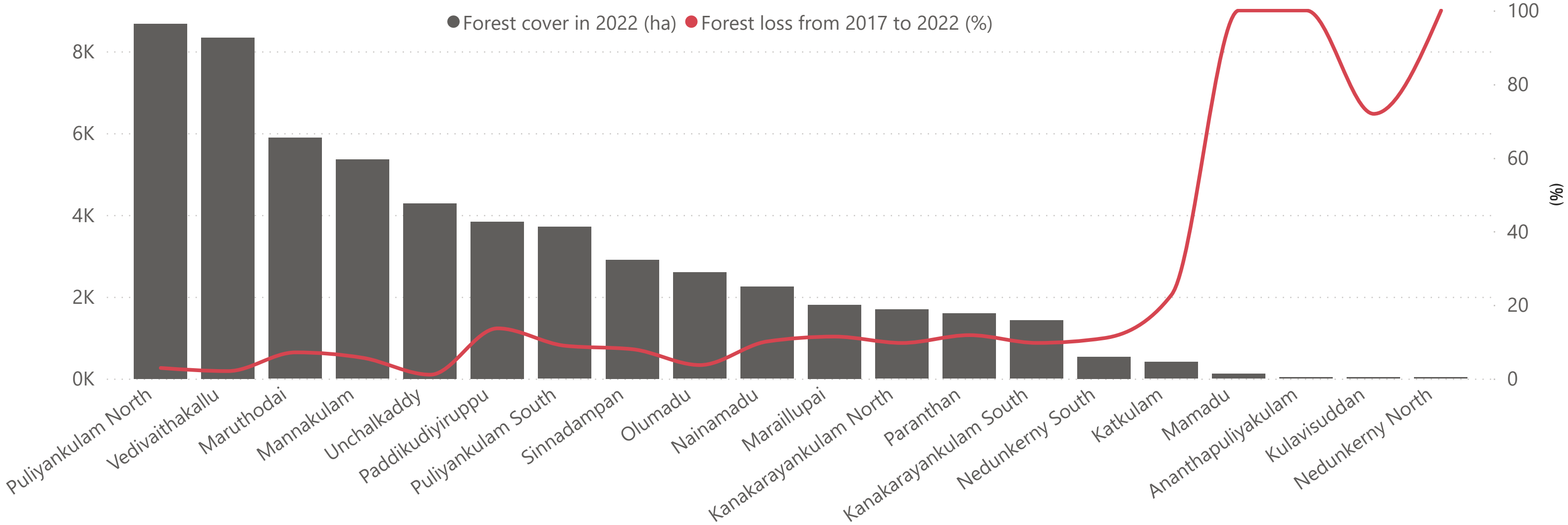
Hazard, exposure and vulnerability values were calculated as a relative indicator (for more details please see the Annex 2)

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 incidences in Sri Lanka happened in open forests, while 62% were within 2 km of the forest edge[21].

Table 3 shows Puliyankulam North as the GND most at risk with 2 registered elephant attacks. The high risk is driven by the highest population density and forest area, the dependency ratio is 34%. Vedivaithakallu and Nainamadu follow, both with around 14% of low-income families, 30% dependency ratio, and over 30% of families engaged in agriculture. Vedivaithakallu has the second largest forest area and third largest population density, but had no recorded elephant attacks, whereas Nainamadu, had eight incidents. According to local authorities' data, 15 GNDs out of the 20 registered elephant attacks, the highest in Nedunkerny South, with nine incidents. The impact of deforestation is evident in Vavuniya North, the DSD had an average of 212 ha of forest disturbance across all GNDs in the last five years, representing 277% of the current forest area size (Figure 8).

Maruthodai, Mannakulam, Unchalkaddy, and Paddikudiyiruppuhave have large forest areas and relatively low population density. With the correct protection and conservation efforts application, they have the potential to sustainably host human and elephant populations. Unchalkaddy, Nedunkerny North, and Ananthapuliyakulam present the lowest risk to HEC, resulting from low hazard and exposure indicators. However, the three GNDs have high vulnerability indexes with high socio-economic dependency and Unchalkaddy with highest livelihood dependency on agriculture and inland fishery.

Figure 8. Forest disturbance in the last 5 years[24]



MULTI-HAZARD RISK

Vavunyia North'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 (≥0.14 out of 1) is Ananthapuliyakulam and high risk (≥0.07 out of 1) are Katkulam, Puliyankulam South, Mamadu, Vedivaithakallu, Maruthodai, Paddikudiyiruppu, and Puliyankulam North.

Ananthapuliyakulam presents the highest drought risk, combined with a high flood risk. The GND has high vulnerability due to 20% of female-headed households, the highest share of older people and 70% of low-income families. Katkulam has a combination of high flood and HEC risks, with 21% of female-headed households and 18% of families with members with a disability contributing to its vulnerability. Puliyankulam South presents a combination of the three hazards.

The higher exposure to natural hazards and the socio-economic vulnerability of the population increases the risk to communities highly dependent on natural resources for their livelihoods. Vavunyia North has an average of 37% of families engaged in agriculture and 34% earning daily wages between 2000 and 3000 LKR, this further impacts their ability to prepare for, respond to, and recover from shocks. Unchalkaddy, Paddikudiyiruppu, and Ananthapuliyakulam have over 65% of families engaged in agriculture. The lack of livelihood diversification might pose a threat in the future. 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.

Mannakulam, Kanakarayankulam North, and Nedunkerny North present the lowest multi-hazard risk, the first two having low flood and drought exposure, but medium HEC risk, and the third with low drought and HEC exposure.. Mannakulam has the lowest vulnerability index.

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 Vavunyia North present opportunities for a multi-pronged approach to mitigating disaster risks and their impact on communities.

Map 5. Multi-hazard map

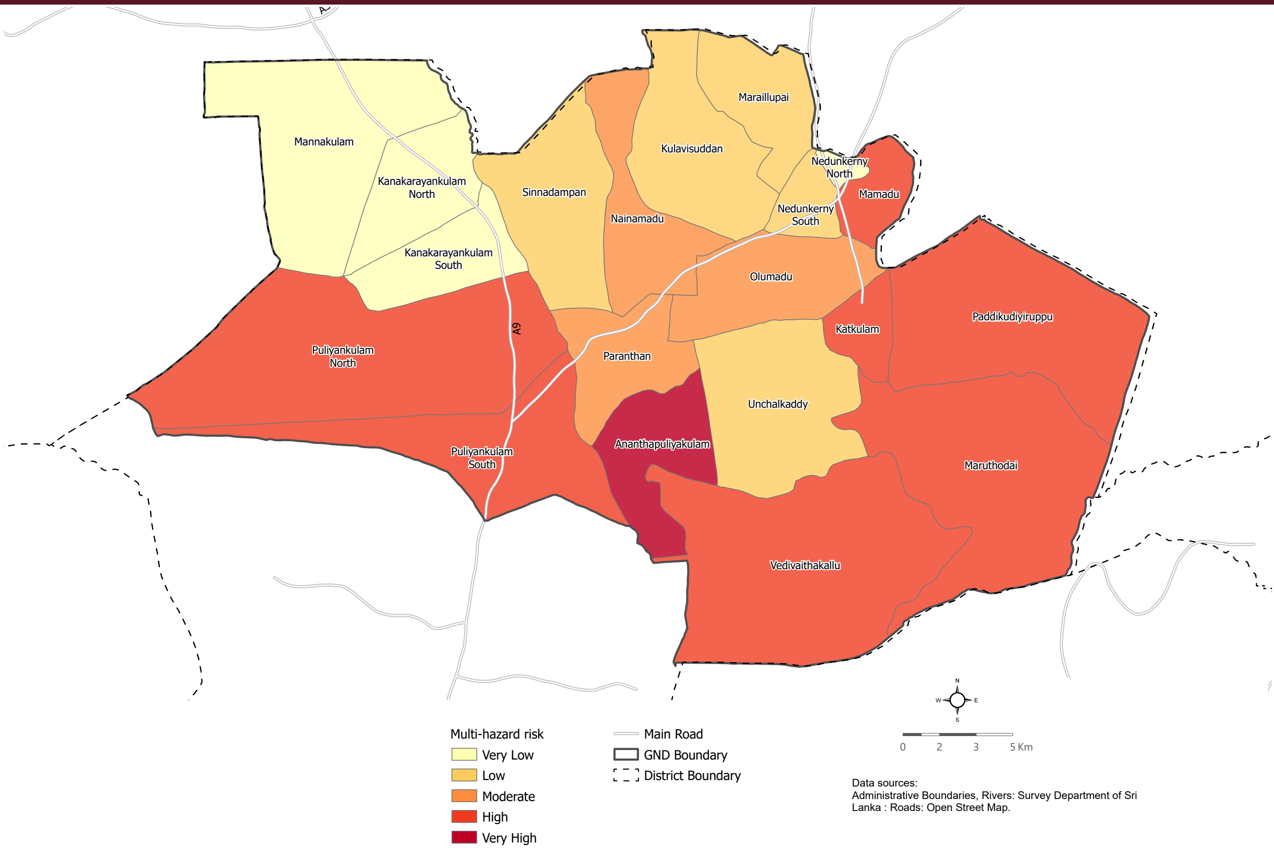


Table 4. Multi-hazard risk index

GND	Flood	Drought	HEC	Multi-hazard risk
Ananthapuliyakulam	**0.07**	**0.34**	**0.02**	**0.145**
Katkulam	**0.15**	**0.03**	**0.08**	**0.089**
Puliyankulam South	**0.08**	**0.10**	**0.09**	**0.089**
Mamadu	0.11	0.06	0.07	0.080
Vedivaithakallu	0.08	0.02	0.13	0.076
Maruthodai	0.14	0.05	0.04	0.075
Paddikudiyiruppu	0.09	0.08	0.06	0.074
Puliyankulam North	0.03	0.04	0.15	0.072
Nainamadu	0.03	0.05	0.10	0.063
Paranthan	0.04	0.11	0.03	0.060
Olumadu	0.08	0.03	0.05	0.053
Unchalkaddy	0.08	0.05	0.00	0.046
Sinnadampan	0.02	0.03	0.08	0.045
Maraillupai	0.04	0.03	0.04	0.036
Kulavisuddan	0.02	0.06	0.03	0.035
Nedunkerny South	0.03	0.00	0.07	0.033
Kanakarayankulam South	0.02	0.00	0.07	0.028
Nedunkerny North	0.08	0.00	0.00	0.027
Kanakarayankulam North	0.00	0.00	0.06	0.020
Mannakulam	0.00	0.00	0.06	0.020

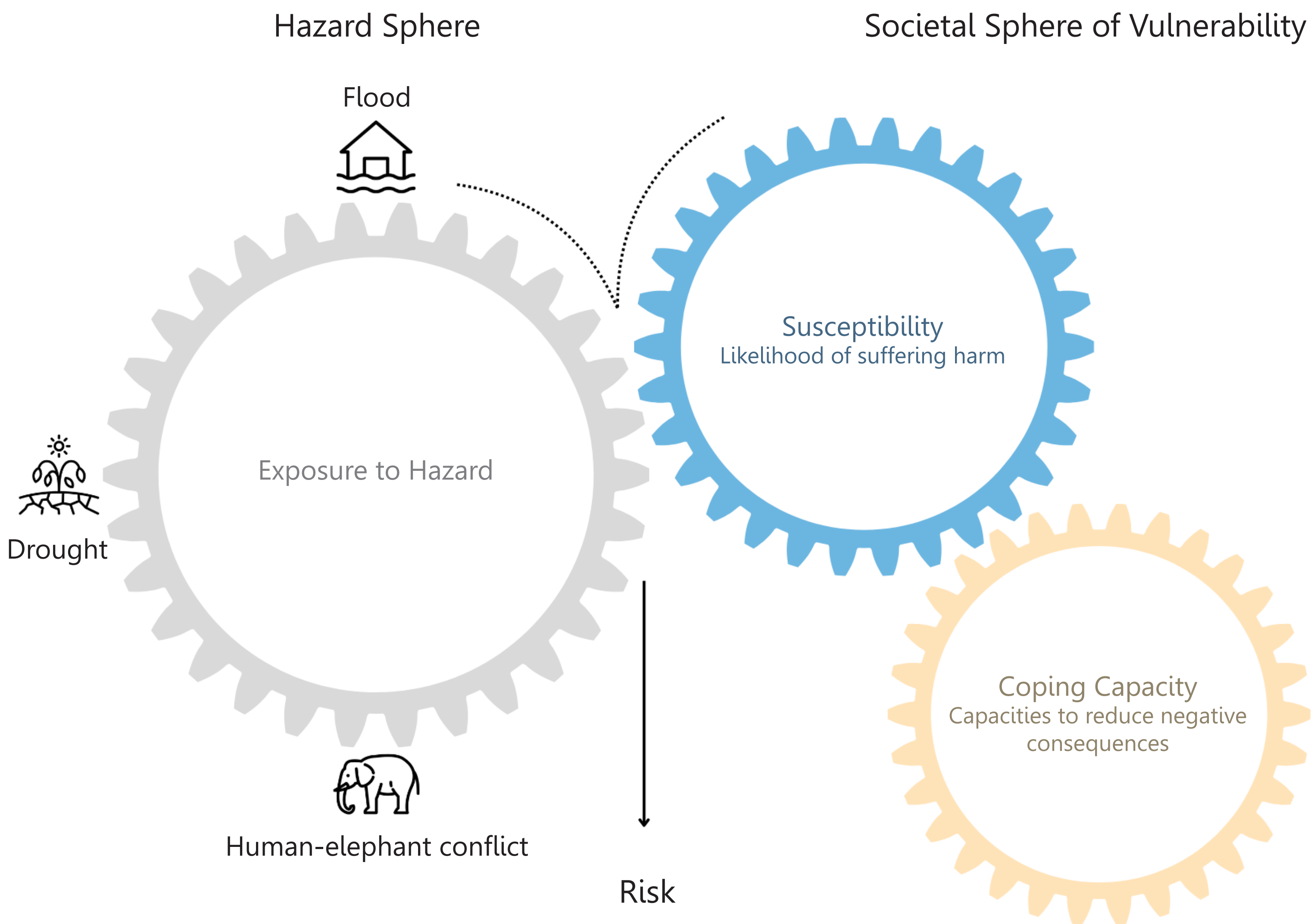
OTHER POTENTIAL HAZARDS

Other hazards also affect the population in Vavuniya North, 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, 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 calculated for drought, flood and HEC

ANNEX 2

Hazard, exposure and vulnerability index calculations

Hazard	Data source	Methodology
Drought	NASA Modis data[25] for vegetation and land-surface temperature data as well as CHIRPS rainfall datasets[26] from Earth Engine Data Catalog[27]	VCI data derived from Modis EVI[28] (2003-2023) using the UN-Spider methodology (GEE code[29]). VHI was calculated using NDVI[30] and LST[31] data based on UN-Spider methodology[32] (GEE code). The SPI[33] 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[34].
Flood	European Space Agency's Sentinel-1 synthetic aperture radar (SAR) data 2019-2022 from Earth Engine Data Catalog[35]	Spider flood assessment methodology[36] 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[37]	Forest fragmentation was detected using LandTrend methodology[38] 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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