SRI LANKA

Area-Based Risk Assessment in Vavuniya South Divisional Secretariat Division

Vavuniya 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 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 South 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 South 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.

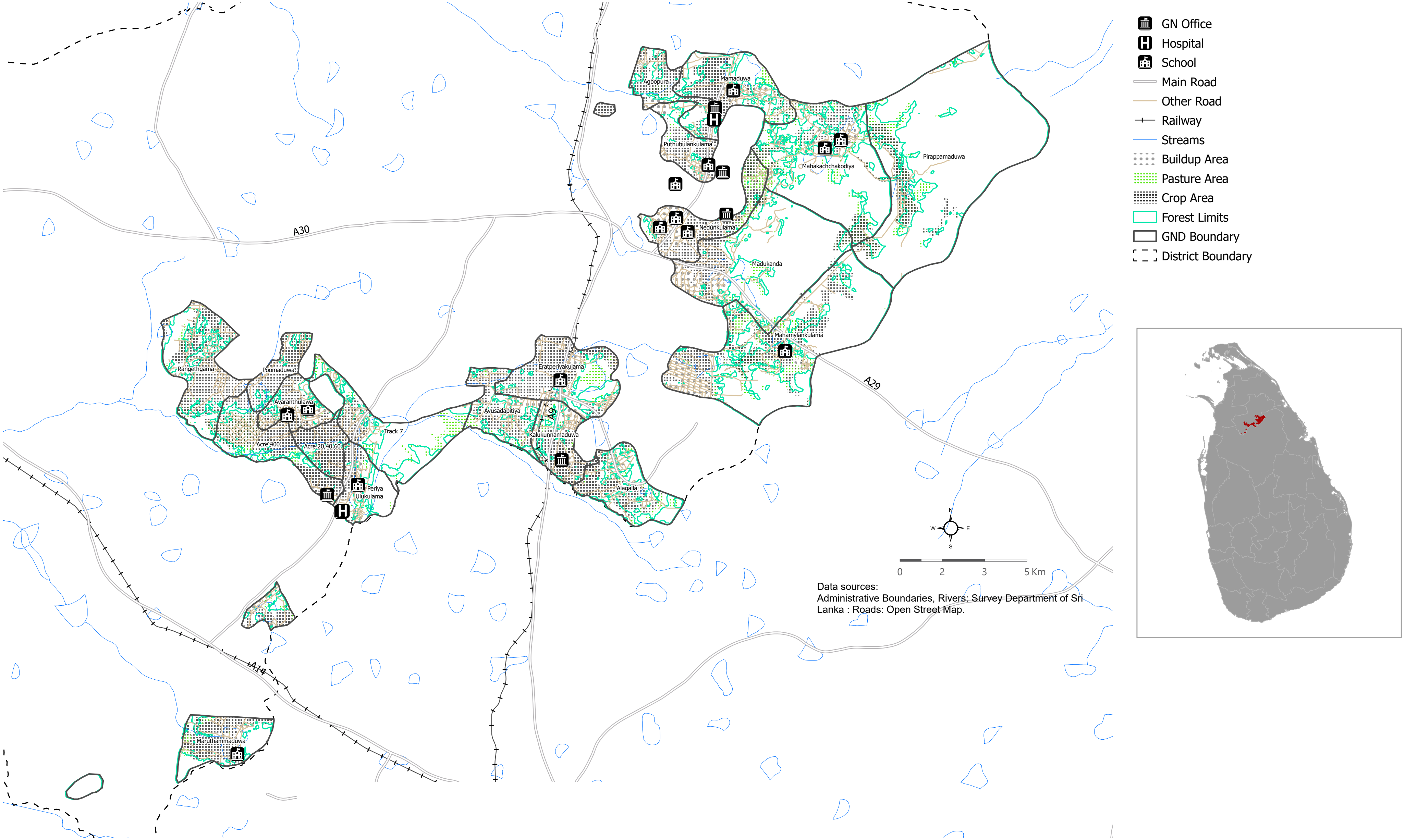
Through the study, IMPACT identified three GNDs, namely Nedunkulama, Madukanda, and Mahamailankulama as the most at risk for multiple hazards. Nedunkulama and Madukanda present the highest flood risk, combined with a high drought risk and Mahamailankulama has the highest HEC risk and above-average flood and drought risks. Nedunkulama has high vulnerability due to having 21% of female-headed households, 47% dependency ratio and 44% of low-income families. The vulnerability index increases the risk of communities to all hazards. Madukanda and Mahamailankulama have a high dependency ratio, around 25% of female-headed households, and 33% and 43% of low-income families, respectively.

In Poomaduwa, the population has the highest level of vulnerability regarding social dependency, with 64% of female-headed households 32% of families with members with a disability, and a high share of children and older people. Social dependency is when an individual or group relies on another individual or group for resources, support, or guidance. Track 7 presents the highest family livelihood dependency on agriculture and inland fishery.

Pirappamaduwa has the lowest economic situation, with 62% of households earning daily wages between 2000 and 3000 LKR and 15% 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 South against single and multi-hazard scenarios.

Map 1. Overview map of Vavuniya South 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 Northern province, Vavuniya district, Vavuniya South DSD covers an area of 188.5 km², with a population of 16,617 individuals, of whom 51% are female and 29% children, living across 20 Grama Nilhadari Divisions (GNDs) and 19 villages. It is estimated that the dependency ratio reaches 36,4%, which is the population below 15 and above 60 years old. The average population density is 88,2/ km².

The terrain in Vavuniya South is mainly flat, with several lagoons and water bodies contributing to agriculture, livestock and fishing activities. Vavuniya South is located in the dry zone of Sri Lanka, and 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. Vavuniya South was strongly affected by the 26-year civil war and now faces various natural hazards.

Administratively, the Division constitutes a part of the Wanni Electoral District, with one local body functioning in this Division, the Vavuniya South Sinhala Pradeshiya Sabhas.

Overall, Vavuniya South's geography significantly shapes its economy, with livelihood activities primarily revolving around agriculture. Out of 188.5 km² of the area, 54.6 km² is for paddy cultivation, the activity stands out as the predominant agricultural activity. The average yield of paddy was 11,625 Mt between both seasons. The farmers primarily engage in highland crop cultivation in 15.14 km² apart from paddy cultivation in this region. In addition to those livelihood activities, freshwater fishing is being conducted on a small scale in the inland water source.

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

The ABRA measured the risk in the 20 GNDs in Vavuniya 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 Vavuniya South 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)[3]. 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[4]).
- **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 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 nor exhaustive of all natural hazards in Vavuniya 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[5] (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[6]). MODIS Normalized differentiated vegetation index (NDVI[7]) and MODIS Land Surface Temperature (LST[8]) 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[9]. 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[10] 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 South (Map 2), the exposure index is considerably high across the DSD with 22% of the total area and an average of 32% of cropland affected by drought and 3% of pasture land. In total terms, Madukanda presents the highest hazard index, with the largest drought area, 740 ha, covering 37% of the GND area.

Mamaduwa has over 90% of its territory affected by drought, and another three GND have between 35% and 50% affected land. Acre 400 L.B.Coloni has almost all cropland affected by drought, ten GNDs have between 40% and 75% of drought-affected cropland. Mamaduwa has

Map 2. Drought exposure

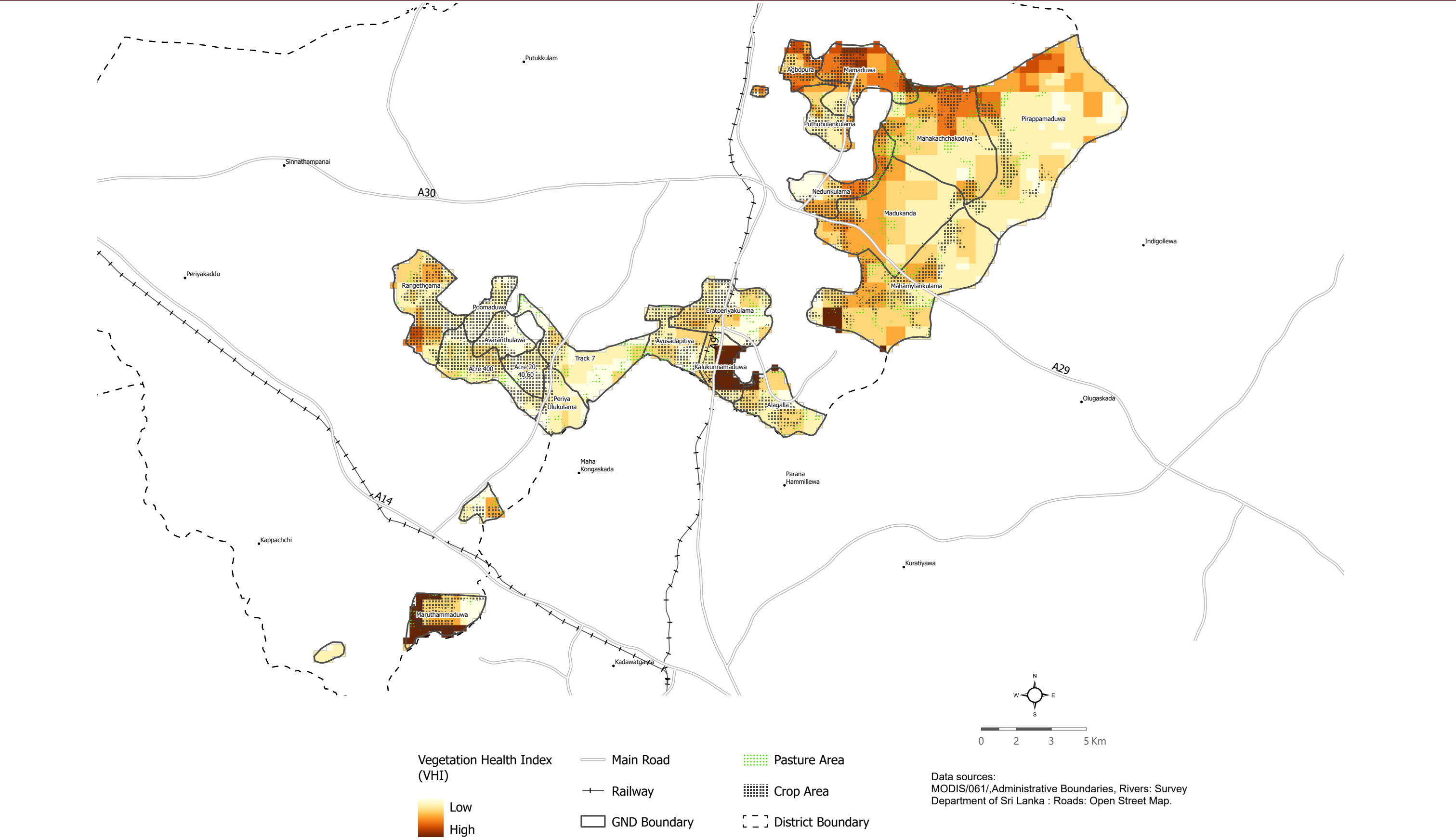


Figure 1. Drought area (ha) per GND[11]

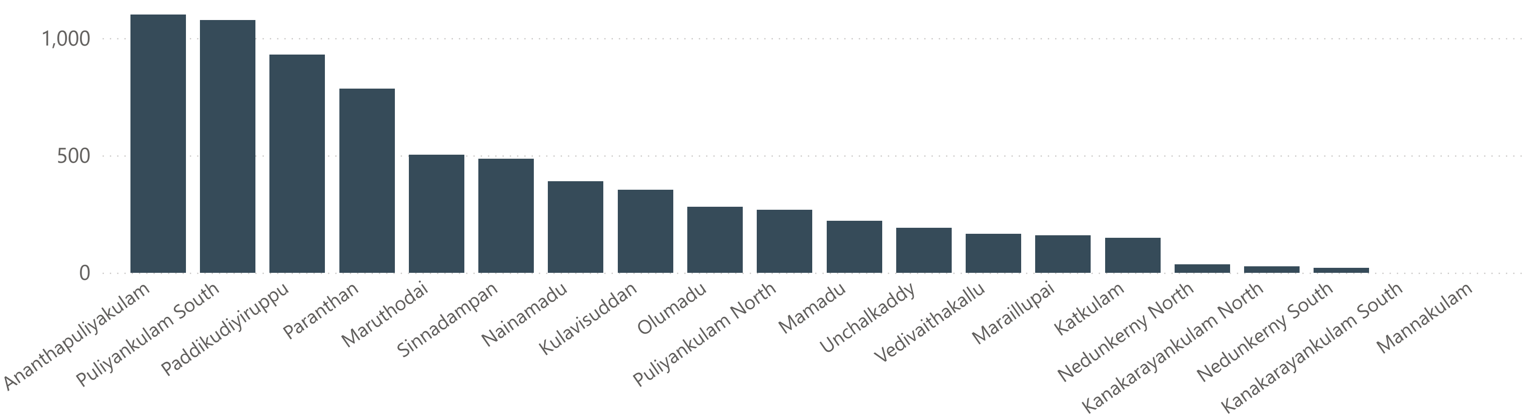


Table 1. Drought risk index				
GND	**Hazard**	**Exposure**	**Vulnerability**	**Risk**
Mamaduwa	**0.98**	**0.61**	**0.40**	**0.243**
Mahakachchakodiya	**0.92**	**0.58**	**0.31**	**0.164**
Madukanda	**1.00**	**0.42**	**0.31**	**0.130**
Pirappamaduwa	0.89	0.23	0.49	0.099
Nedunkulama	0.50	0.44	0.44	0.098
Agbopura	0.39	0.46	0.51	0.090
Mahamailankulama	0.63	0.38	0.36	0.087
Puthubulankulama	0.14	0.36	0.59	0.030
Rangethgama	0.40	0.27	0.27	0.030
Maruthammaduwa	0.21	0.42	0.34	0.029
Irattaperiyakulama	0.05	0.38	0.44	0.008
Acre 400 L.B.Coloni	0.00	0.56	0.42	0.000
Alagalla	0.00	0.14	0.20	0.000
Acre 20, 40, 60	0.00	0.11	0.23	0.000
Avaranthulawa	0.00	0.10	0.20	0.000
Avusadapitiya	0.00	0.33	0.39	0.000
Kalukunnamaduwa	0.00	0.20	0.26	0.000
Periyaulukkulama	0.00	0.23	0.67	0.000
Poomaduwa	0.00	0.00	0.38	0.000
Track 7	0.00	0.02	0.32	0.000

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

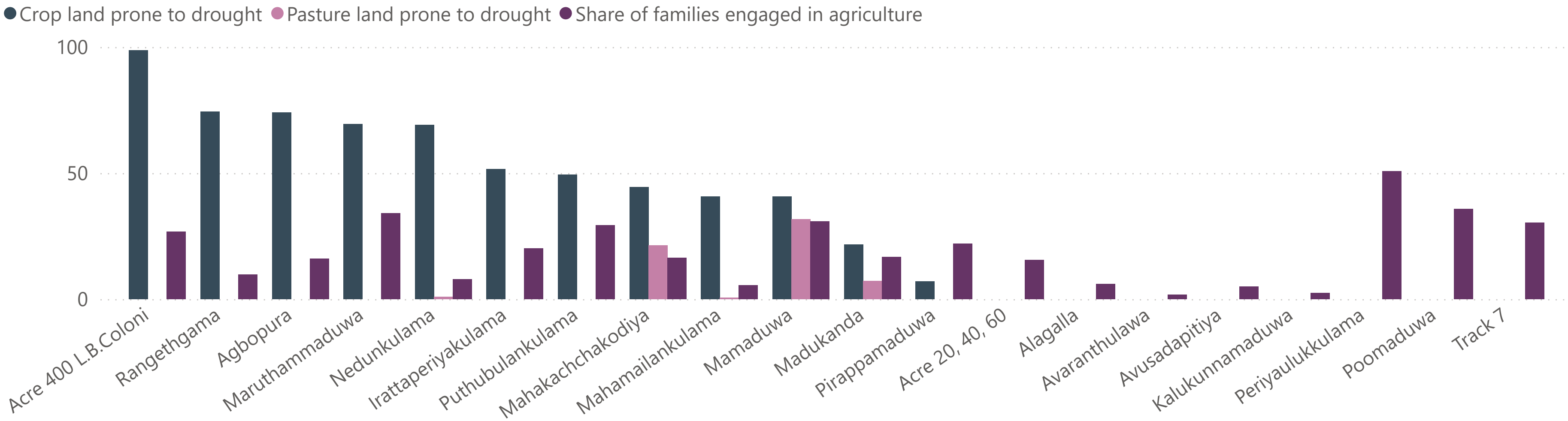
the largest affected pasture land, 32%, with 41% affected cropland, and the second largest drought area. Only nine out of all GNDs have less than 20% drought-affected cropland.

Beyond the high hazard and exposure indexes, Mamaduwa has 31% of families engaged in agriculture, a 45% dependency ratio, and 32% of families' daily wages between 2000 and 3000 LKR. The combination of high hazard, exposure, and vulnerability leads the GND to the highest risk of drought. Mahakachchakodiya and Madukanda follow with high-risk indexes, both with large drought areas affecting crop and pasture lands. The GNDs have around 16% of families engaged in agriculture and a 45% dependency ratio. Mahakachchakodiya has 37% of low-income families and Madukanda 23% of female-headed households, contributing to the socio-economic dependency.

The analysis suggests a risk of severe agricultural and livestock production decline in Maruthammaduwa, Mamaduwa, Puthubulankulama, and Acre 400 L.B.Coloni have between 25% and 35% of families engaged in agriculture, with affected cropland between 40% and 99%. Nine GNDs have zero risk of drought, due to no affected areas, however, GNDs like Periyaulukkulama, with the highest vulnerability index, can face great risk with the likely expansion of drought in the country.

The data presented in Figure 2 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.

Figure 2. Percentage of drought-affected areas and agricultural families[12]



FLOODS

The rainy season in Vavunyia South 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[14].

Between 2018 and 2020, satellite images showed that 1345 hectares of Vavuniya South were flooded. The largest flooded areas were registered in Track 7, Irattaperiyakulama, and Mamaduwa, with 229 ha, 143 ha, and 138 ha respectively. The flooded areas in the three GNDs represented over 38% of flood cover in Vavuniya South. The exposure indicators assessed included the affected population density, the percentage of crop area and built-up area, and the lengths of roads and railways within flooded zones.

Table 2 indicates that Nedunkulama is at the highest risk due to its high hazard exposure and vulnerability. It has the largest percentage of cropland within a flood zone, 27%. The GND has the second largest affected population density and the built-up area within a flood zone. Beyond the high hazard-exposure index, 45% of

Map 3. Flood exposure

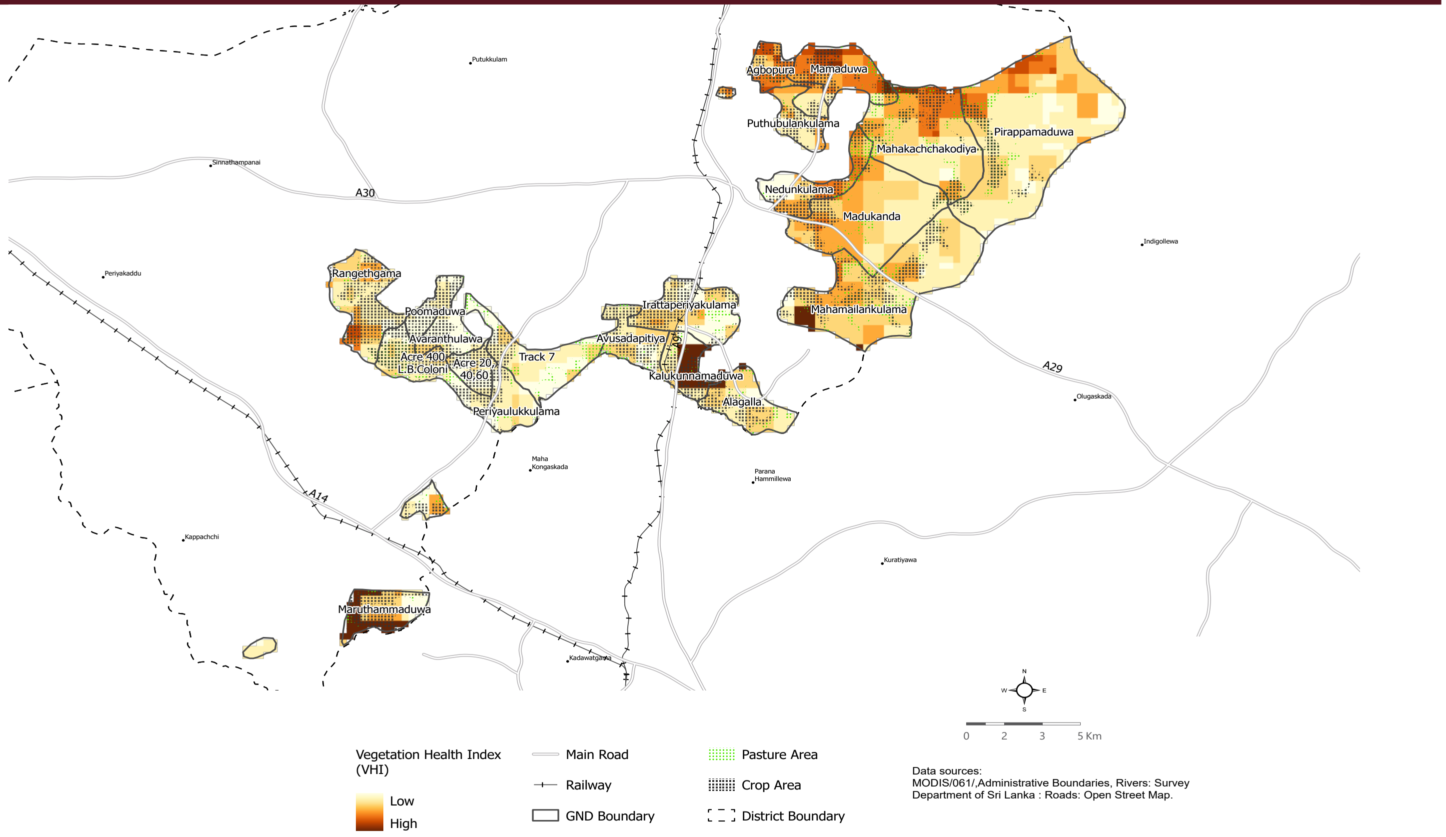


Figure 3. Flood-affected areas and inland fishery and agricultural families[13]

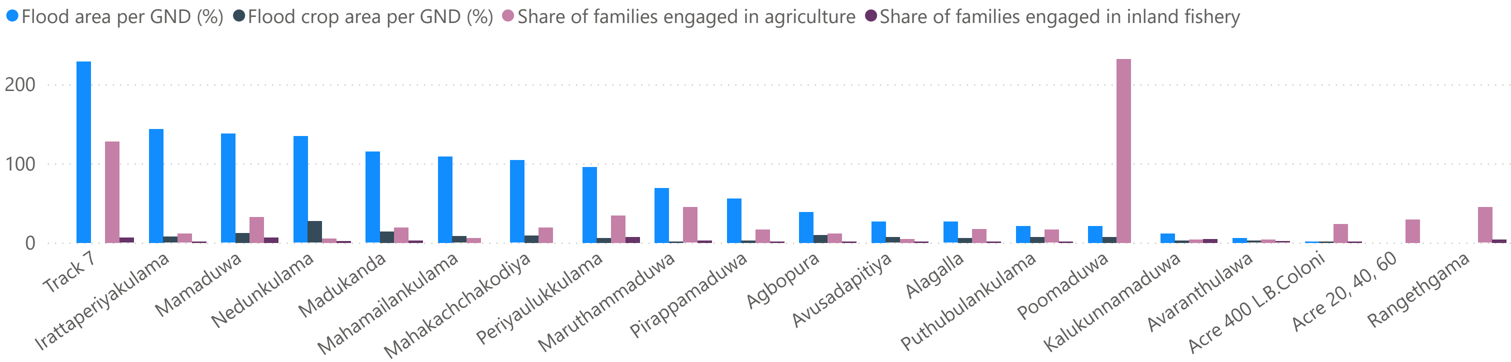


Table 2. Flood risk index

GND	Hazard-Exposure	Vulnerability	Risk
Nedunkulama	**0.74**	**0.39**	**0.285**
Madukanda	**0.61**	**0.36**	**0.218**
Periyaulukkulama	**0.41**	**0.46**	**0.187**
Alagalla	0.40	0.37	**0.149**
Irattaperiyakulama	0.32	0.35	0.111
Agbopura	0.25	0.42	0.106
Mahamailankulama	0.27	0.39	0.105
Mahakachchakodiya	0.26	0.37	0.094
Puthubulankulama	0.22	0.41	0.091
Mamaduwa	0.18	0.40	0.073
Avusadapitiya	0.17	0.42	0.073
Kalukunnamaduwa	0.15	0.41	0.060
Poomaduwa	0.06	0.82	0.046
Track 7	0.07	0.52	0.036
Maruthammaduwa	0.11	0.14	0.015
Pirappamaduwa	0.03	0.43	0.014
Avaranthulawa	0.03	0.40	0.011
Acre 400 L.B.Coloni	0.01	0.38	0.004
Acre 20, 40, 60	0.00	0.37	0.000
Rangethgama	0.00	0.72	0.000

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

families have a daily income between 2000 and 3000 LKR and the dependency ratio is 47%, leading the population to high vulnerability. Madukanda and Periyaulukkulama follow with high hazard-exposure indexes, dependency ratio, and share of low-income families. Madukanda has the highest affected population density, with 26% of female-headed households, and Periyaulukkulama has almost 35% of families engaged in agriculture and 36% of unemployed individuals.

Rangethgama, Acre 20, 40, 60, and Acre 400 L.B.Coloni have the lowest risk due to having low hazard exposure, with low flooded areas during the assessed period, and affected population density. However, Rangethgama has the second highest vulnerability index, with 45% of families engaged in agriculture, almost 50% of dependency ratio, and 53% of low-income families. This poses a threat to the population in the likely event of stronger rain and flood events.

The distribution of flood risks in Vavunyia South underscores the need for flood management plans, especially during agricultural seasons, to mitigate adverse effects. The DSD has on average 35% of families engaged in agriculture. Agricultural production is critical for the livelihood and food security of families.

Figure 5. Annual rainfall in Vavuniya South[16]

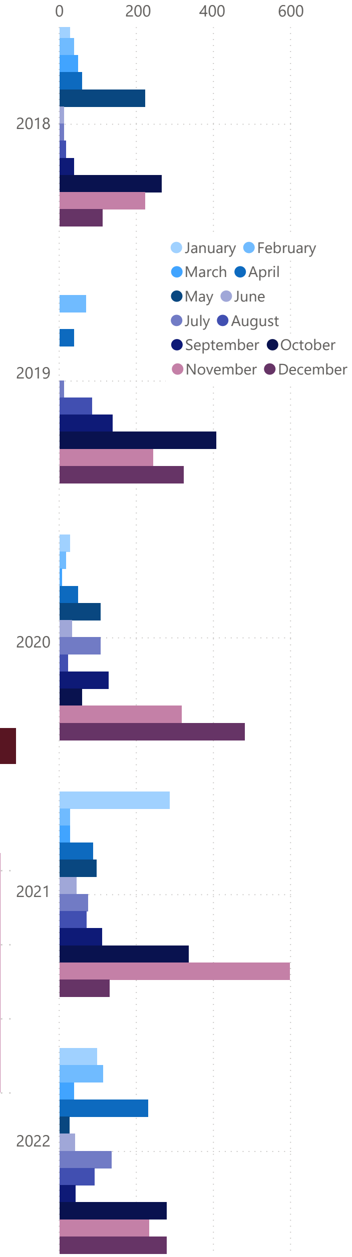
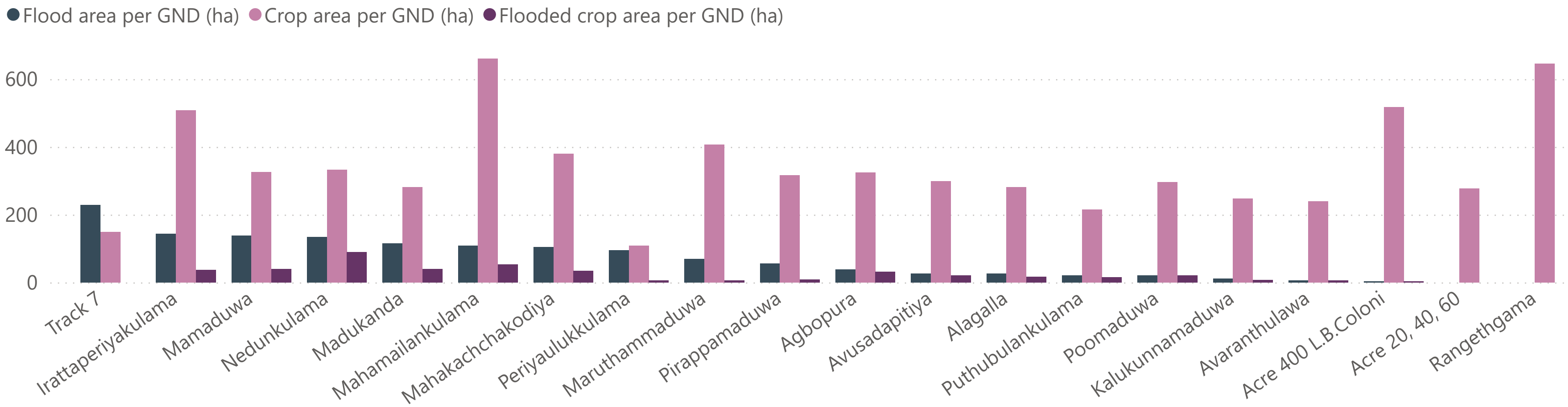


Figure 4. Crop area, flood area, and flooded crop area per GND[15]



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[17].

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

Map 4. Human-elephant conflict exposure

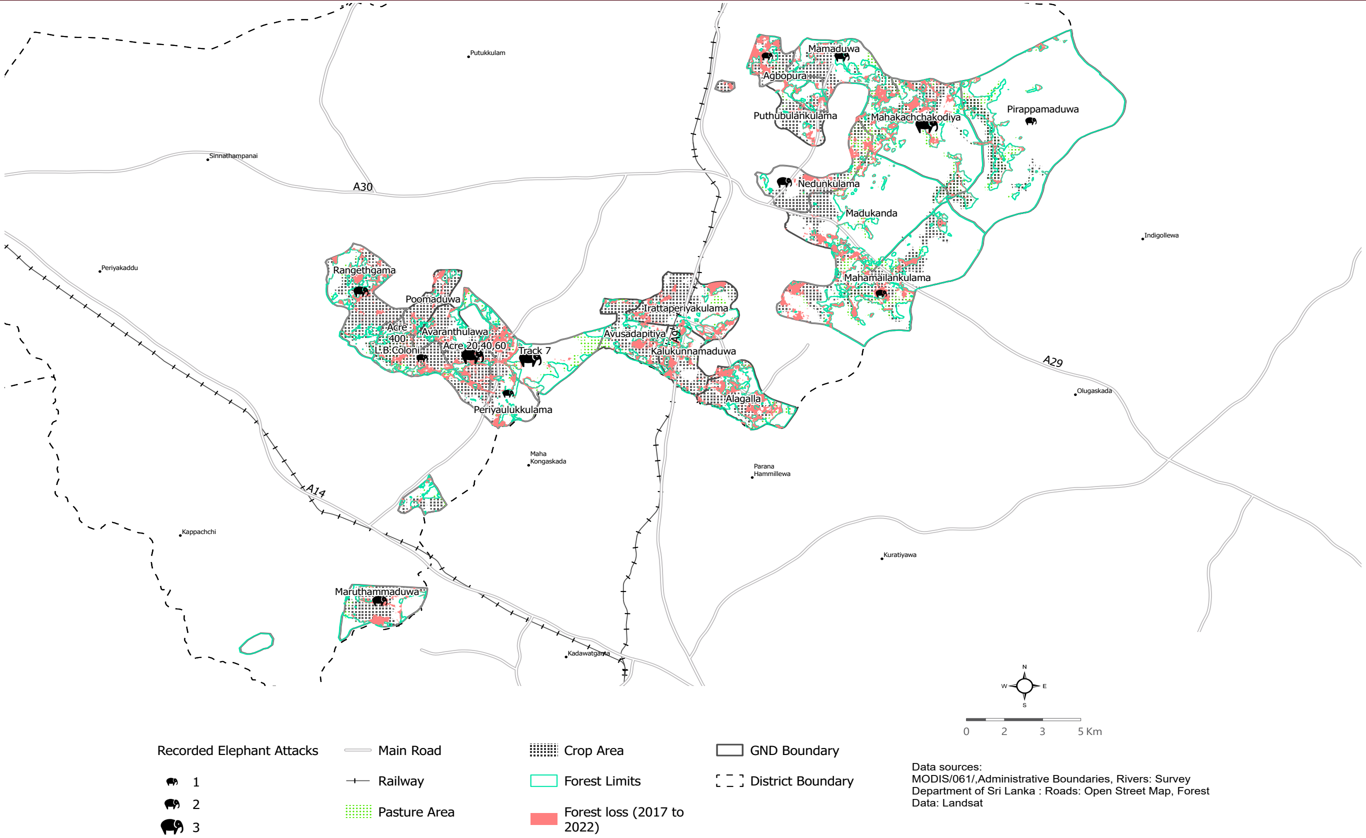


Figure 6. Human death and property damage caused by elephants/Elephant death and human density[20]

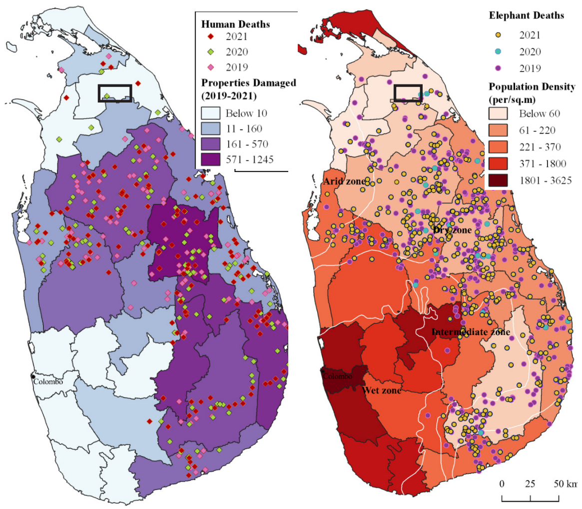


Figure 7. Human and elephant deaths in Sri Lanka[19]

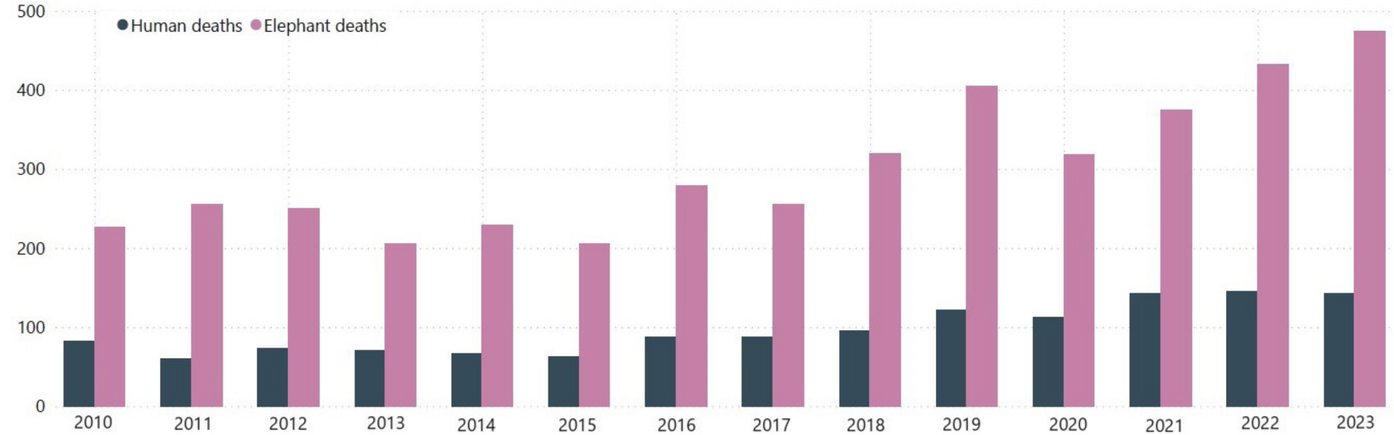


Table 3. HEC risk index

GND	Hazard	Exposure	Vulnerability	Risk
Mahamailankulama	**0.58**	**0.71**	**0.50**	**0.207**
Mahakachchakodiya	**0.69**	**0.62**	**0.32**	**0.136**
Pirappamaduwa	**0.47**	**0.60**	**0.39**	**0.108**
Madukanda	0.22	0.81	0.34	0.062
Mamaduwa	0.27	0.43	0.49	0.056
Irattaperiyakulama	0.16	0.61	0.48	0.048
Kalukunnamaduwa	0.12	0.59	0.65	0.044
Agbopura	0.23	0.62	0.30	0.044
Maruthammaduwa	0.18	0.56	0.42	0.043
Acre 400 L.B.Coloni	0.19	0.69	0.28	0.036
Periyaulukkulama	0.12	0.70	0.41	0.034
Nedunkulama	0.24	0.60	0.24	0.034
Avusadapitiya	0.08	1.00	0.39	0.031
Alagalla	0.23	0.41	0.33	0.031
Acre 20, 40, 60	0.29	0.32	0.20	0.019
Track 7	0.50	0.06	0.43	0.012
Rangethgama	0.32	0.07	0.23	0.005
Puthubulankulama	0.01	0.58	0.42	0.001
Avaranthulawa	0.00	0.30	0.21	0.000
Poomaduwa	0.02	0.00	0.34	0.000

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

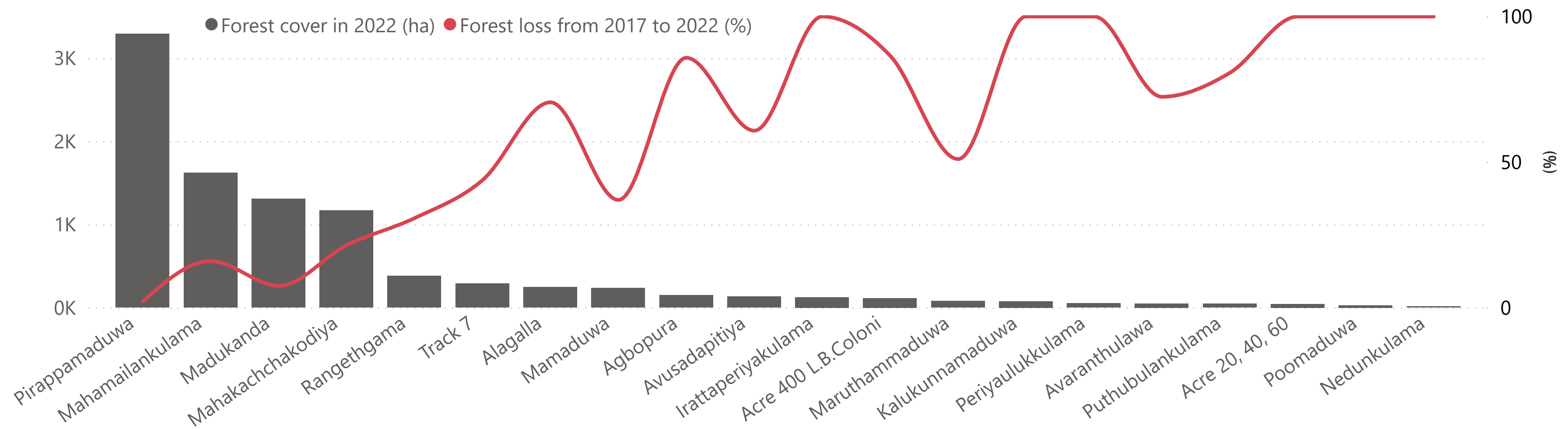
agricultural fields and human-occupied areas. Farmers may view elephants as threats to their livelihoods, increasing the likelihood of retaliatory measures. Between 2015 and 2021, 54% of incidences in Sri Lanka happened in open forests, while 62% were within 2 km of the forest edge[18].

Table 3 shows Mahamailankulama as the GND most at risk with one registered elephant attack. The high risk is driven by the highest forest disturbances in the last five years and high population density and forest area. The dependency ratio is 44% and 20% of households earn daily wages between 2000 and 3000 LKR. Mahakachchakodiya and Pirappamaduwa follow with a high dependency ratio and around 20% of low-income families. Mahakachchakodiya had three elephant attacks and the second largest forest disturbance, and Pirappamaduwa with the largest forest area and 15% of unemployment.

According to local authorities' data, 12 GNDs out of the 20 registered between one and four elephant attacks. The impact of deforestation is evident in Vavuniya South, the GND had 2100 ha of forest disturbance in the past 5 years, 22% of the current forest cover. Eight GNDs registered over 100 ha of forest loss (Figure 8).

Considering Vavuniya South's GNDs small areas and the elephant attacks in most of them, the hazard index can rise according to the elephant's migration paths, if the correct protection measures are not taken. Poomaduwa, Puthubulankulama, and Avaranthulawa present the lowest risk to HEC, resulting from the low hazard in all and low exposure in Poomaduwa. However, Poomaduwa and Avaranthulawa have high vulnerability-driven socio-economic dependency.

Figure 8. Forest disturbance in the last 5 years[21]



MULTI-HAZARD RISK

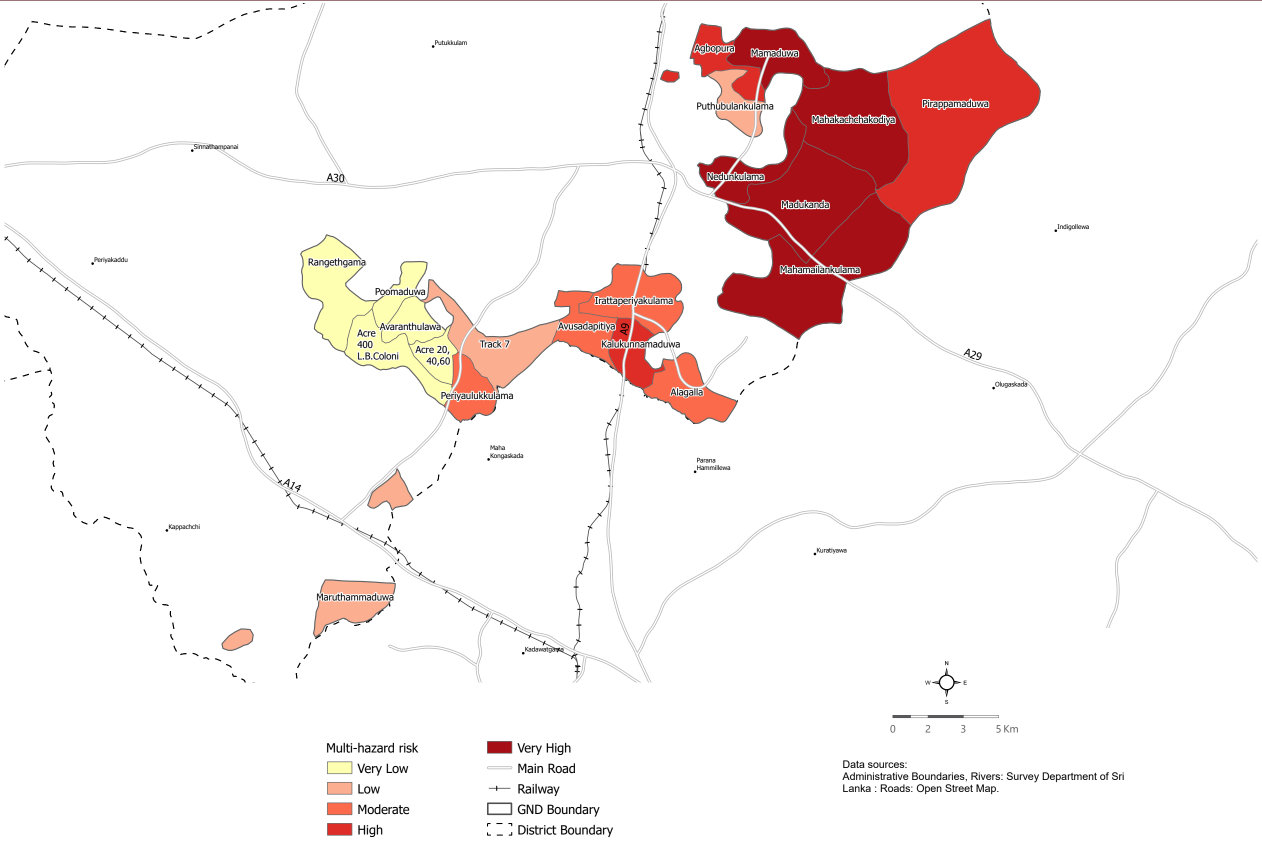
Vavunyia South's multi-hazard risk analysis, presented in Table 4 and Map 5, was calculated based on the three assessed risks: flood, drought, and HEC. The GNDs with very high risk (≥0.12 out of 1) are Nedunkulama, Madukanda, Mahamailankulama, Mahakachchakodiya, and Mamaduwa.

Nedunkulama and Madukanda present the highest flood risk, combined with a high drought risk. Mamaduwa and Mahakachchakodiya have the highest drought risk, combined with a high HEC risk, and Mahamailankulama has the highest HEC risk.

Nedunkulama has high vulnerability due to having 21% of female-headed households, 47% dependency ratio and 44% of low income families. The vulnerability index increases the risk of communities to all hazards. Madukanda and Mahamailankulama have high dependecy ratio, around 25% of female-headed households, and 33% and 43% of low income families, respectively.

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

Map 5. Multi-hazard map



South has an average of 35% of families engaged in agriculture, 44% of dependency ratio, and 46% earning daily wages between 2000 and 3000 LKR, this further impacts their ability to prepare for, respond to, and recover from shocks. 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.

Avaranthulawa, Acre 20, 40, 60, and Rangethgama present the lowest multi-hazard risk, with low flood and drought exposure and the lowest vulnerability to HEC.

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

Table 4. Multi-hazard risk index

GND	Flood	Drought	HEC	Multi-hazard risk
Nedunkulama	**0.29**	**0.10**	**0.03**	**0.139**
Madukanda	**0.22**	**0.13**	**0.06**	**0.137**
Mahamailankulama	**0.11**	**0.09**	**0.21**	**0.133**
Mahakachchakodiya	0.09	0.16	0.14	0.131
Mamaduwa	0.07	0.24	0.06	0.124
Agbopura	0.11	0.09	0.04	0.080
Periyaulukkulama	0.19	0.00	0.03	0.074
Pirappamaduwa	0.01	0.10	0.11	0.074
Alagalla	0.15	0.00	0.03	0.060
Irattaperiyakulama	0.11	0.01	0.05	0.056
Puthubulankulama	0.09	0.03	0.00	0.041
Kalukunnamaduwa	0.06	0.00	0.04	0.035
Avusadapitiya	0.07	0.00	0.03	0.035
Maruthammaduwa	0.02	0.03	0.04	0.029
Track 7	0.04	0.00	0.01	0.016
Poomaduwa	0.05	0.00	0.00	0.015
Acre 400 L.B.Coloni	0.00	0.00	0.04	0.013
Rangethgama	0.00	0.03	0.00	0.012
Acre 20, 40, 60	0.00	0.00	0.02	0.006
Avaranthulawa	0.01	0.00	0.00	0.004

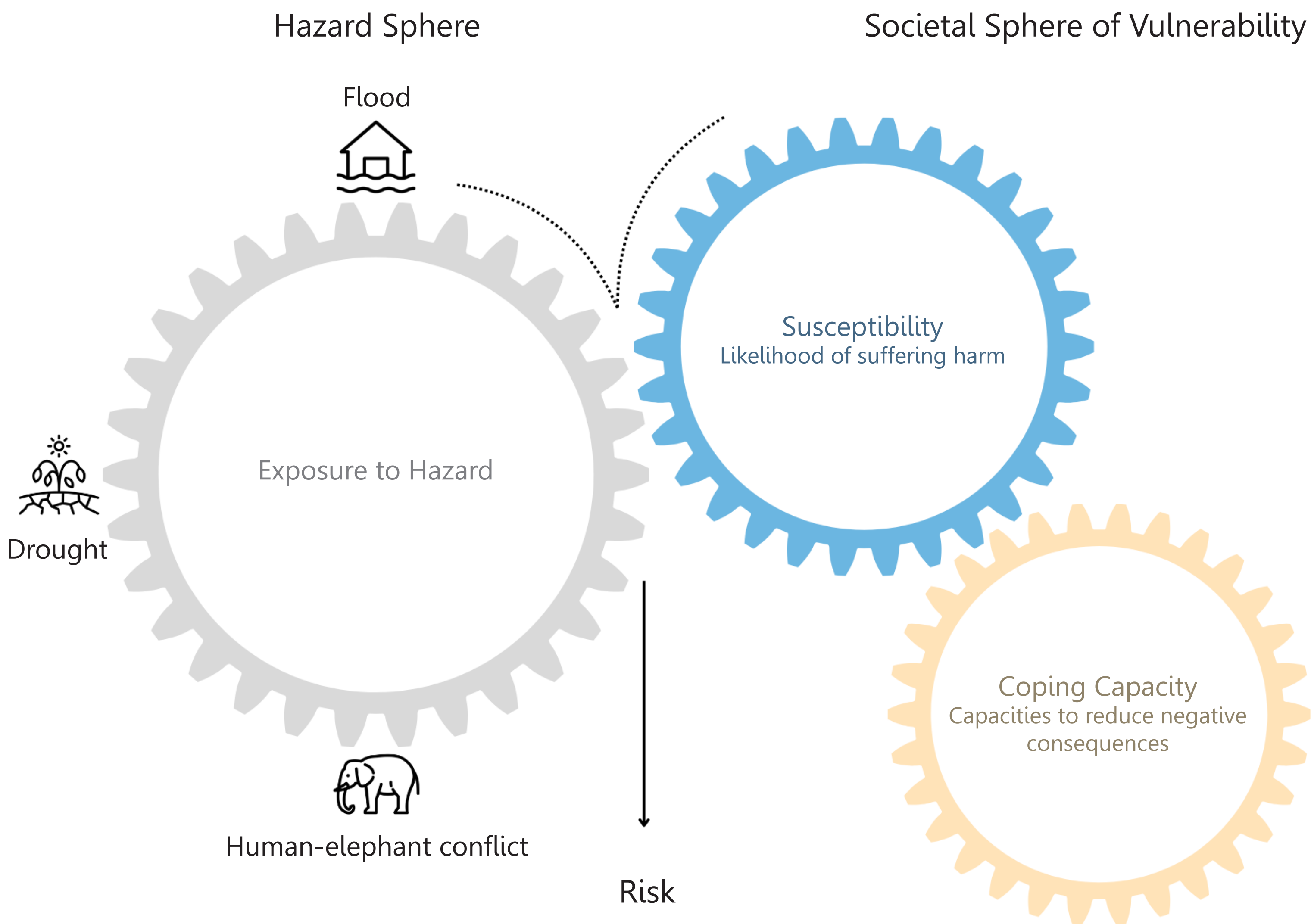
OTHER POTENTIAL HAZARDS

Other hazards also affect the population in Vavuniya South, 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[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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