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AREA-BASED RISK ASSESSMENT

Donetsk Oblast - Mariupolskyi Raion

August 2021

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ACTED

SeeD CENTRE FOR SUSTAINABLE PEACE AND DEMOCRATIC DEVELOPMENT

Contents

Executive summary

After more than six years, armed conflict In Ukraine continues to affect over 5 million people, 3.5 million of whom are in urgent need of protection and humanitarian assistance[1]. In parallel, the **population remains vulnerable to pre-existing natural and industrial hazards.** Both conflict-related damage, as well as dilapidation due to lack of maintenance of systems and infrastructure which could otherwise cope with these hazards, have heightened vulnerability, alongside limited local capacity to plan and prepare.

In 2020, ACTED, IMPACT and the Center for Sustainable Peace and Democratic Development (SeeD) launched a **resilience-building project in the Sea of Azov region** (covering the Kherson, Donetsk, and Zaporizhzhia oblasts in Eastern Ukraine), with the financial support of the European Union. The project aims to develop socio-economic, psychosocial, and environmental policies and programs, and to build local capacity to influence environmental policies and practices in and around Mariupol.

As a key outcome of this project, a comprehensive **area-based risk assessment (ABRA) for Mariupolskyi Raion has been developed.** The ABRA aims to investigate the level of exposure of populations and infrastructure to anthropogenic and natural hazards affecting the raion, by collecting, processing, and utilising existing openly-availabe data from 2020-2021. The ABRA utilises secondary data from a range of sources, including from global geospatial data portals, data requested from local and national authorities, as well as results of surveys conducted by IMPACT.

Subsequently, a deeper dive into the k**ey hazards and vulnerabilities specifically affecting Mariupol City Council** aims to assist communities, local government and industries to better predict, prepare for and respond to current and future risks in the city. The assessment is also intended to support implementation of risk reduction programmes, resilience-building activities and help to inform local-level disaster risk reduction planning.

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Mariupolskyi Raion

Outside of Mariupol City, Mariupolskyi Raion is largely rural. The population, largely reliant on agriculture for their livelihoods and the wider economy, is **highly exposed to land degradation, soil erosion and drought.**

37% of agricultural land in the raion has degraded in the past two decades, whilst persistent droughts have led to yield reductions, including reductions in cereal yield of over 60% in 2012. **100% of the population in Kalchytska Hromada and 51% of the population in Nikolska Hromada of Mariupolskyi Raion are rural**, exposing them to drought, land degradation and soil erosion.

The steppe zone[a] of Ukraine, where Mariupol Raion is located, is particularly **vulnerable to climate change**. With forecasts pointing towards higher temperatures and lower rainfall, particularly in the driest and warmest months, more extreme events such as droughts and heat waves is likely to become more frequent.

The State Emergency Service of Ukraine (SESU) data indicates **emergency service access (e.g. firefighters units) is restricted by poor infrastructure and safety concerns in and around settlements close to the contact line (CL),** which increases the wildfire risk along the CL.

Critical infrastructure is often in poor condition, lacks maintenance and is exposed to conflict incidents, putting populations at risk and more vulnerable to other hazards.

26km of oil & gas pipelines, 59km of electricity lines, 1 water pumping station, 1 dam, 49 communication towers, and other **infrastructure are located within 5km of the CL** and highly exposed to failure as a result of shellings.

Mariupol City

Mariupol is a highly industrialised city, and its population is at risk from hazards such as **air pollution, exposure to hazardous facilities, illegal landfills, flooding, landslides and urban heat islands.**

Kalmiuskyi District of Mariupol City was found to have the highest overall risk[b] based on the exposure to hazards and vulnerability of the population.

Due to **large industrial zones and limited green space, urban heat islands**[c] **are common**, which are particularly pronounced during heat waves. Increasing the area of green space could help cool the city down, build resilience to flooding and landslides by acting as a natural buffer, and improve people's quality of life.

The **city is responsible for 15% of Ukraine's total emissions deriving from stationary pollution sources,** such as industrial plants and power stations. As such, air pollution is a major concern for populations living in this city. **Kalmiuskyi, with a population of over 122,000[2], is the most polluted district.**

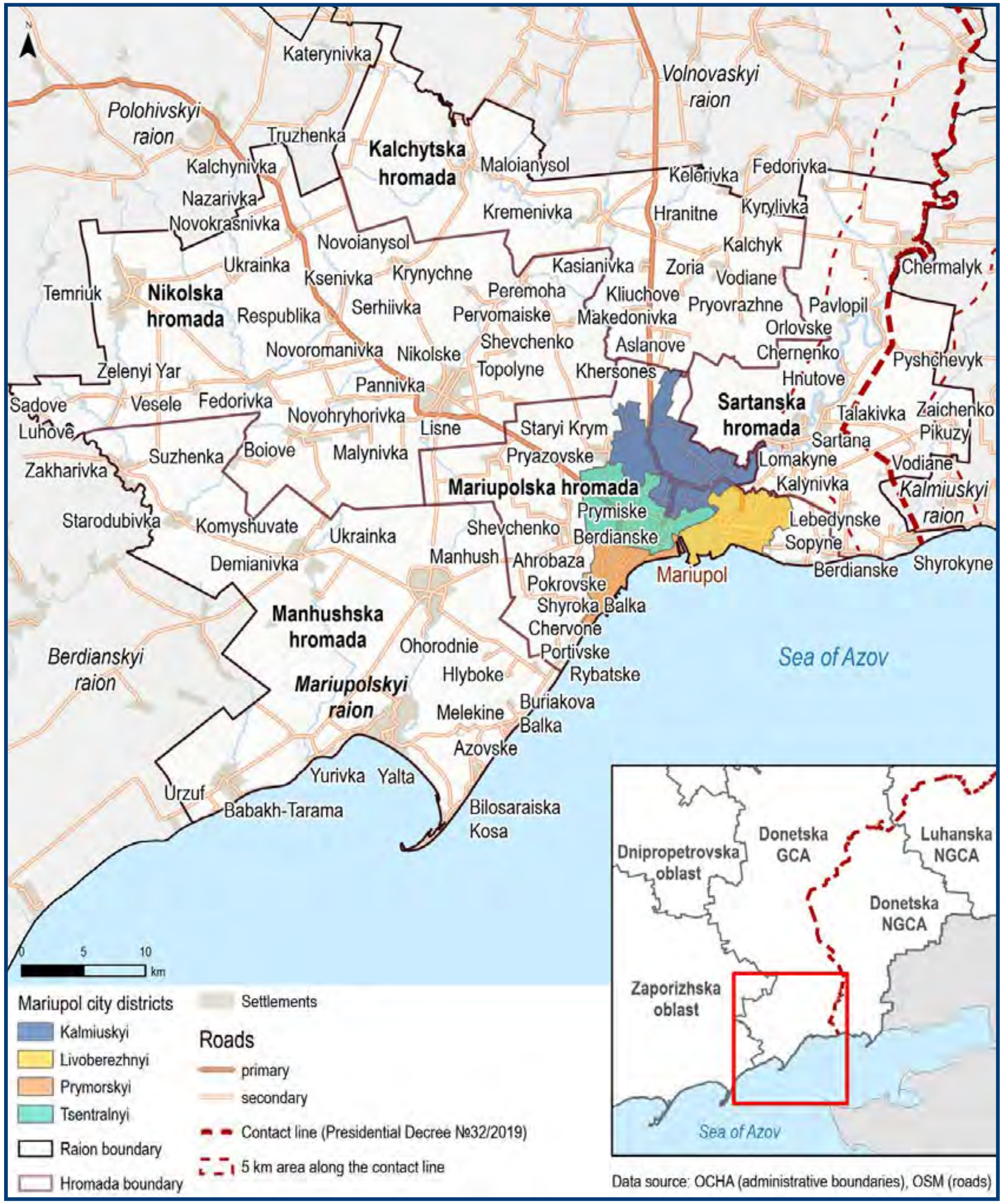
Mariupol City has over 450,000 inhabitants, exposed to a range of hazards. **Over 7700 buildings lie in the zone of potential groundwater flooding.**

The majority of recorded illegal landfills in Mariupol City are located within or close to zones of potential groundwater flooding, increasing the potential of surface water and environmental contamination.

a The steppe zone is a bioclimatic zone of Ukraine originally characterised by natural grassland. See page 18 for more details.
b The overall hazard risk was determined by looking at a range of different factors, which is explained further in the Methodology section (pages 6-7) and the Annex.
c An urban heat island occurs when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat.

Introduction

Location of Mariupolskyi Raion, showing hromadas and city districts



Area overview

Mariupolskyi Raion is located in Donetsk Oblast, Ukraine. It was created as part of the decentralization reform in Ukraine in July 2020.

The Raion profile includes[4]:

- Population: **622,552, with 18% internally displaced**
- Area: **2655,7 km^2**
- Hromadas: **Kalchytska, Manhushska, Nikolska, Sartanska, Mariupolska.**
- Largest city: **Mariupol (436,972)**

Background

After more than six years, civilians continue to bear the brunt of the armed conflict in Eastern Ukraine. Since April 2014, more than 3,000 persons have died, and 9,000 have been injured. The conflict has also created over 1.5 million Internally Displaced Persons (IDPs)[3]. Today, despite the Minsk agreements, 3.5 million remain in urgent need of protection and humanitarian assistance[1].

In parallel, the population remains vulnerable to pre-existing natural hazards, such as extreme weather and climate change. The region is intersected by critical infrastructure, which remain in poor condition and are exposed to sporadic conflict-related damage. Much of this infrastructure, such as power, water and communication networks, are crucial to support local capacity to plan, prepare and respond to disasters.

The contact line (CL) passes through the eastern edge of the raion. Populations in this area face conflict-related hazards including frequent shelling, significant landmine/UXO contamination and utility cuts, which are particularly dangerous in winter as people are unable to heat their homes.

Such hazards are compounded by pre-existing industrial and ecological concerns in this heavily industrialised region. Anthropogenic hazards include air pollution, water contamination and threats of attacks on hazardous facilities. These generally lack monitoring and maintenance, due to the additional hazards posed by conflict, as well as ambiguity over the parties responsible for such maintenance and monitoring.

Methodology

Methodology overview

The objective of this area-based risk assessment (ABRA) was to improve understanding of hazard exposure in Mariupolskyi Raion, and specific urban hazards and risks affecting Mariupol City to support resilience building and inform local-level disaster risk reduction (DRR) planning.

The key **research questions** were as follows:

1. What is the natural and anthropogenic hazard exposure of populations and critical infrastructure in Mariupolskyi Raion?

- What are the key environmental and demographic characteristics and primary built assets and infrastructure[a] in the raion?
- What are the main hazards and their characteristics (frequency, duration, intensity) that populations, the environment, and built assets are exposed to in rural and urban areas within Mariupolskyi Raion?
- To what extent are populations, environment, and assets exposed to natural and anthropogenic hazards in the raion?

2. What is the hazard, vulnerability and risk profile of populations and built assets in different neighborhoods of Mariupol City?

3. What is the resilience profile of Mariupol City and what are the key areas for action to support resilience building in the city?

As mentioned, the analysis was split into two sections: hazard exposure within Mariupolskyi Raion, and risks (including both hazard exposure and vulnerability data) for Mariupol City specifically.

This research involved comprehensive secondary data review and analysis, as outlined in the following section, and in more detail in Annex 1.
Openly-available regional and global geospatial data (provided that sufficient resolution was available) was utilised for hazard exposure analysis. The risk profile was calculated based on available secondary data from assessments undertaken by IMPACT, and other data provided by local authorities.

Methodological approaches used within this work fall within the framework of The Global Facility for Disaster Reduction and Recovery (GFDRR), a global partnership that helps countries better understand and reduce their vulnerability to natural hazards and climate change[5].

Hazard-exposure analysis can serve as a useful indication of which hromadas/settlements in the raion to prioritise for further data collection and taking mitigation measures. The risk analysis can serve as evidence for further primary data collection to support DRR initiatives in neighbourhoods of high concern in Mariupol City and implementing risk reduction programmes in targeted areas.

See a brief overview of data and analysis undertaken for both sections below. See Annex 1 for more details.

Analysis overview

Hazard exposure in Mariupolskyi Raion

Natural and socionatural hazards

- Wildfire frequency and intensity from Fire Information for Resource Management System (FIRMS)[b]
- Land degradation trends, calculated in Trends Earth
- Soil erosion, based on Revised Universal Soil Loss Equation (RUSLE model)
- Drought hazard and exposure based on accumulated vegetation condition index and rural population fraction
- Heat waves, identified from percentage of days above 37 ˚C during the summer months
- Cold waves, identified from percentage of days below -15 ˚C during the winter months
- Biodiversity loss, based on study of natural vegetation cover in the raion
- Coastal landslide susceptibility based on soil type, slope angle and vegetation cover

Anthropogenic (man-made) hazards

- Exposure of infrastructure (electrical, water, oil and gas, communication networks) to conflict incidents
- Air pollution - concentrations of various atmospheric pollutants and population exposure.

An analysis of COVID-19 trends was also included.

Finally, a multi-hazard exposure analysis was undertaken, to review the main hazards and level of intensity and exposure in each of the hromadas.

Risks in Mariupol City

This section focuses specifically on Mariupol City and looks at the main risks faced by the city. As explained in the key definitions on the following page, risk is calculated as the product of hazard exposure and vulnerability. These two components were calculated, then summed to get a measure of risk for each district.

Hazard exposure in Mariupol City

- Industrial hazards and air pollution: mean distance from residential areas to industrial facilities and average concentrations of pollutants above permitted concentrations.
- Waste management: number of residential buildings within 200m of illegal landfills
- Flooding and landslides: percentage of residential areas covered by flood hazard zone, plus locations of landslide susceptibility.
- Urban heat islands: percentage of days with land surface temperature above 37 ˚C in each district.

Vulnerability profile

A vulnerability profile was calculated for each district of the city, based on a range of indicators, split into susceptibility, coping capacity and adaptive capacity components, as outlined in detail in Annex 1.

Multi-hazard risk

Finally, multi-hazard risk was calculated from the combination of hazard exposure and vulnerability for each district. See Annex 1 for more details.

a Here, critical infrastructure and built assets refers to transport systems, ports, electricity, water and communications• systems, health clinics, emergency and public administration services, etc.

b An additional sub-section looks into SESU reported fires and capacity in reaching settlements along the Contact line (CL)

Information gaps and limitations

Unfortunately IMPACT were not able to obtain suitable vulnerability data for the whole Mariupol Raion, and vulnerability index was calculated at city level only. Hence why only hazard exposure, but not the multi-hazard risk, was investigated for the Raion. This remains a limitation as hazard exposure does not give the full impression of how likely populations are to be adversely impacted by hazards based on societal vulnerabilities.

Some datasets should be verified further, in particular OpenStreetMap (OSM) data on infrastructure. Whilst this was the best available data, there may be gaps present (missing buildings, roads, etc), or updates needed.

It should also be noted that while suggested risk mitigation approaches have been outlined in each section based on desk review as well as conclusions from this analysis, these should be considered as preliminary suggestions only as a starting point to facilitate further discussion among experts in this type of programming.

Key terms and definitions

Hazard

Hazards refer to a "process, phenomenon or human activity that may cause loss of life, injury or other health impact, property damage, social and economic disruption or environmental degradation[6]". Eighteen hazards were identified in Mariupolskyi Raion: 9 of which are natural or socionatural[a], whilst 8 are anthropogenic. COVID-19 was also included, which is classified as a biological or health hazard.

Conflict in this assessment is both considered a direct hazard and also as a variable that hinders coping capacity of the society. It is not however included as a standalone hazard in this assessment.

Conflict as a hazard looks both at the exposure of the population to conflict incidents, but also exposure of critical infrastructure such as the water network, gas and oil pipelines, and the electricity network. Note also its part in the chain of cascading risks, given that shelling and landmines pose an additional threat to hazard response.

Exposure

Exposure is defined as the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas[7]. In this ABRA, the locations of population, infrastructure and built assets are considered as part of the exposure component of the analysis for both Mariupolskyi Raion and Mariupol City sections.

Datasets on population and built assets are derived from global data sources such as OSM buildings and infrastructure layers, and REACH Capacity and Vulnerability Assessment (CVA, 2021) settlement population estimates.

Vulnerability

Vulnerability is defined as 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[8].

Vulnerability refers to the societal sphere, and its spatial interaction to a hazard is what defines disaster risk. Where there is exposure to a hazard but low societal vulnerability there is low risk. As mentioned, suitable vulnerability data was only available for the city of Mariupol, so a full risk profile is only available here.

Components of vulnerability include **susceptibility,** which is the likelihood of suffering harm from one of the assessed hazards; **coping capacity**, the capacities to reduce negative consequences; and **adaptive capacity**, the capacities to develop and maintain long-term strategies to ensure social resilience to hazards and shocks. Vulnerability was calculated for districts of Mariupol City, based on these components. The indicators were provided by an Urban Capacity and Vulnerability Assessment (UCVA) of basic services in Mariupol undertaken by IMPACT in 2019. Data was also requested from Mariupol City Council.

Risk

According to the UN Office for Disaster Risk Reduction (UNDRR), disaster risk is defined as "the potential loss of life, injury, or destroyed or damaged assets which 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[9]."

The World Risk Index, developed by the UN University's Institute for Environment and Human Security and Bündnis Entwicklung Hilft, calculates disaster risk based on the exposure to key natural hazards as well as social vulnerability in the form of the population's susceptibility and their capacity for coping and adaptation.

The ABRA takes this approach for assessing disaster risk in Mariupol City Council, through assessing the multiplication of a settlement's hazard exposure by its vulnerability at neighbourhood level. The specific indicators and their weighting used in the risk calculation are further illustrated in Section 2 (Risks in Mariupol City).

Resilience

Resilience is intimately linked to vulnerability and the ability of a community to cope and adapt to disasters. In this assessment is defined as an ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions[10].

Resilience is analysed and assessed by several selected indicators based on operational framework for making cities resilient of the Sendai Framework at the local level. They are: analyses of a future scenarios of hazard exposures and related to them vulnerability patterns; assessment of the capacity and adequacy of critical infrastructure and identification of ecosystem services and nature-based solutions within Mariupol City Council area.

a Socionatural hazards are associated with a number of natural and anthropogenic factors, such as climate change and environmental degradation.

1. Hazard exposure - Mariupolskyi Raion

Exposure to natural and anthropogenic hazards

Source: Operational News Service

Natural and socionatural hazards

Outside of Mariupol City, the population of Mariupolskyi Raion is largely rural. Based on the UNDRR Hazard Classification[11], the main natural hazards these communities are exposed to are: environmental and hydro-meteorological, including **drought, soil erosion, land degradation, wildfires and extreme temperature.** Some of these, such as climate change, are **socionatural, in that anthropogenic factors** are also involved in their generation. Agriculture, and those dependent on it, are particularly exposed to such hazards, which often result in notable crop yield reductions.

Recent regional trends indicate **declining precipitation and increasing temperatures linked to climate change.** These changes will likely lead to higher frequency and intensity of extreme events. On the coast, including in and around Mariupol City, **flooding, sea level rise, coastal erosion and landslides pose risks to populations and assets.**

Conservation of ecosystems is one of the best ways to mitigate against natural hazards. For example, planting vegetation can help to stabilise landslide-prone slopes, as well as limit land degradation and soil erosion processes. **Raising community awareness** of hazards and **installing early warning systems** also play a crucial part in the disaster risk reduction cycle. Natural hazard mitigation and risk reduction should also be carefully considered in **urban planning.**

Wildfires

Wildfires pose a major hazard to the environment, people and infrastructure. Triggered by a variety of natural and anthropogenic activities, they can lead to public health risks and mortality, and destroy swathes of natural habitat, buildings and infrastructure. With rising global temperatures (p. 19), and an increase in frequency and severity of heatwaves, the number of fires is growing each year.[12]

Map 1.1 shows wildfires in Mariupolskyi Raion from NASA`s satellite-based Fire Information for Resource Management System (FIRMS), between 2001 and 2020, whilst Table 1.1 shows the frequency of fires by hromada per year. Presumed vegetation fires were extracted.

Forest cover in Mariupolskyi Raion is limited, covering just 3.5% of the land area. When comparing fire locations with land cover data, it is clear that the majority of recorded vegetation fires occurred on agricultural land. A study investigating land cover type of burn scars from or MODIS (Moderate Resolution Imaging Spectroradiometer) data across Ukraine between 2006 and 2008 found that 93% of recorded wildfires occurred on agricultural land, with just 7% occurring in forests[13].

Map 1.1. Average intensity of vegetation fires, with conflict incidents

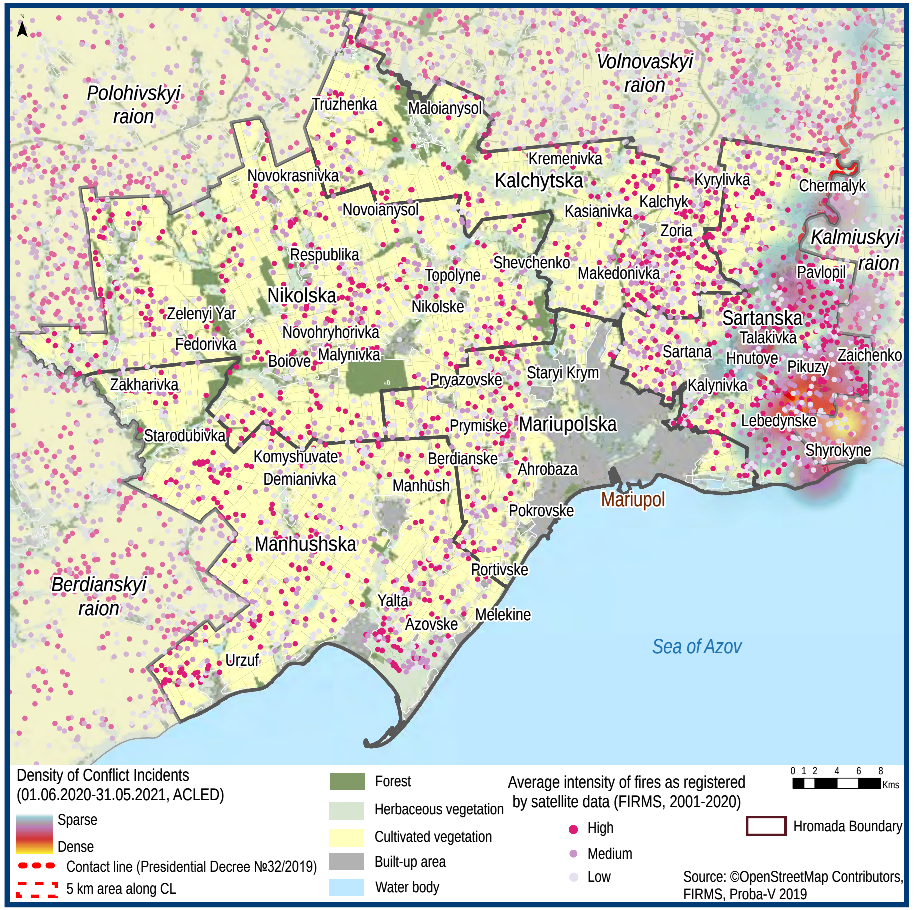


Table 1.1. Annual fire frequency for hromadas in Mariupolskyi Raion (incidents per year)

Hromada	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Kalchytska	40	16	4	17	26	36	13	21	34	25	24	7	7	61	37	59	71	8	29	9	544
Manhushska	69	19	1	9	80	39	70	40	31	31	19	0	18	37	54	26	66	14	37	13	673
Mariupolska	59	33	55	26	53	36	86	59	59	48	39	49	46	47	42	43	67	13	13	9	882
Nikolska	106	36	7	6	35	40	62	23	37	34	34	6	16	32	44	21	93	12	44	6	694
Sartanska	47	38	9	2	36	28	38	57	54	28	29	5	19	84	20	60	143	41	32	28	798

Although illegal in Ukraine, cropland burning is commonly practiced as an inexpensive and simple method to quickly remove post-harvest residue. In southern Ukraine, burning often coincides with winter wheat harvests in late summer. Unfortunately, crop burning results in a deterioration of soil fertility and increases erosion susceptibility. The practice also results in poor air quality, negatively affecting human health. Many forest fires are likely to start due to ignition from fires on neighbouring agricultural land. It has been suggested that negligent crop burning practices could have led to the wildfires at Chernobyl in 2020 for example[14].

The map indicates a high concentration of wildfires in close proximity to the contact line (CL), which may have been triggered by activities related to the conflict. Artillery shelling in areas of dry forest and hot, dry weather conditions was a suggested cause of the fires in Luhansk in 2020[15]. Landmine contamination is another potential trigger for wildfires, which can also hinder access for emergency responders[16].

Urban fires are also common in Mariupol City. SESU statistics on trips to reports of fires indicate that the majority of call-outs in the raion occurred in Mariupolska hromada. Between 2015-2019, 42% of fires occurred in open areas, whilst 24% occurred in residential buildings, followed by 16% in municipal buildings and infrastructure.

Suggested mitigation approaches

- Monitor wildfires using satellite-based methods, e.g. FIRMS/VIIRS
- Educate and incentivise farmers to adopt alternative practices
- Forestry management: develop firebreaks, utilise natural barriers, e.g. high moisture plants, etc.
- Raise awareness of community shelters (see this Map).

Fires (all) - State Emergency Services of Ukraine (SESU) Data

This page reviews data provided by the State Emergency Services of Ukraine (SESU) pertaining to trips relating to fire reports, and travel time from the nearest SESU unit to settlements along the contact line (CL) close to Mariupol City.

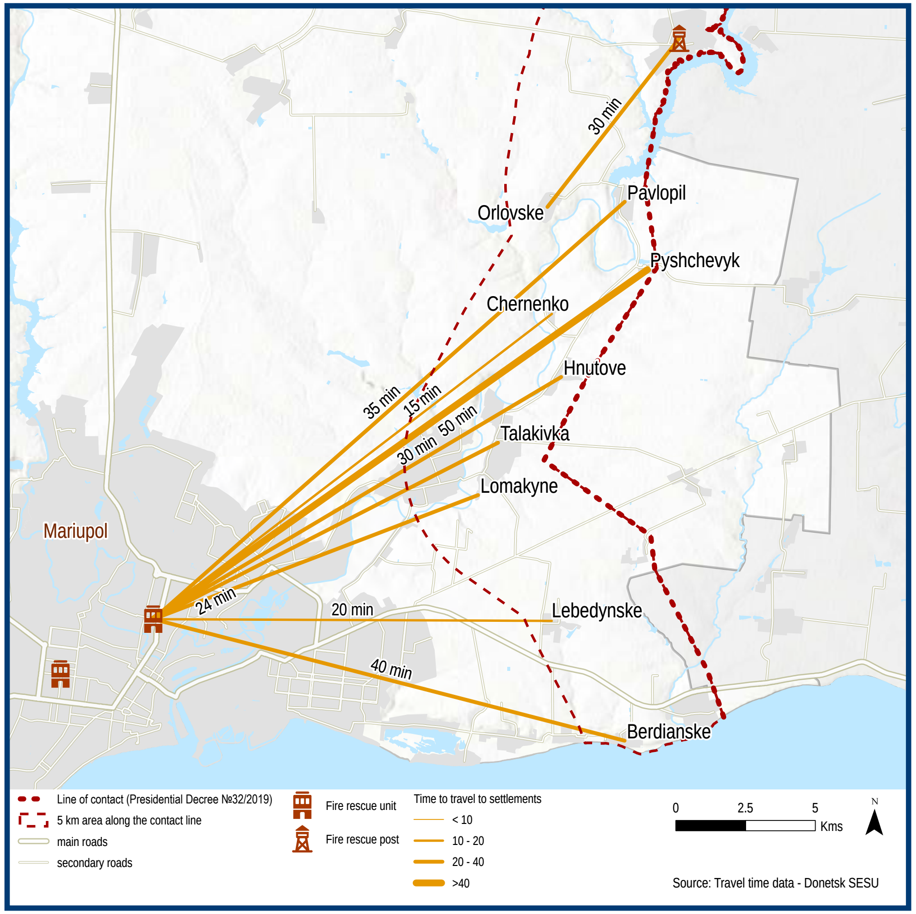
Between 2015 and 2017, many SESU reports to fire events in the area are located in open areas (Table 1.2). This might be a result of the common agriculture practice of stubble burning to prepare a field for sowing, which may lead to the uncontrolled spread of fire. It also leads to soil moisture loss, which is already limited in this context.

Also, for the period from 2015 to 2019, a large number of SESU visits were made to residential buildings (1230), as well as municipal buildings and infrastructure (835). This may be due to conflicts events, as Mariupolskyi Raion is located near the CL. Many fires in this area occur due to short circuits in buildings, poor quality, or old electrical wiring.

SESU access to settlements in the 5 km zone near the CL is an average of 30 minutes (Map 1.2). The route is complicated due to the quality of the road surface, the relative remoteness of some settlements and security issues, given that four settlements are located almost directly on the CL. Most settlements are served by response units in Mariupol.

According to map 1.3, the average annual number of SESU trips to reports of fire in Mariupolskyi Raion is more than 1000 for the period 2015-2018. The largest number of departures was recorded in Kramatorsk Raion. This is due to the fact that this is one of the largest new raions in Donetsk Oblast and many SESU units are located here, and thus, have an increased ability to respond to fires.

Map 1.2. Travel time to settlements along CL from nearest SESU unit



Map 1.3. Average annual number of SESU trips to reports of fires (2015-2018), with recent conflict incidents

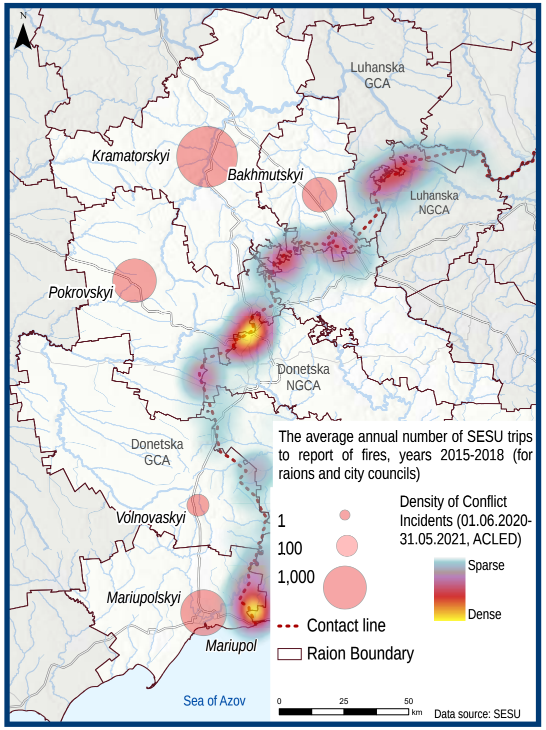


Table 1.2. Number of reports to fires by affected area by year (data from SESU)

Affected area	2015	2016	2017	2018	2019	Grand total
Abandoned or destroyed building	35	31	30	22	19	137
Municipal buildings and infrastructure	55	38	47	346	349	835
Open area	608	609	667	129	141	2154
Outbuilding	117	124	163	151	100	655
Residential buildings	228	254	240	319	189	1230
Transport	28	19	26	28	18	119

As part of the Sustainable Development Goals (SDGs), governments are provided with a frame work to monitor and report on progress towards achieving better living conditions for their people. SDG 15.3.1 focuses on land degradation and monitors the state and health of land, soils and, more broadly, ecosystem services. Land degradation is "the reduction or loss of biological or economic productivity" of land[17]. The indicator is calculated as a proportion of total land area and is labelled as degraded, improved or stable.

Map 2.1. shows land degradation data for agricultural land in Mariupolskyi Raion from 2001 to 2018. It is measured by combining the 3 indicators: soil organic carbon degradation, land cover degradation and productivity state degradation. The data demonstrates that 37% of the total land area degraded, 60% remained stable, whilst only 3% is improving (Chart 2.1.). At the hromada scale (Table 2.1.), Mariupolska Hromada has the greatest proportion of degraded land, at 62%, followed by Manhushska Hromada, at 50%.

To calculate the indicator for a certain area, three sub-indicators are computed: trends in land cover; land productivity; and carbon stocks. If one of these indicators has a declining trend for a specified land unit, the land unit will be classified as degraded, even if the other two indicators are improving ("One Out, All Out" principle)[18].

The first sub-indicator, land cover change, analyses each land unit to determine if the land cover changed or remained the same. If it changed, it is necessary to determine if the change is an improvement, in terms of ecosystem services, or a degradation.

The second sub-indicator, land productivity, is the biological capacity of land to produce food and is usually approximated using vegetation indices; notably NDVI[a].

The third and final sub-indicator, carbon stocks, is currently estimated by the soil and organic carbon (SOC) indicator, which is the "amount of carbon stored in soil".

Since 2001, more and more land in Mariupolskyi Raion has become degraded, with negative effects on agricultural suitability and productivity. As such, efforts should be focused on restoring productivity, land cover and soil carbon to achieve positive results in improved land area.

Map 2.1 Land degradation in Mariupolskyi Raion (2001-2018)

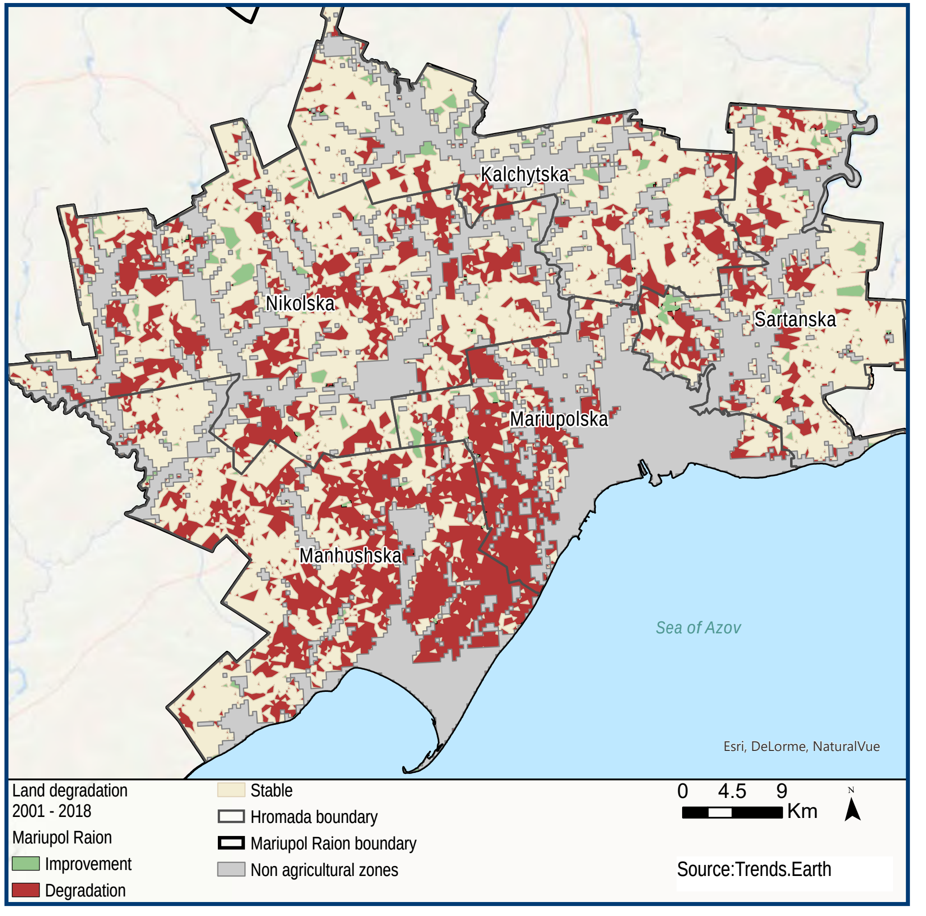
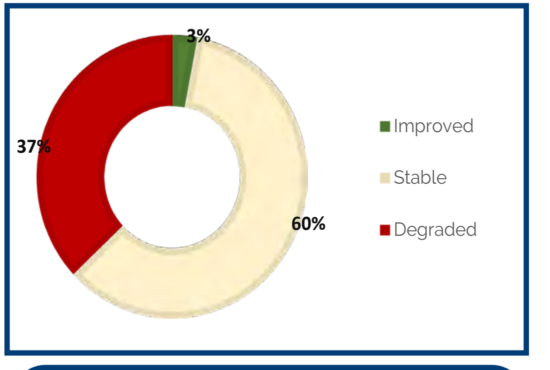


Table 2.1. Land change summary by hromada (2001-2018)

	Kalchytska	Mariupolska	Manhushska	Nikolska	Sartanska	Mariupolskyi Raion total
Total area	328 km²	173 km²	492 km²	582 km²	300 km²	1883 km²
Improved	4%	3%	1%	3%	6%	3%
Degraded	19%	62%	50%	34%	26%	37%
Stable	77%	35%	49%	62%	68%	60%

a Normalised difference vegetation index (NDVI) is a vegetation index calculated from remotely-sensed imagery used to estimate the greenness / desnity of vegetation. More information here

Chart 2.1. Total land change, Mariupolskyi Raion



Suggested mitigation approaches

- Reforestation can help prevent soil degradation
- Use organic farming methods, e.g. adding compost to capture carbon and reduce flooding risks
- Reduce ploughing as it adversely affects soil fertility
- Implement industrial farming policies for environmental sustainability

83% of soils in Mariupolskyi Raion were found to be productive and good-quality chernozems[20].

However, intensive agriculture practices, excessive land tillage and high proportion of row crops create a risk of soil degradation due to erosion in the raion.

Climate change, including increased drought frequency, as well as ravine-beam relief, exacerbate this.

Water and wind erosion are one of the primary causes of land and soil degradation. Water- and wind-eroded areas within the raion are clearly visible as light areas on spring satellite images of arable land (Fig. 3.1).

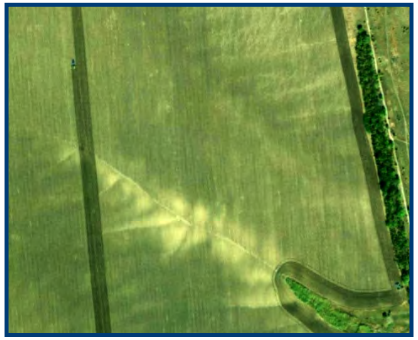
It is estimated that over 500 million tonnes of soil are eroded annually from arable land in Ukraine, resulting in soil fertility loss across 32.5 million ha, equivalent to around USD 5 billion in nutrient equivalent[21].

One of the most common methods of soil erosion assessment is the RUSLE model (Revised Universal Soil Loss Equation)[22], which calculates annual soil losses as a function of rainfall erosivity, soil erodibility, topography, landuse management, and soil conservation support practice.

The rainfall erosivity factor was derived from the global rainfall erosivity dataset. Soil erodibility factor was elaborated from a soil map, and topographic factors were calculated based on the 30m SRTM elevation model. Landuse management factor was elaborated based on Copernicus land cover[23] and OpenStreetMap datasets. A map of accumulated distances to forested shelterbelts (windbreaks) was developed and used as the soil conservation factor.

Map 3.1. Annual average soil loss, Mariupolskyi Raion

Fig. 3.1 Google Earth images from April 2018 showing eroded arable land

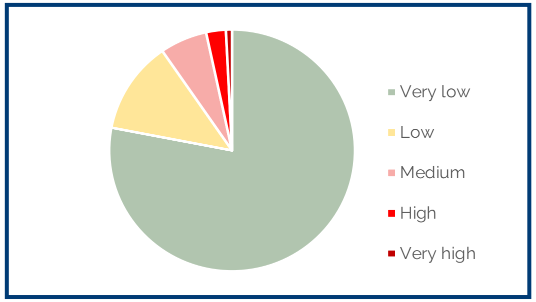


Results indicate Kalchytska, Sartanska and Mariupolska hromadas were most exposed to soil erosion with 6-8% of agricultural land having medium erosion rates (up to 10 t/ha annual soil losses) and 4-5% agricultural lands with high and very high erosion rate (>10 t/ha/year). Chart 3.1. shows the percentage of land affected by different levels of erosion across the whole raion.

Suggested mitigation approaches

- Introduce further conservation agriculture with no-till technology to help maintain soil fertility, enhance drought resilience and reduce fuel consumption and production costs[19]
- Restore natural windbreaks / shelterbelts (e.g. linear planted bushes)
- Reserve agricultural land on slopes >3˚ for growing perennial grasses, including medicinal herbs
- Support development of consultancy services on Climate Smart Agriculture practice

Chart 3.1. % agricultural land exposed to different levels of erosion, Mariupolskyi Raion



Drought - hazard

In the past two decades, a number of significant droughts occurred in Ukraine, including in 2003, 2007, 2012, 2017 and 2020. The steppe zone (Map 7.2), including Mariupolskyi Raion, suffers the greatest impacts[24], experiencing anomalously low precipitation and high temperatures compared to Ukraine as a whole.

Based on a 2021 socioeconomic survey undertaken across the Azov Sea Area (ASA) by IMPACT, 52% of interviewed households in Mariupolskyi Raion (excluding the city) cited drought as one of their primary environmental concerns (one of the highest response rates[a]). Many also voiced concerns over crop yield losses due to extreme weather events including drought.

Map 4.1 shows overall drought hazard, based on accumulated vegetation condition index (VCI) between 2001 and 2020. Lower overall values indicate higher drought hazard. VCI is a drought severity index, calculated here using satellite-derived vegetation health data (MODIS EVI)[25], based on [UN-Spider methodology][26].

Chart 4.3 shows average spring and summer VCI for the raion over the same time period. Drought severity is categorized according to Table 4.1, with lower values relating to increasingly severe droughts.

Recent droughts have had significant impacts on crop yields in Mariupolskyi Raion, and the wider area, particularly of cereals and sunflower. Drought in 2012 led to a 63% reduction in cereal yield compared to the previous year[27]. Chart 4.4 shows annual cereal yields in Mariupolskyi Raion against average VCI in June, the pre-harvest month (when the crop should be at peak condition). Also see the [Azov Sea Area Trade and Environment Monitor dashboard] for more detailed information.

Climatic trends across the ASA have been changing over the last 20 years, as Charts 4.1 and 4.2 show. Precipitation has been falling, whilst temperatures have been rising. Soil moisture has also been decreasing over the past 20 years. Snow cover, which plays an important role in protecting crops from frost in winter and providing a water source through snowmelt in spring[28], has been falling.

Map 4.1. Drought hazard in Mariupolskyi Raion

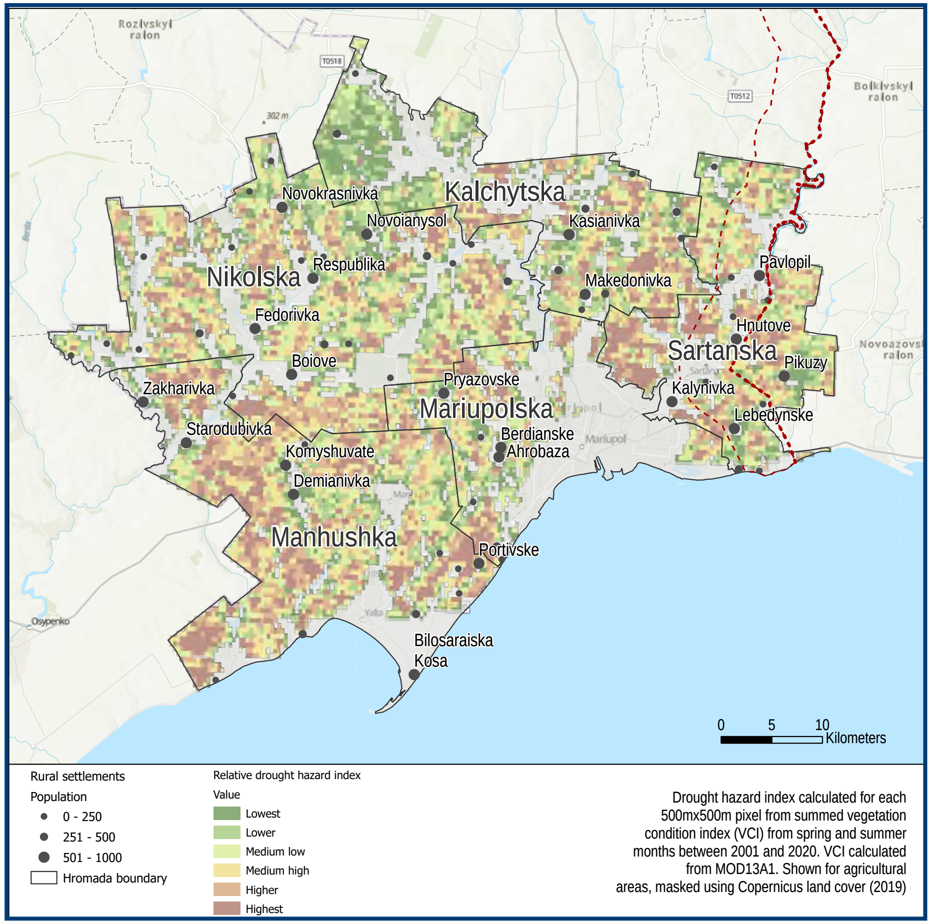


Chart 4.1-2. Climatic trends in Mariupolskyi Raion

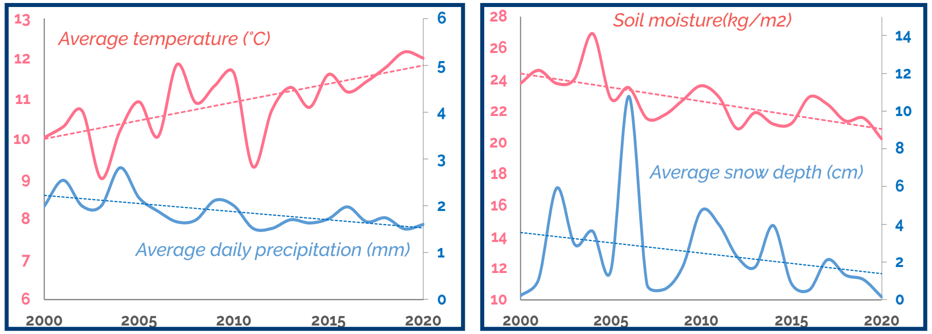


Chart 4.3. Vegetation condition index (VCI), Mariupolskyi Raion, notable droughts marked

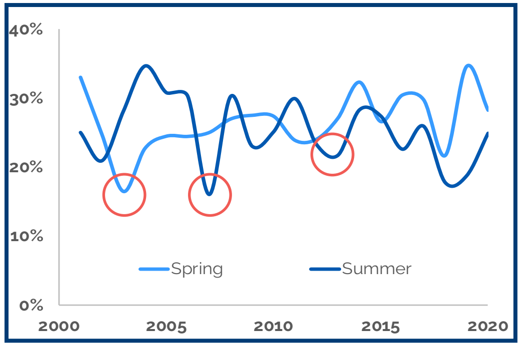


Table 4.1. vegetation condition index (VCI) categories of drought severity

VCI value (category)	20-30% (moderate)
>40% (no drought)	10-20% (severe)
30-40% (light)	<10% (extreme)

Suggested mitigation approaches

- Utilise existing early warning systems to prepare for droughts
- Landscape contouring and adjustment, e.g. developing ridges and furrows, basins, and water spreading.
- Sustainable agricultural water management and rainfall retention
- Grow drought-resistant crops

a Compared to 26% around Kherson, 29% around Zaporizhzhia and 51% around Berdyanskyi.

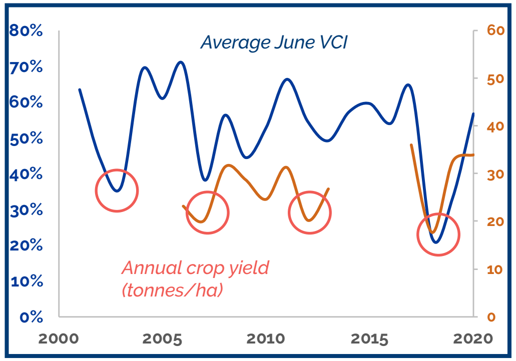
Drought - hazard exposure

To estimate the population most exposed[b] to drought, a drought exposure index was calculated based on agricultural land area, population proportion reliant on agriculture, and drought hazard[c]. The proportion of population living in rural settlements was used as a proxy for exposed population, assuming that many of these people work in agriculture, or rely on it for self-supply[29]. More details provided in Annex 1.

As indicated in Map 4.2, Nikolska and Kalchytska Hromadas are most exposed to drought. This is due to a combination of high drought hazard and a largely rural population. Note that whilst Kalchytska has relatively lower drought hazard, the entire population lives in rural settlements, making them more exposed to such events.

b It is important to get an understanding of exposure to see the number of people who would actually be affected by drought. Hazard and hazard exposure do not correlate exactly for all hromadas, as Table 4.2 shows.
c Drought hazard here is measured according to accumulated VCI (2001-2020), see previous page

Chart 4.4. Average June VCI and annual cereal crop yield, Mariupolskyi Raion



Map 4.2. Hromada-level drought hazard exposure in Mariupolskyi Raion

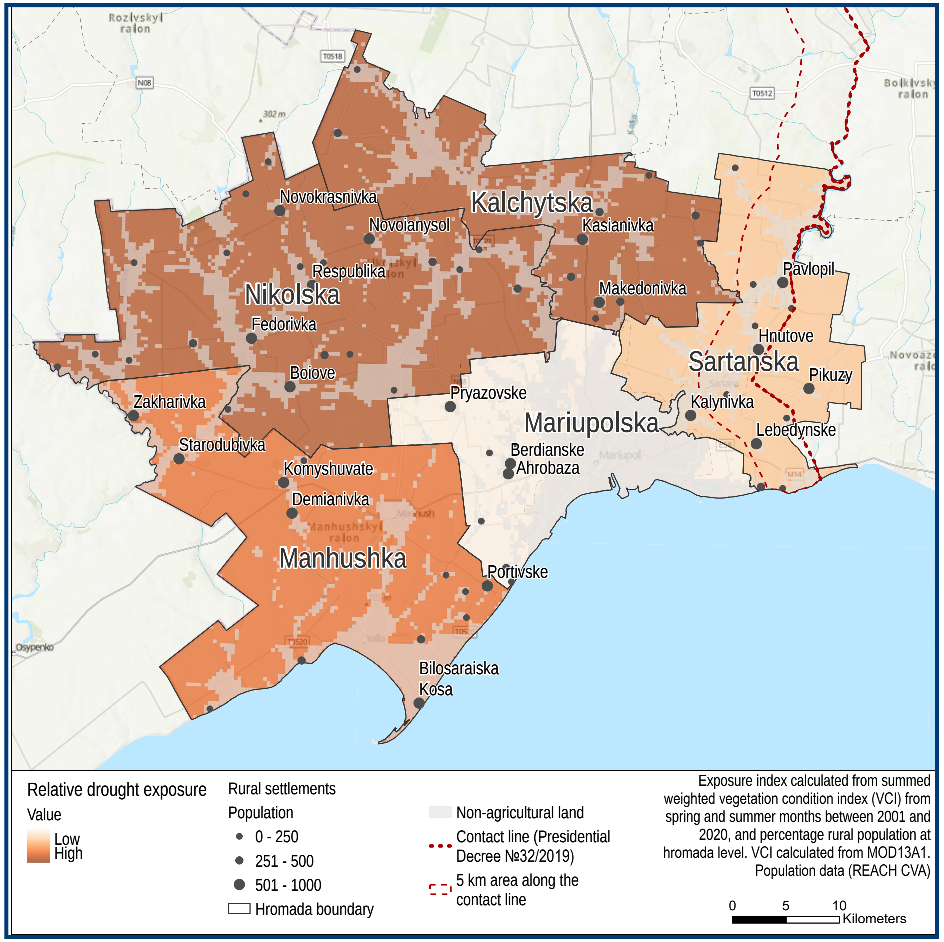


Table 4.2. Drought hazard and exposure at hromada level

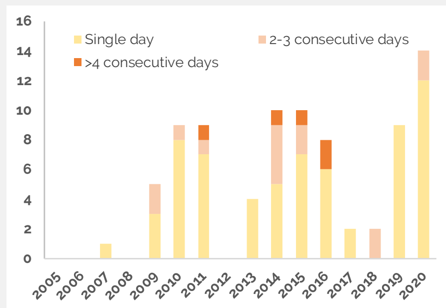
Hromada	% agricultural land	Relative Drought Hazard Index (%)	% rural population (drought exposure)	Relative drought hazard exposure (%)
Kalchytska	75	16	100	32
Manhushska	77	28	43	25
Mariupolska	46	9	1	0.2
Nikolska	74	31	51	32
Sartanska	76	16	34	12

Dry winds

Dry winds[30] adversely affect crop productivity, lowering the quality and quantity of grain. Occurring in arid conditions, dry wind events are defined as single or consecutive days with a maximum temperature >25˚C, relative air humidity <30% and wind speed at 10m height >5m/. Data was analysed for Mariupol weather station for the 2005-2020 period[31].

Extended periods of dry winds are especially dangerous to cereals, affecting ear emergence and flowering in the early growth stages, as well as causing early ripening and desiccation of grain before it has fully developed. Chart 4.5 shows the number of dry wind events, classified by length. **A clear increase in the number of days with dry winds can be observed over the time period for Mariupol and surrounding areas**. Dry winds can also help fuel wildfires (see p. 9).

Chart 4.5. Annual no. dry wind events, classified by number of consecutive days, Mariupol City



The World Meteorological Organisation (WMO) defines a heat wave as a period in which the daily maximum temperature exceeds the average maximum temperature by at least 5˚C for five or more consecutive days, the baseline period being defined as 1961–1990[32].

Heat waves have a significant impact on society as they increase both mortality and morbidity, put strain on both infrastructure (water systems, healthcare) and ecosystems due to droughts and by increasing probabilities of forest fires[33].

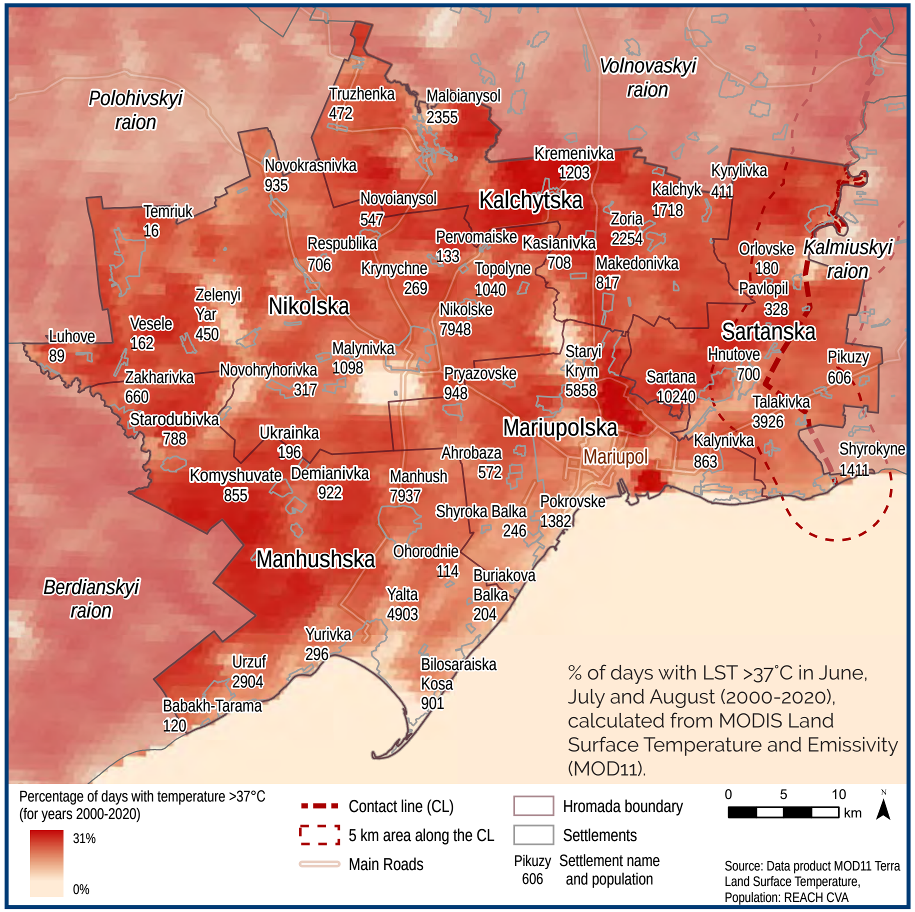
Extreme heat is a leading cause of disaster-related deaths. According to the world's largest study of global climate-related mortality that lasted two decades (2000-2019), high temperatures lead to around 489,000 annual deaths worldwide[34].

Map 5.1 displays the average proportion of days during the summer when the land surface temperature (LST) exceeds +37˚C, based on data from MODIS (2000-2020)[35]. A threshold of 37˚C was selected for the lower limit of abnormally high temperatures as it is one standard deviation above the observed mean in the summer season.

The central part of Manhushska Hromada, specifically Demianivka, Komyshuvate, Ukrainka and Starodubivka, are highly exposed to prolonged periods of high temperatures. A similar trend is evident for Kalchytska Hromada, with hot spots in Kremerivka and Kasianivka.

Mariupol City in general experiences a lower proportion of days with extreme heat compared to surrounding areas. However, there are two significant urban heat islands, which correspond to the industrial zones where the two main metallurgic factories are located - Azovstal in the south and Ilyich Steel and Iron Works in the northeast. See page 37 for more details.

Map 5.1. % of days experiencing temperatures >37˚C (2000-2020)



The highest LST in the raion (+49˚C) was observed in 2018. As Chart 5.1. indicates, a continuous gradual increase of mean, maximum and minimum temperature can be observed over the past two decades. In addition, Chart 5.2 indicates the number of days in which people are exposed to extreme temperatures (>37 ˚C). In general, this appears to gradually be increasing. In 2018 for example, this accounted for 48% of the entire summer season (44 days).

Due to climate change, temperatures are expected to continue to increase across Mariupolskyi Raion and Ukraine as a whole. The frequency and intensity of extreme heat events is also expected to increase. See p. 19 for more details.

Suggested mitigation approaches

- Ensure warning system in place to communicate heat forecasts.
- Inform community on WHO recommended practices during heat waves
- Increase water access (cooling centres, drinking water points, etc.)
- Install green roofs and increase green spaces to reduce urban heat island effect.

Chart 5.1. Summer temperatures, Mariupolskyi Raion (2001-2021)

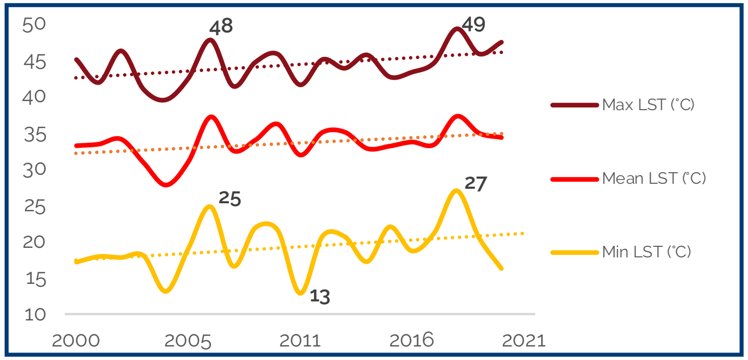
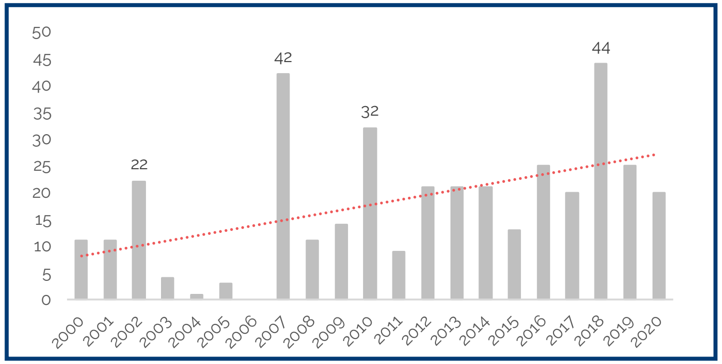


Chart 5.2. Number of days with temperature > 37˚C (2001-2021)



Cold waves

According to a study of global climate-related mortality (2000 to 2019), published in the Lancet, extreme cold resulted in ~4.5 million annual deaths worldwide[36].

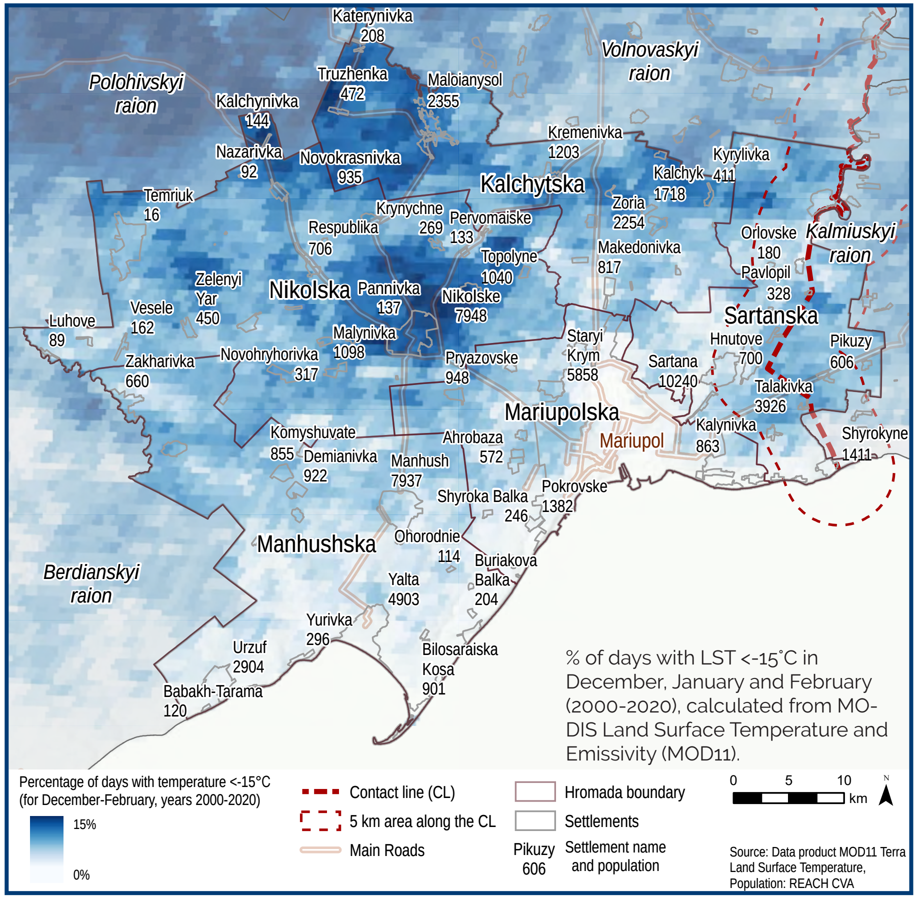
Cold waves are defined by either a rapid drop in air temperature or sustained period of excessive cold[37]. Severe cold is a threat to human health as prolonged exposure can lead to conditions such as hypothermia, frostbite and cardiac arrests[38]. Icy and snowy conditions can also lead to increased risks of road accidents (e.g. lowered visibility from snowfall, decreased traction from ice patches)[39]. Utility networks, such as water, heating and electricity may also be disrupted[40]. In addition, crops may be damaged, affecting food production and livelihoods[41].

Ukraine experienced cold waves in 2006, 2012 and 2017. Following the arrival of two Arctic cold fronts in 2006[42], a record 884 people died as a result of the extremely low temperatures, whilst 2,045 children were evacuated from their homes and were moved to shelters due to lack of heating. Many people exposed to cold waves suffered health problems, as well as hot water and electrical system breakdowns, heating interruptions and carbon monoxide poisoning in attempts to heat shelters.

Information about abnormally-cold temperatures in Mariupolskyi Raion was calculated using MODIS Land Surface Temperature and Emissivity data (MOD11)[43] based on temperature observations in December, January and February (winter), between 2000 and 2019. This is shown in Map 6.1 as the % of days with temperatures below -15˚C during this period.

The data suggests that inland areas, including Nikolske, Kalchynivka and Novokrasnivka settlements in Nikolska

Map 6.1. Percentage of days experiencing cold waves (2000-2020)



Hromada, as well as Truzhenka and Katerynivka settlements in Kalchytska Hromada are most exposed to cold waves.

Mariupol City and coastal settlements experience the least days with extremely low temperatures, with warm air masses from the Sea of Azov having a moderating effect on temperatures in the winter season.

The number of days per year that the raion experienced temperatures below -15˚C is shown in Chart 6.2. The highest number of extremely cold days were observed in 2002, 2006 and 2012. In general, mean winter temperatures have been rising, although there is no obvious trend in minimum and maximum temperatures.

The lowest temperatures (up to -30˚C) were observed in 2002, whilst - 25˚C was reached in 2006 and 2019.

Suggested mitigation approaches

- Ensure vulnerable groups can access financial support for heating.
- Provide shelters for the homeless and raise awareness of them.
- Ensure warning system in place to warn residents of cold waves.
- Increase awareness of home heating best practices, especially during failure of mains supply.

Chart 6.1. Winter temperatures, Mariupolskyi Raion (2001-2021)

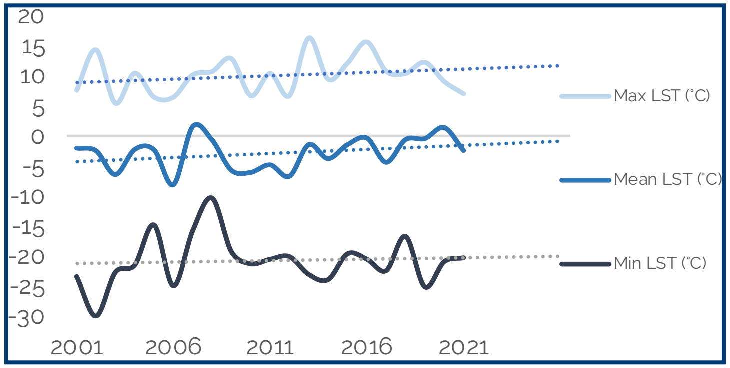
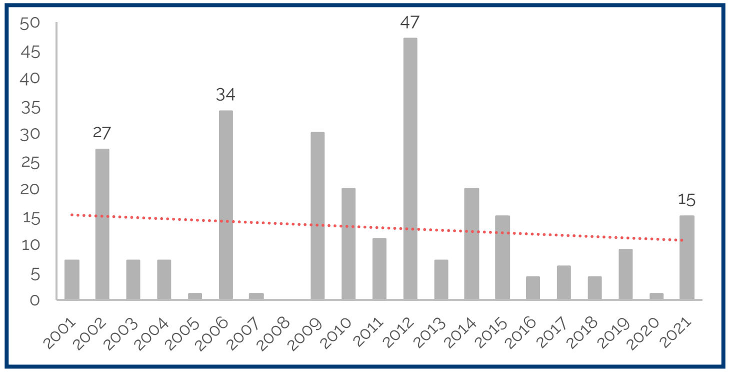


Chart 6.2. Number of days with temperature < -15˚C (2001-2021)



The most common type of landscapes in Mariupolskyi Raion are the anthropogenically-altered agricultural landscapes, consisting of arable land, pastures, hayfields, natural and semi-natural grasslands, protective forest belts, wetlands and water bodies.

Arable land occupies about 70% of the raion area, resulting in a high level of ploughing. This could lead to considerable loss of biodiversity due to land degradation, reduced ecosystem productivity, and diminished natural habitat area.

Ten protected areas are located in Mariupolskyi Raion to preserve the unique steppe ecosystems. The extent of this climatic zone is shown in Map 7.2. They cover 42.4 km^2 in total (just 1.6% of the raion area). This is less than the Ukraine average share of 6.1%, and much less than the percentage of protected areas (15%) planned in Ukraine in accordance with the State Strategy for Regional Development until 2020 (which, however, has not been achieved).[44]

The main indicators of the landscape structure related to biodiversity conservation include: the level of fragmentation of natural lands, the shape and areas with natural vegetation, its combination and connectivity, i.e. the ability of species to migrate to search for food and reproduction. Map 7.1 shows the percentage of the raion area with natural vegetation (grasslands, forest, wetlands, and water bodies) per square km.

The green color on the map indicates areas with prevailing natural vegetation, which play an important role in climate regulation, disaster mitigation and

Map 7.1. Natural land cover in Mariupolskyi Raion

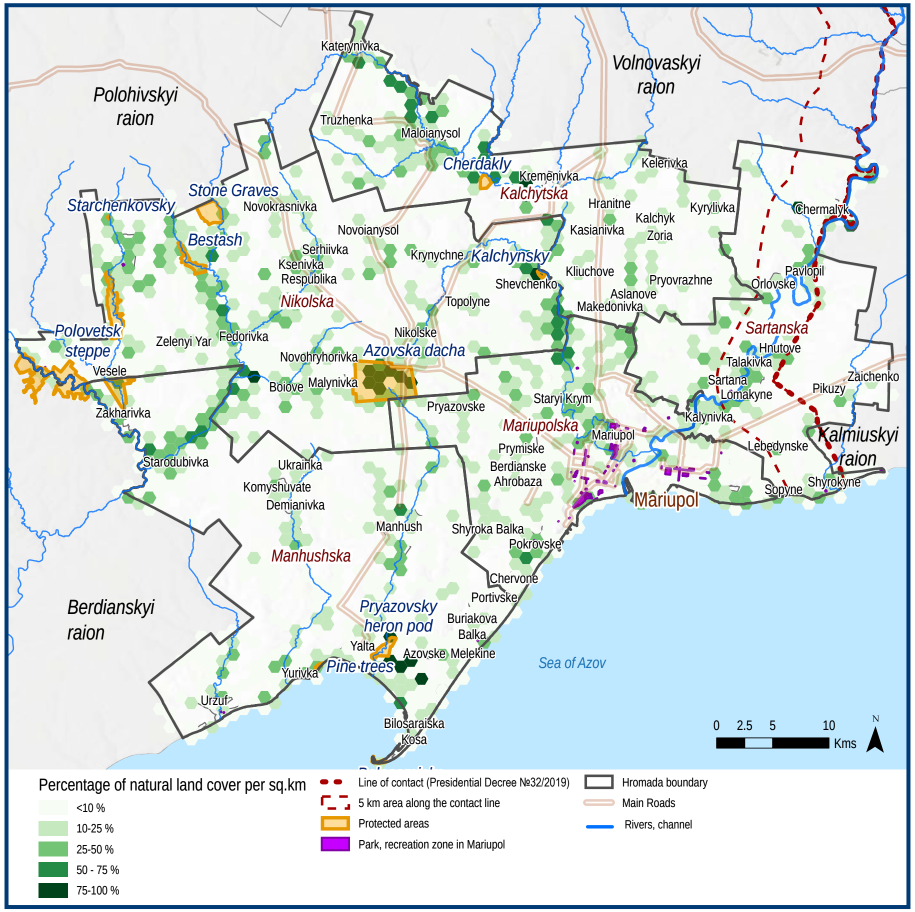


Table 7.1. Land cover types in Mariupolskyi Raion

Land cover type	Area (km^2)	% of total area
Agriculture lands	1848	70.2
Forest	169	6.4
Grasslands	350	13.3
Shrubs	0.6	0.0
Sparse vegetation	2.1	0.1
Urban / built up area	201	7.6
Water bodies / seas	17.8	0.6
Wetlands	44.5	1.7

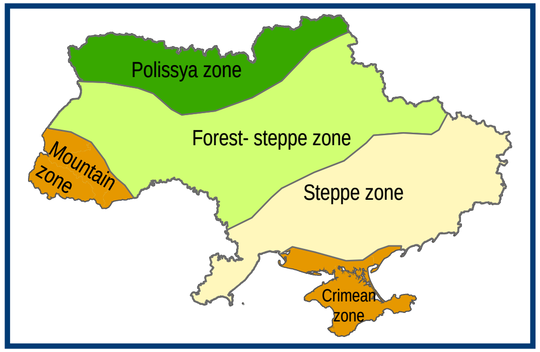
biodiversity support, and where new natural reserves can potentially be created. In addition, the 90-km coastal zone area should be considered in future land use planning. The zone also has a potential for the development of protective areas and sustainable recreation, in particular the area around Bilosaraiska spit.

Until recently, the steppes occupied about 40% of the current territory of Ukraine, but are particularly degraded today. Every third species in the Red List of Ukraine are connected to steppe ecosystems. Around 500 species are recorded in the Global Biodiversity Information Facility database over the Mariupolskyi Raion area. Although this information indicates only the number of species recorded by observers, it cannot be used as an absolute indicator, although it can indicate the priority of field surveys.

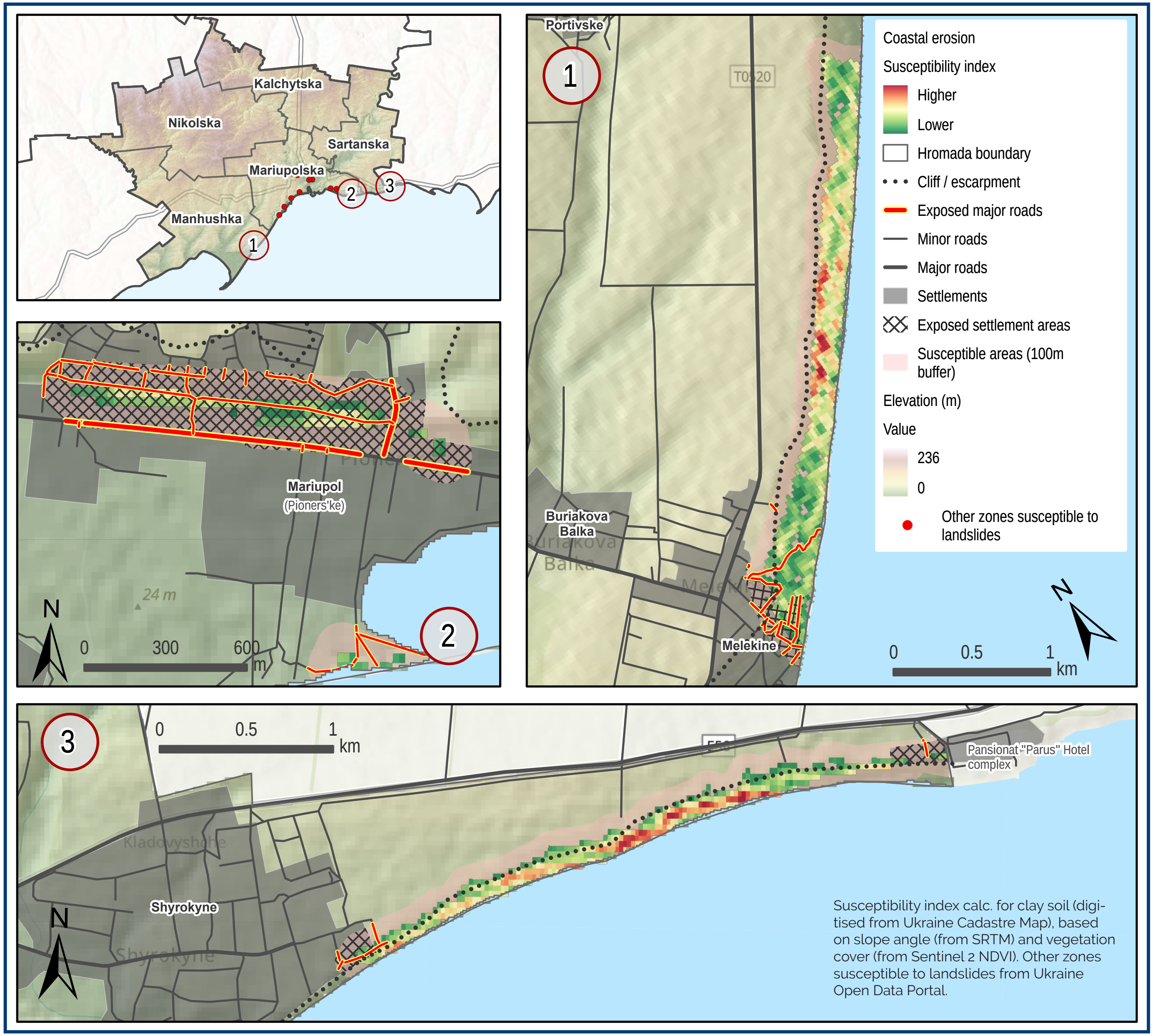
Suggested mitigation approaches

- Use cadastre maps to identify areas not privately owned or leased, where new conservation zones can be established, e.g. ravines, gullies, riverbeds.
- Develop scheme of ecological network and wildlife corridors within hromadas.
- Regularly monitor biodiversity and strengthen control in protected areas
- Support rewilding initiatives

Map 7.2. Climatic zone map of Ukraine



Map 8.1. Exposure of settlements and roads to coastal landslides in Mariupolskyi Raion



Sections of the Azov coast are susceptible to landslides[a], particularly areas of clay cliffs[45]. In Mariupolskyi Raion, this includes the areas east of Shyrokyne, east of Melekine, and around Pioners'ke, as highlighted in Map 8.1. Areas within these zones with steeper slopes and lower vegetation cover have higher susceptibility.

Vegetation can reduce susceptibility by acting as a natural buffer, with roots absorbing water that may trigger erosion and dispersing energy from storm surge and stabilising sediment. No trees were identified in the susceptible areas, leading to increased susceptibility to landslides in these zones if root structures are not intact.

In 2013, slope movements in Melekene (inset 1) led to significant deformations of buildings and agricultural lands. Both heavy rainfall and storm waves can trigger coastal landslides, which are likely to be exacerbated by climate change and sea level rise[46].

Abrasion is another common phenomenon, occurring mostly in unprotected coastal areas in the western outskirts of Mariupol. Recession rates of 0.5-1m/year are typical. Abrasion can also lead to intensification of landslides and poses the threat of destruction of residential buildings, farmland and other infrastructure. Sixteen villages are located in the zone of abrasion development within the raion.

Finally, mining areas are prone to land subsidence throughout eastern Ukraine. Other geohazards include minor earthquakes, which occur infrequently in surrounding regions, and can further destabilise soil.

Suggested mitigation approaches

- Avoid new developments in landslide and geohazard risk zones
- Utilise natural buffers such as trees and vegetation to stabalise slopes

a Note that other localities, particularly in Mariupol City (red dots on map), are also susceptible to landslides (see p.36).

Although the global climate fluctuates naturally, dramatic changes in temperature, precipitation and extreme weather in recent years are largely down to human activity.

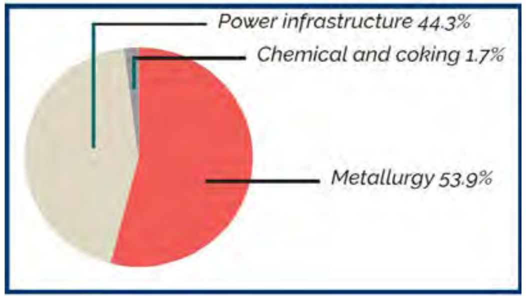
Burning of fossil fuels, deforestation, and livestock farming lead to emissions of "greenhouse gases," (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Influx of these gases into the atmosphere is leading to increased global warming and extreme weather events[47].

As a highly-industrialised city, various sectors contribute to GHG emissions in Mariupol and the wider Donetsk Oblast, with metallurgy and power generation being the largest contributors (Chart 9.1). As limited data exists for Mariupol Raion, this discussion is espanded to Donetsk Oblast, which contains Mariupol Raion, as well as the whole of Ukraine.

In 2017, Ukraine emitted 5.02t of CO_2/capita, which is below the EU average 6.88t /capita. However, CH_4 and N_2O emissions were above that of many European countries such as Germany and the UK[48].

Of the 234Mt of CO_2 emitted by Ukraine in 2016 due to fossil fuel burning for energy production and manufacturing, 54% was related to coal. This is significantly higher than the EU average of 29%. There is a heavy reliance on coal for energy production in Ukraine, accounting for 1/3 of the country`s total energy production[49].

Chart 9.1. Primary industrial contributors to GHG emissions in Donetsk Oblast



Map 9.1. Projected changes in (a) max. temperature of warmest month and (b) precipitation of driest quarter (1970-2000 / 2041-2060), Ukraine

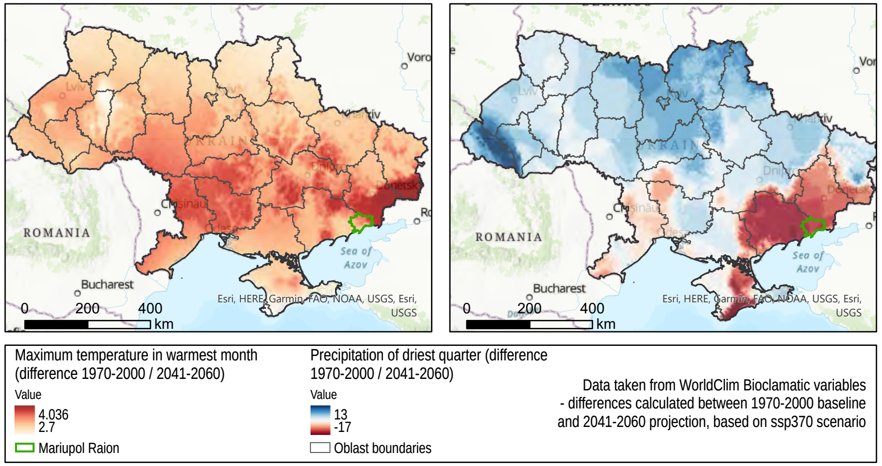


Fig. 9.1. Projected changes in bioclimatic variables of interest, Mariupolskyi Raion, between 1970-2000 and 2041-2060[53]

+2.8˚c Annual mean temperature increase

+3.5˚c Increase in max. temp. in warmest month

+1.5mm Increase in precipitation of coldest quarter

+6.5˚c Change in mean temperature in driest quarter

+3.1˚c Increase in minimum temperature in coldest month

-9.0mm Decrease in precipitation in warmest quarter

-5.2mm Decrease in precipitation of driest quarter

-2.6mm Decrease in annual precipitation

Warmer temperatures and lower rainfall, *particularly in the driest and warmest months could lead to more heat waves and droughts*

A number of bioclimatic variables from WorldClim[50] were analysed to estimate projected temperature and precipitation changes from the baseline (1970-2000) to the near future (2041-2060) in Mariupolskyi Raion (Fig. 9.1). **Temperatures are projected to increase and precipitation to fall, particularly in the driest and warmest quarters respectively (Map 9.1).** These trends correspond to recent historic climatic trends (see p.12), and such changes are only likely to lead to increased heat waves and droughts, and other extreme events such as flooding.

Ukraine ratified the Paris Agreement in 2016, committing the country to reduce GHG emissions to at least 40% below 1990 levels by 2030[a]. Whilst recent data indicates emissions[b] have fallen below this level[51], this is primarily due to post-Soviet deindustrialisation, rather than progressive moves towards a green economy. In December 2020[52], Ukraine announced its updated Nationally Determined Contributions (NDCs) on 2030 emission targets[c], which still falls short of achieving a 1.5˚C-compatible ambition level.

Suggested mitigation approaches

- Raise awareness of communities and relative stakeholders about consequences of climate change
- Adapt and plan for extreme events
- Factor climate change impacts into new developments across the raion

a Including LULUCF. Human activities impact terrestrial carbon sinks such as forests, through land use, land-use change and forestry (LULUCF) activities, altering CO_2 exchange (carbon cycle) between terrestrial biosphere system and atmosphere. LULUCF removals are expected to have minor impacts in future in Ukraine

b Excluding LULCF

c A national climate plan highlighting climate actions, including climate-related targets, policies and measures governments aims to implement in response to climate change and as a contribution to global climate action.

Sea level rise

Map 10.1. Population and infrastructure exposure to sea level rise

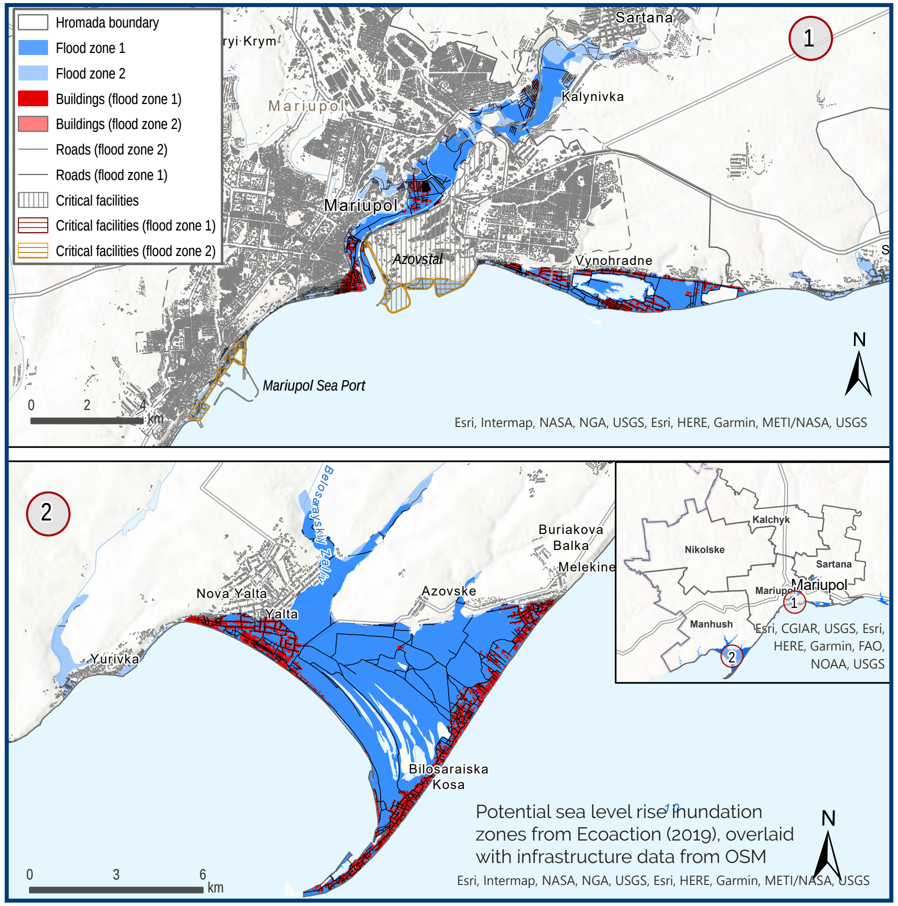


Table 10.1. Infrastructure exposed to sea level rise in Mariupolskyi Raion[54]

Infrastructure type	Flood zone 1	Flood zone 2
Buildings (total no.)	8,838	10,825
Roads (km)	264	373
Railways (km)	17	88
Power lines (km)	29	38

Sea level rise in the Sea of Azov is linked to three main processes at various scales: 1) global sea level rise due to climate change; 2) regional vertical movements of the earth's crust; 3) localised seasonal floods and storms causing temporary surges in sea level[55].

Aside from tectonic movements, **sea level in the Sea of Azov has overall been rising at a rate of 1.5 ± 0.69 mm/year throughout the 20th Century, which can affect low-lying housing or block transportation routes**. These changes can be attributed to climate change and global sea level rise due to influx of meltwater from glaciers and ice sheets[56], as well as thermal expansion of the oceans as they warm[57].

Global rates of sea level rise are in fact accelerating[58] (Chart 10.1), and the level of the Black Sea and Azov Sea is expected to rise by 0.36m - 0.46m by 2100. These estimates are based on emission scenarios "RCP4.5", an intermediate emission scenario, and "RCP8.5", the "worst-case" scenario, respectively, and are used for upper and lower bounds for the interpretation of the data in this section.

Map 10.1. shows two flood hazard zones: (1): area inundated by sea level rise of +82cm in 2100, based on projected climate change impacts of the highest GHG emission scenario (rcp8.5), and (2): estimated area exposed to short-term seasonal fluctuations of sea level due to storm surge (+79cm). Within Mariupolskyi Raion, these zones cover an area of 53.35km² and 67.48km² respectively, with **Mariupol City and Bilosarayskyy Peninsular most affected**.

See **Flooding** page for details of **flooding in Mariupol City**

Under this level of sea level rise, which can be considered a worst-case scenario, 8.4% of the area of Mariupol City would be affected, including a number of hazardous facilities such as Mariupol Sea Port and Azovstal steel and iron works. The latter is considered to be one of the most dangerous facilities in the overall flooded zone and could cause an environmental disaster if large amounts of hazardous substances from this facility were released into the sea.

In zone 1: 14% of the affected area is residential, 6% is farmland, 2% is industrial and 5% is forest.

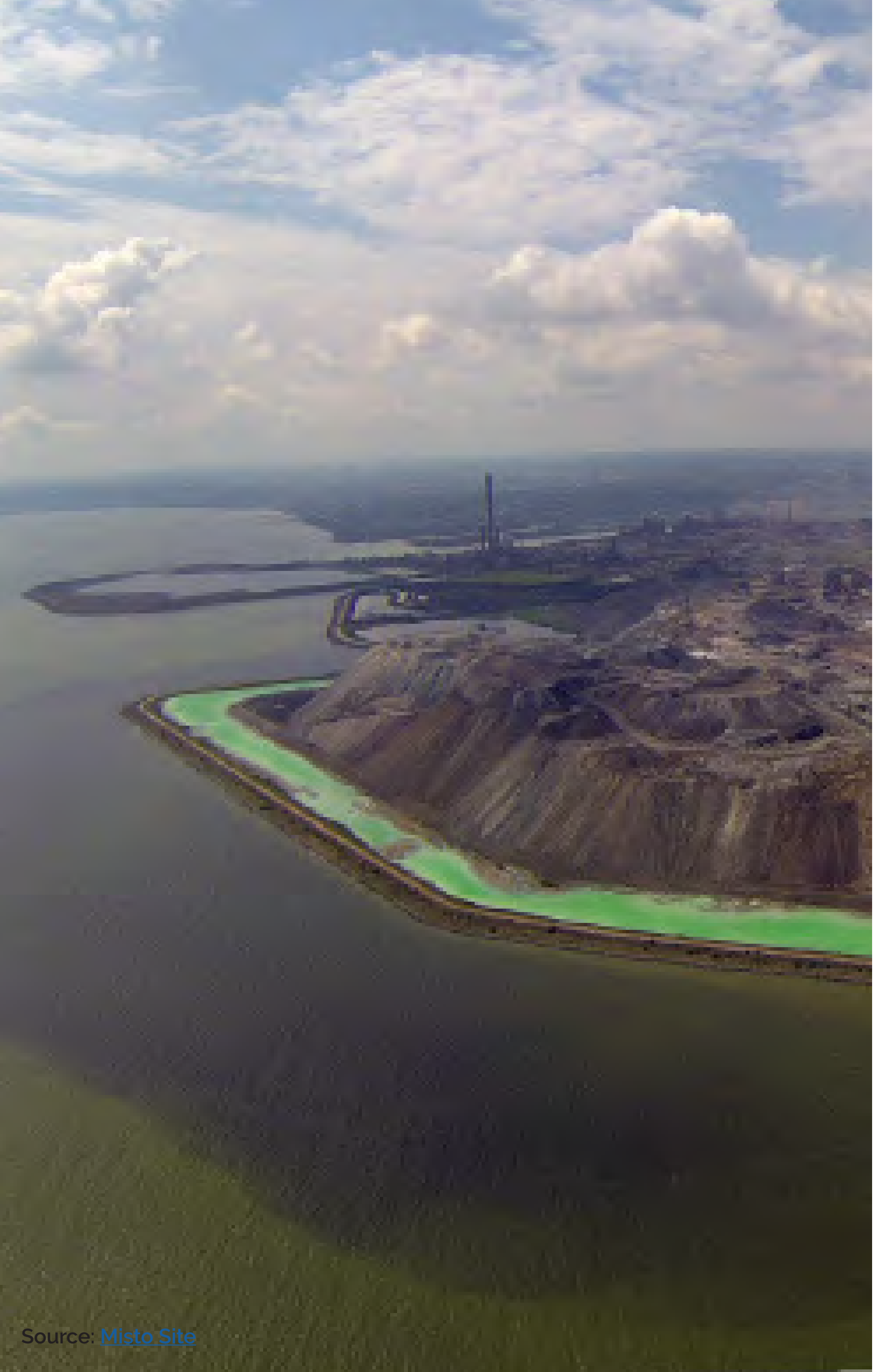
In zone 2: 13% of the area is residential, 18% is farmland and 5% is industrial, whilst 8% is covered by forest.

Table 10.1. provides details on the types of infrastructure and facilities that could be affected by this projected sea level rise[a]. Coastal defenses would need to be installed to prevent inundation. Otherwise, many buildings would need to be relocated, whilst roads, railways and powerlines would need to be diverted further inland.

a Note that data is taken from OpenStreetMap and may not include all features of interest.

Suggested mitigation approaches

- Raise awareness of potential flood zones due to sea level rise
- Avoid further developments in potential flood zones
- Invest in coastal defenses
- Utilise natural buffers against storm surge (e.g. forests, vegetation)



Source: Misto Site

Anthropogenic hazards

Anthropogenic hazards, also known as human-induced hazards, are generated entirely or predominantly by human activities and choices. The Donbass is a heavily-industrialised region of Ukraine. Mariupolskyi Raion is littered with **hazardous facilities** and **dated critical infrastructure systems**, which pose potential risks to the population and environment in case of damage or targeted conflict-related attacks.

In this chapter, detailed sections outline **exposure of various types of infrastructure to conflict incidents** across Mariupolskyi Raion, and highlight cascading impacts to the population and the environment.

Air pollution is another major hazard discussed here, particularly affecting the population of Mariupol City and other industrial areas.

Ensuring industrial equipment is updated and maintained to the **highest safety and environmental standards** and closing down sites that do not meet these standards is an essential step to building resilience. Confirming facilities are adhering to emission limits and regulations, and preparing **suitable contingency plans** are some further critical mitigation measures that can be taken to reduce the risk to populations and the environment.

Hazardous facilities - exposure to conflict

Since the outbreak of armed conflict in Donetsk and Luhansk regions in 2014 Mariupol remains close to the frontlines. The eastern part of Mariupolskyi Raion, particularly Sartanska Hromada, is most exposed to conflict. Both infrastructure and settlements are at risk of shelling and other conflict-related incidents. See box on p. 27 for more details.

In addition to being exposed to the conflict, **Donetsk Oblast is one of the most industrialised regions in Ukraine. According to the Donbass Environment Information System and the SESU Register of Potentially Dangerous Objects, there are 17 hazardous facilities in Mariupolskyi Raion (including within 25km of the raion). Many are located within Mariupol City.**

These facilities include metallurgical factories, water treatment works, quarries, chemical factories, and Mariupol Port. Many are in poor condition and require a lot of maintenance, whilst some have been abandoned but may still pose an environmental or health threat.

This section provides an overview of all hazardous objects in and around the raion, their exposure to conflict incidents, plus an environmental and health risk assessment from potential chemical accidents or attacks. The chapter on Mariupol City later in this report also provides a more in-depth analysis of hazardous industrial facilities within the city boundaries

As shown in Table 11.1, while there do not seem to be any direct-targetted attacks on hazardous facilities, many conflict incidents have occured close to Pavlopil Dam and pumping station over the past 18 months. This could have an impact on

Map 11.1. Critical infrastructure facilities and exposure to conflict

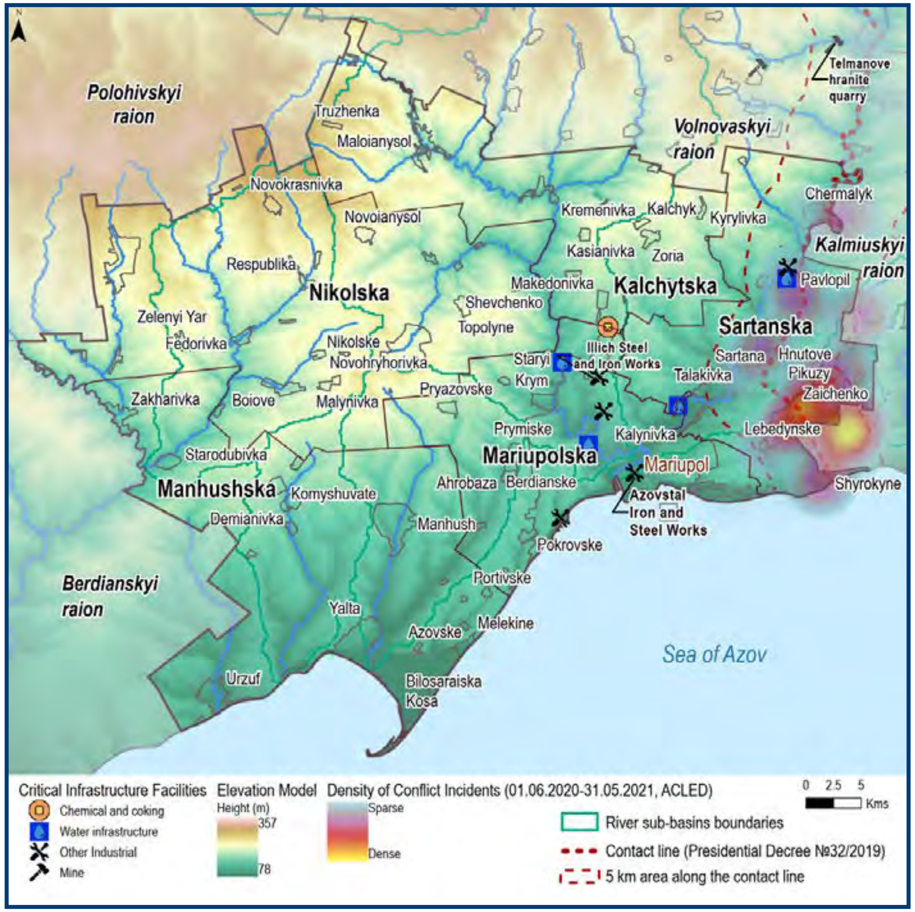


Table 11.1. No. conflict incidents within 2.5km of a hazardous facility[59]

Facility name	Nearest settlement	2020 (Jan-Jun)	2020 (Jul-Dec)	2021 (Jan-Jun)
Pavlopil Reservoir Dam	Pavlopil (<150m)	40	2	16
Pavlopil water supply syst. - Pump-ing stn. 1 (Donbass Water Co.)	Pavlopil (<150m)	40	2	17
Mariupol water filtering station 2	Mariupol (Tsent.)	1	1	3
Concern Azovmash metallurgy factory (Site A)	Mariupol (Kalmiuskyi)	1	1	3
Karan Granite Quarry (abandoned)	Myrne (300m) *Volnovakha Rn.	0	0	1

civilian populations, since attacks on water infrastructure facilities pose a threat to access to safe water, as well as risk of toxic chlorine gas release (see p.24).

Here, an environmental and health risk assessment of the sites is provided in light of a potential conflict incident or other cause of damage to the facility. The analysis is based on the FEAT methodology.

Flash Environmental Assessment Tool

The [Flash Environmental Assessment Tool (FEAT)] helps identify existing or potential environmental impacts from hazardous chemicals released from industrial facilities, that pose risks to humans and the environment, following sudden-onset disasters[60].

In the following section, the FEAT 2.0 Guide has been used to conduct a desk review of the hazardous chemicals potentially present in industrial facilities across the raion and determine potential human and environmental exposure pathways. Exposure is provided in distances (km) based on estimated substance quantities (kg) to provide insight into the potential exposure in the case of a disaster.

The FEAT methodology was developed for UNEP and UNOCHA and is based on EU Directives on hazardous substances.

Metallurgy industry

Mariupolskyi Raion is home to a number of major facilities associated with the metallurgical industry, including **Ilyich Steel and Iron works, Azovstal Metallurgical plant**, and **Concern Azovmash metallurgy factory**. All are located in Mariupol City, and suffer from outdated equipment and lack environmental safety controls, which can compound hazards and exposure to them.

Air pollution is a major issue in the city, with the majority of emissions being produced by

Hazardous facilities - environmental assessment

the metalurgical industry. Some equipment has since been updated, leading to some air quality improvements[61]. There is however also a risk to groundwater and surface waters due to tailing dams[62], whilst spoil heaps also cause extensive dust pollution. Find out more in the Air Pollution chapter, and also the Mariupol City chapter.

Emissions from these facilities are high in particulate matter[a], and other toxic substances such as **carbon monoxide, phenol, formaldehyde. and hydrogen sulfide** (Globally Harmonized System of Classification and Labeling of Chemicals (GHS classification): Toxic Gas, Acute Tox. 1).

***Hydrogen sulfide is dangerous to human health, particularly respiratory systems, and** can be **lethal to humans** on inhalation.*

In addition, **waste from tailing dams** (GHS classification: Toxic Liquid Acute Tox. 1, Aqu. Acute 1) associated with the metallurgical industry poses a threat to humans and the environment (soil, groundwater and rivers can all be receptors).

***Waste from tailings** may pose **a threat to humans through heavy metal deposits, and** can be **lethal** if exposed to large quantities. Also poses a threat to soils and rivers.*

Mariupol Sea Port

The predominant types of cargo handled at Mariupol Sea Port include grain, coal and construction materials, as well as metallurgical products. However, the port also handles smaller quantities of hazardous cargo, and in 2020 handled 165 tonnes of oil and 31 tonnes of fertiliser[63].

Chemicals used in **agricultural fertilisers**, like ammonium nitrate can be very hazardous if not stored safely, as exemplified by the 2020 Beirut Port blast, where an explosion of a warehouse storing the chemical for 6 years killed >200 people[64].

*Released quantities of **Nitrogenous fertilisers** (GHS classification: Toxic Gas, Acute Tox. 1) exceeding 10,000kg could be carcinogeous or **fatal to humans** at <100m, and **dangerous to health** at up to 2km distance.*

Petroleum industry

Azov Oil Company LLC oil depot is located on the northern outskirts of Mariupol City. Whilst the site of the petroleum refiner is now derelict, soil and water contamination could still occur if the site was improperly abandoned.

*Quantities of 10,000,000kg or greater of petroleum (crude oil) (GHS classification: flammable, Flam. Liq. 1) can be **lethal to humans** within 400m and **dangerous to health** up to 600m. As little as 1000kg of oil poses a threat to the environment, affecting **soil and rivers** and causing (reversible) adverse effects to aquatic organisms.*

Water treatment facilities

A number of water treatment works are located in Mariupolskyi Raion, including **Mariupol water filtering station (1), Mariupol water filter station (2) and dam (KP "Water of Donbass" industrial base).**

Attacks on these facilities not only impede access to drinking water but also pose a threat to public health and the environment due to the release of chlorine. **Chlorine** is usually stored as liquefied compressed **gas** at water treatment facilities (GHS Classification: Toxic Gas, Acute Tox. 1).

*Quantities > 1 million kg of **chlorine gas** may be **lethal to humans** in close proximity, and **dangerous to health** from 2-5km distance.*

*In **liquid form, chlorine may be lethal to humans, or dangerous to health, particulary respiratory systems**. It also poses a threat to **soils and rivers** up to 10km away when large quantities are released, and can cause fatal injuries in wildlife.*

Other facilities

There are various other facilities that could pose a potential hazard within 25km of Mariupolskyi Raion, including:

Telmanove Granite Quarry, near Hranitne, Volnovakha Raion: in December 2014, shelling struck key infrastructure at the facility. Work at the plant has since been suspended.

Karan Granite Quarry, near Myrne, Volnovakha Raion: operations ceased in January 2014. Today the site is abandoned, whilst the quarry itself is flooded, posing a risk of groundwater contamination. Shelling occurred in 2015 at Karan Station, used for the transportation of dangerous goods.

Suggested mitigation approaches

- Upgrade equipment and close sites that do not meet the highest safety and environmental standards
- Conduct detailed site-specific health and environmental risk assessments
- Develop contingency plans for potential accidents or targeted conflict incidents at major hazardous sites
- Create plans to manage abandoned or closed industrial and waste facilities

a Particulate matter are microscopic particles of solid or liquid matter suspended in the air, including pm10 and pm2.5, which are inhalable and can cause serious health issues

2 Detailed information on substances, exposure quantities and distances can be found in the FEAT 2.0 Pocket Guide. Focus here is on the "first priority response" in case of an accident at a hazrdous facility, and on the most likely exposure pathways, based on expert opinion.

Spoil tips and tailing dams - exposure to conflict

Industrial facilities scattered across Mariupolskyi Raion produce a variety of waste material, often stored in spoil tips and tailings dams. A spoil tip consists of waste removed during mining or production processes, whilst a tailing dam is an earth-filled embankment dam used to store by-products of mining operations. Both are hazardous as they contain chemically dangerous substances.

Map 12.1. displays spoil tips, tailings dams, recent conflict incidents, and rivers exposed to contamination due to waste discharge[a]. As shown, many spoil tips are located close to rivers, whilst many tailing dams sit directly on the Azov coast. This includes one of the largest spoil tips in the area, part of the nearby metallurgy plant, which rises to 40m in Mariupol city.

To assess population exposure to spoil tips, their locations were identified in relation to settlements. According to the Ministry of Health Protections' Decree N°173, spoil tips should be located at a safe distance (300-500m depending on height) from settlements, and should be cultivated to minimise visual impact, prevent excessive heating and limit dust production, which can be dangerous to human health.

At least 30 spoil tips were found to be located in the raion. Although this is less than in northern Donetsk Oblast, at least 11 are located within settlements, mostly in Mariupol City. A further 4 are within 300m of settlements. Some tips may be abandoned and lack any proper monitoring and maintenance.

In terms of tailing dams, the main hazards are dam failures, representing low probability high impact events; and diffuse pollution, which occurs more frequently. At least 8 tailing dams were found to be located within Mariupolskyi Raion, all within or around Mariupol City. Five conflict events were recorded <2.5 km from tailing dams, and 30 within 5 km between January 2020 - June 2021 (based on Armed Conflict Location and Event Data Project (ACLED) data[65]). Tailing dams and spoil tips northwest of Sartana are located closest to the CL and were exposed to the majority of these incidents.

Map 12.1. Spoil tips and tailing dams, and exposure to conflict incidents

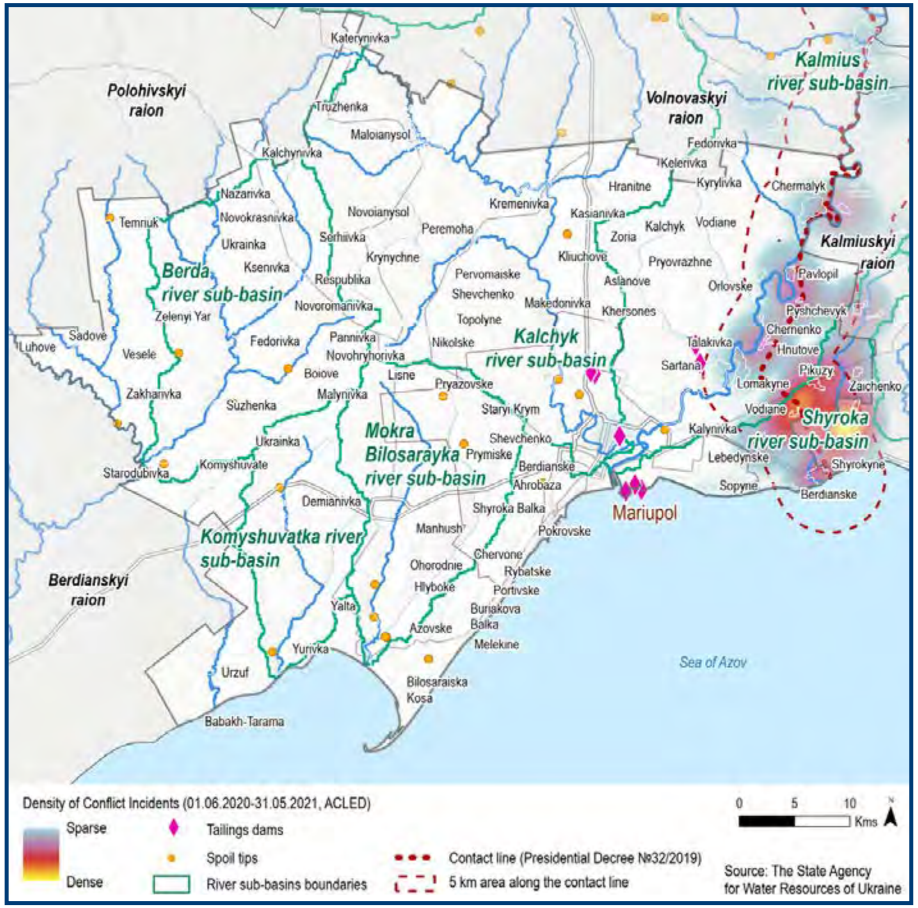
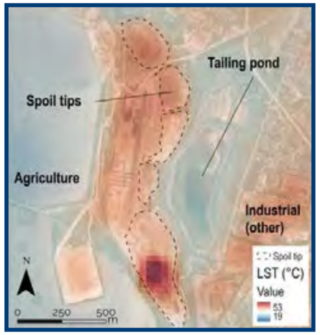


Table 12.1. Spoil tips, tailing dams, conflict incidents

Key information	No. tailing dams	No. spoil tips
Sites located within settlements	6 (75%)	11 (37%)
Sites located within 500m of settlements	7 (88%)	15 (50%)
Sites where conflict incidents occurred within 2.5km (January 2020 - June 2021)	1 (13%)	1 (3%)
Sites with a water source within 500m	8 (100%)	22 (73%)

Map 12.2. Spoil tip heat island



Although the remaining dams were located further from the CL and thus from the threat of direct attacks, further incidents cannot be ruled out. Importantly, the tailing dams of the Azovstal facility are located just over 5km from the nearest conflict incidents recorded in the past 18 months. These tailing ponds are separated from the sea by a dam and irreparable pollution of the Azov Sea would occur if damaged. Maintenance of sites is therefore essential to avoid contamination and failure. See Mariupol City section.

Surfaces of spoil tips can reach very high temperatures, creating localised "heat islands". Map 12.2., derived from Landsat 8 data in July 2020, indicates significant temperature differences between spoil tips in Kalmiuskyi (Mariupol City), and its surroundings. Temperature on the spoil tips averages at 37˚C (max. 48˚C), compared to ~28-30˚C in surrounding areas. Vegetation on spoil tips can significantly help reduce the temperature of these zones. See p. 37.

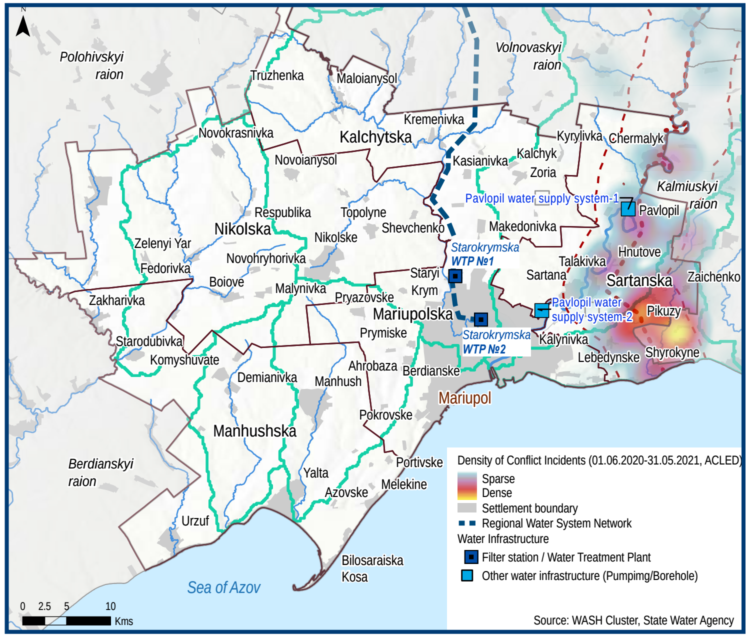
Suggested mitigation approaches

- Utilise FEAT 2.0 guide and Ministry of Health Protections' Decree to better understand exposure.
- Ensure proper maintenance of tailings dams and spoil tips
- Plant vegetation on spoil tips to reduce visual impact, reduce erosion risk and limit dust production

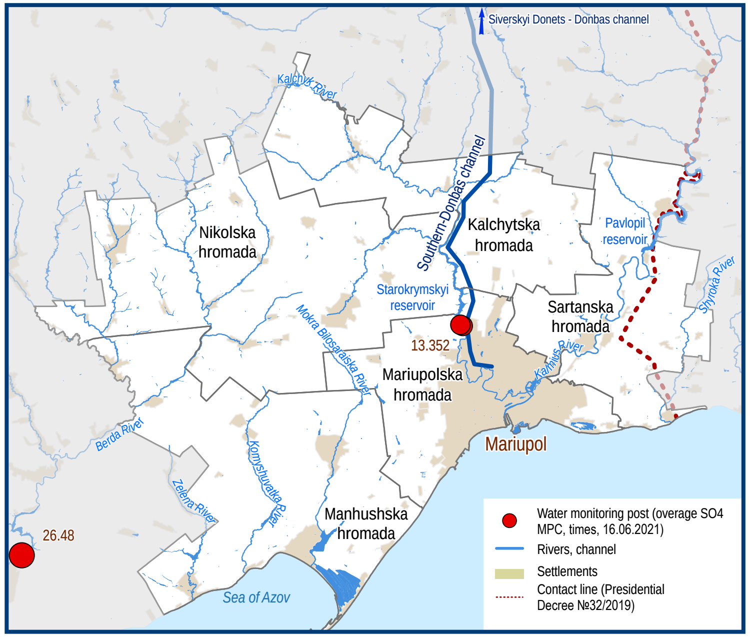
a Data indicating tailing dam and spoil tip locations was collected by IMPACT through satellite imagery digitisation, OSM data, and review of State Agency for Water Resources of Ukraine data.

Water supply infrastructure - exposure to conflict

Map 13.1. Water supply infrastructure, exposure to conflict



Map 13.2. Water monitoring post data



Functional water infrastructure is critical for pubic and industrial use. During and after a disaster, water supply networks are especially essential to ensure basic water and sanitation. As with most of the critical utility infrastructure in the region, much of the water supply infrastructure in Mariupolskyi Raion is in disrepair or lacks proper maintenance. Conflict incidents pose an additional threat to the already fragile infrastructure.

Mariupol is supplied with drinking water from two sources: Starokrymskyi Reservoir on the Kalchyk River, which flows into the Kalmius River within the city[a] and the South Donbas water supply system from the Siverskyi Donets River, which passes through the Non-Government Controlled Areas (NGCA). Water from these two sources is mixed at a 3:7 ratio respectively, achieving acceptable quality. The total length of water supply networks in Mariupol City is 1831 km.

Chart 13.1 shows that most of the water taken from both rivers is used for industrial purposes. Drinking and sanitary needs are covered partly by river supply, whilst the remainder is supplied by the South-Donbass water supply system (southern part of Siverskyi Donetsk-Donbass channel). Processing of water takes place at the KP "Water of Donbas" filtering station.

In 2014, the Siverskyi Donetsk-Donbass Canal suffered significant conflict-related damage. Pumping stations were destroyed, pipelines damaged, and many residents left without water for extended periods. Only in April 2016 were all necessary repairs completed, and the third pressure pipeline of the canal was put into operation.

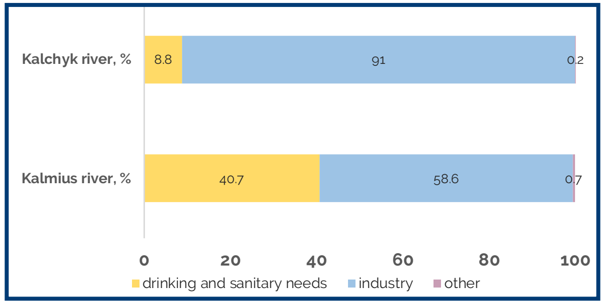
As a result of the conflict, more than 500,000 people, including both residents of Mariupol and temporarily displaced persons, currently face interruptions in quality and safety of drinking water[66]. The Siverskyi Donets-Donbas channel and the Donetsk filtering station are included in the Minsk agreements as strategic objects of life support and must be demilitarized. However, they frequently remain targets of shelling.

Conflict incidents along the South Donbas water supply system could pose threats to human health due to release of stored chlorine gas, as well as direct impact of water supply loss[67]. The pumping station of the first lift of the South Donbass water pipeline is in the "grey" zone and often comes under fire. This pumping station supplies water to Starokrymska water treatment plants 1 & 2, which serve Mariupol, Sartana and Stary Krym.

In April 2019, hostilities caused an accident at the South Donbass water conduit, located in the NGCA. This forced the water supply source to the city of Mariupol to be shifted completely to the Old-Crimean reservoir, which is polluted by about 60%, whilst the water level is less than 20%[68].

A potential alternative for Mariupol would be the Pavlopil Reservoir (see on the map), however it is also located on the CL. The water would also require further purification[69]. Note that the French government recently launched a project to modernise the water supply system in Mariupol[70].

Chart 13.1. Water usage type by river, 2019[71]



Suggested mitigation approaches

» Explore alternative sources for underground water supply

» Introduce modern technologies and methods for water purification

» Relocate infrastructure further from CL

a The quality of this water is unsatisfactory; salinity is ~3-3.5g/dm3, x3 higher than normal.

As with other critical infrastructure, oil and gas pipelines in the raion are in poor condition and are located close to the CL, as indicated in Map 14.1. **From June 2020 until July 2021, 68 shelling incidents were observed near the gas pipeline which extends near the settlements of Orlovske, Pavlopil, Pyshchevyk, and Chernenko**[72].

This infrastructure represents a disaster risk as damage can lead to oil or gas spills which can pollute both water and the atmosphere. In addition, both fuels are a major source of heating for the region, so damage could have critical consequences on the population in the winter months.

In June 2015, conflict-related damage to the Kramatorsk-Donetsk gas pipeline left settlements such as Volnovakha and Berdyansk, and Mariupol City without gas for three days. Due to the interruption of gas supply, work of the major metallurgy factories in the city - which require gas - was also suspended[73]. At that time gas was the last energy resource that was steadily supplied to the city of Mariupol.

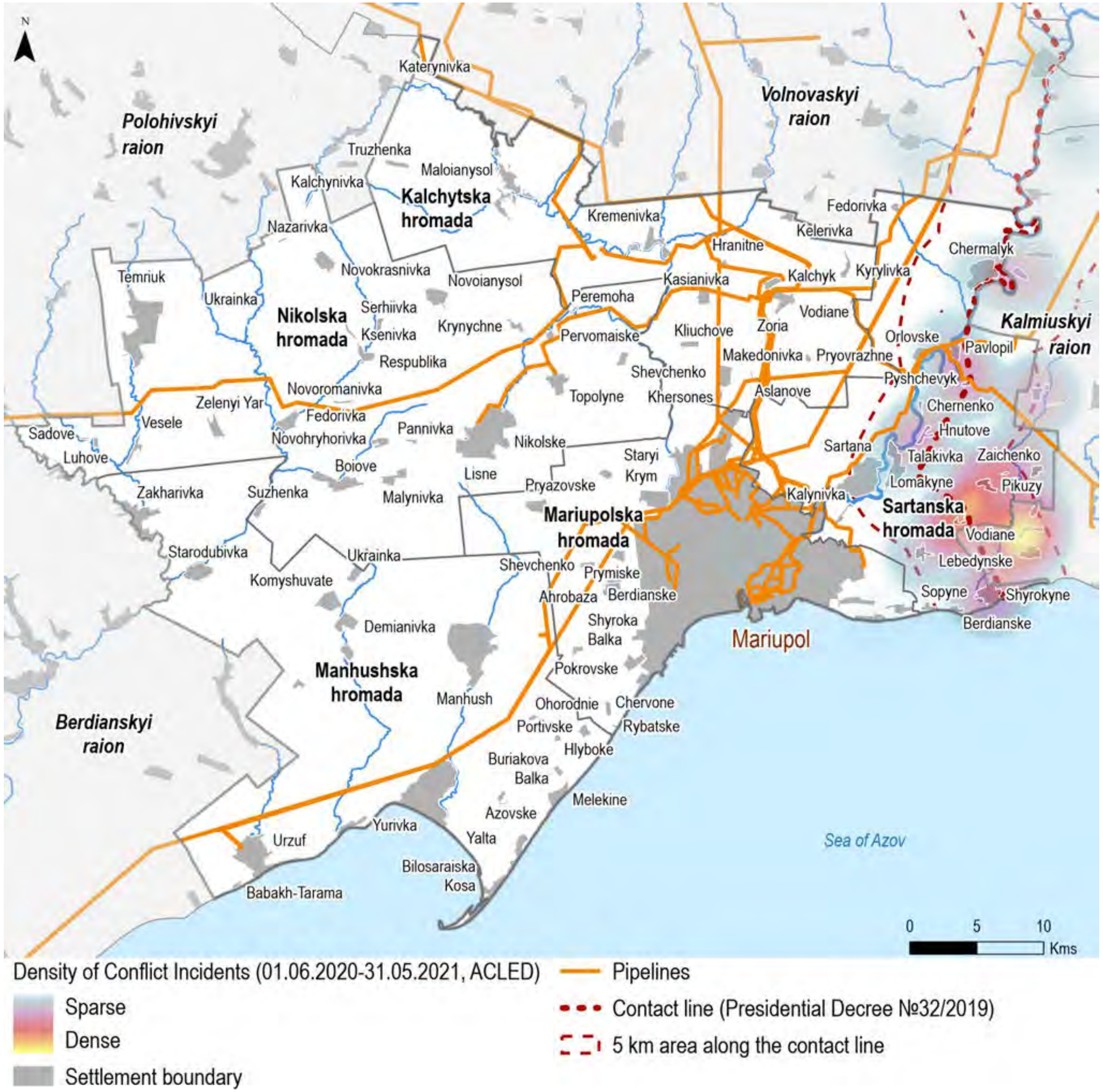
Similarly, in October 2016, conflict-related damage to a gas pipeline left more than 500 houses and around 4.5 thousand villagers in Talakivika (near Sartana) without gas for one whole day[74].

Due to the poor condition and lack of proper maintenance of the network, supply faults and failures are common, irrepsective of conflict incidents.

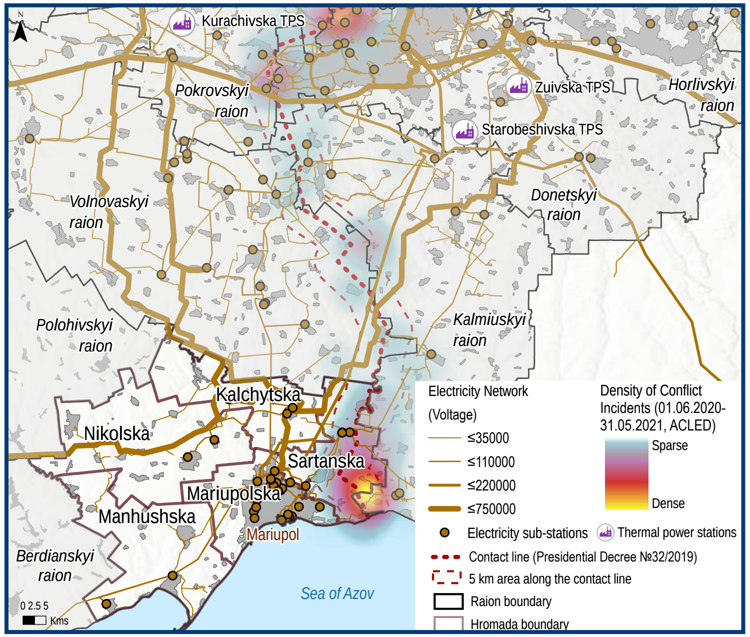
Suggested mitigation approaches

- Raise awareness of residents on risks related to cut of gas supply
- Consider the provision of alternative sources for heating and cooking for affected households

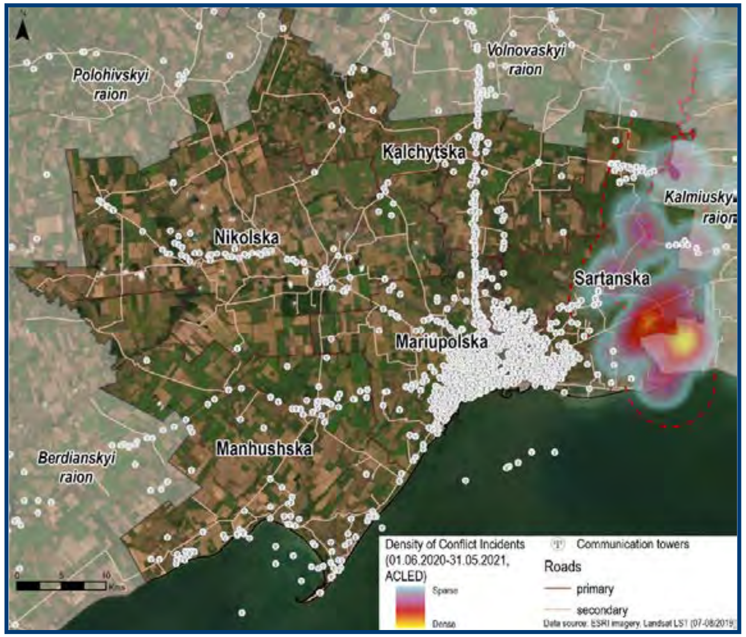
Map 14.1. Oil and gas pipelines, and exposure to conflict incidents



Map 15.1. Electrical network and exposure to conflict



Map 15.2. Communication towers and exposure to conflict



Electricity is critical for both domestic and industrial activities. Because of the linkages between electricity and heating and water supply systems, electricity shortages can have cascading consequences on the ability of households to heat their shelters and access water. **The electricity network in Mariupolskyi Raion is in poor condition. Failures are common, whilst proximity to the CL poses additional complications.**

As information on the Mariupol City level is not available, this section has expanded its focus to the oblast. The main sources of energy production in Donetsk Oblast are fossil fuel-based thermal power stations (TPS). Heating power plants, which utilise water vapor, are also found in the region, but make up just 5% of energy production.

According to ACLED data, 20 shelling incidents were reported close to power lines in the settlements of Talakivka, Lomakine, Berdyanske and Sopyne between June 2020 and July 2021. In October 2016, as a result of shelling in the village of Talakivka, Donetsk region, power lines were damaged, leaving over 300 houses without electricity. **This shows how exposed electrical infrastructure is to conflict. Appropriate mitigation measures are required to prevent disruption to supply.**

Until March 2017, Starobeshivska TPS provided electricity to Mariupol. However, after armed groups seized the TPS, it was no longer serving the city with electricity. Currently, Kurachivska TPS is responsible for centralized electricity supply to Mariupol, which is located around 11km distance from any recent recorded shelling incidents.

Electrical power systems are also significant in supporting infrastructure for telecommunications facilities. Shortage of electricity supply prevents telecommunication systems from operating correctly. In addition, damage may occur directly to telecommunication infrastructure.

Map 15.2 shows that 49 telecommunication towers are located within 5 km of the CL and are highly exposed to conflict incidents. Proximity to conflict incidents may lead to damage or destruction to telecommunications towers and related infrastructure. Disrupted internet and mobile services will have cascading effects, impacting commercial, transportation, banking and service provision systems.

Chart 15.1. Energy production source in Donetsk Oblast, 2020[75]

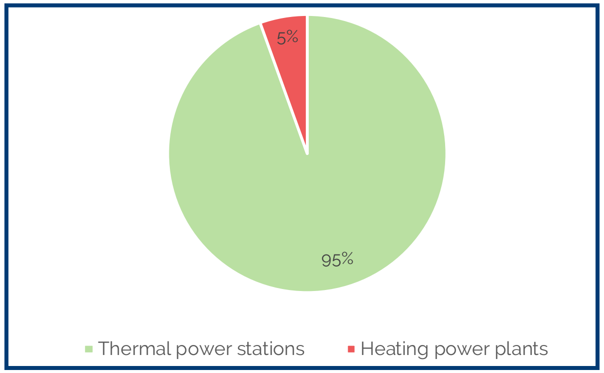


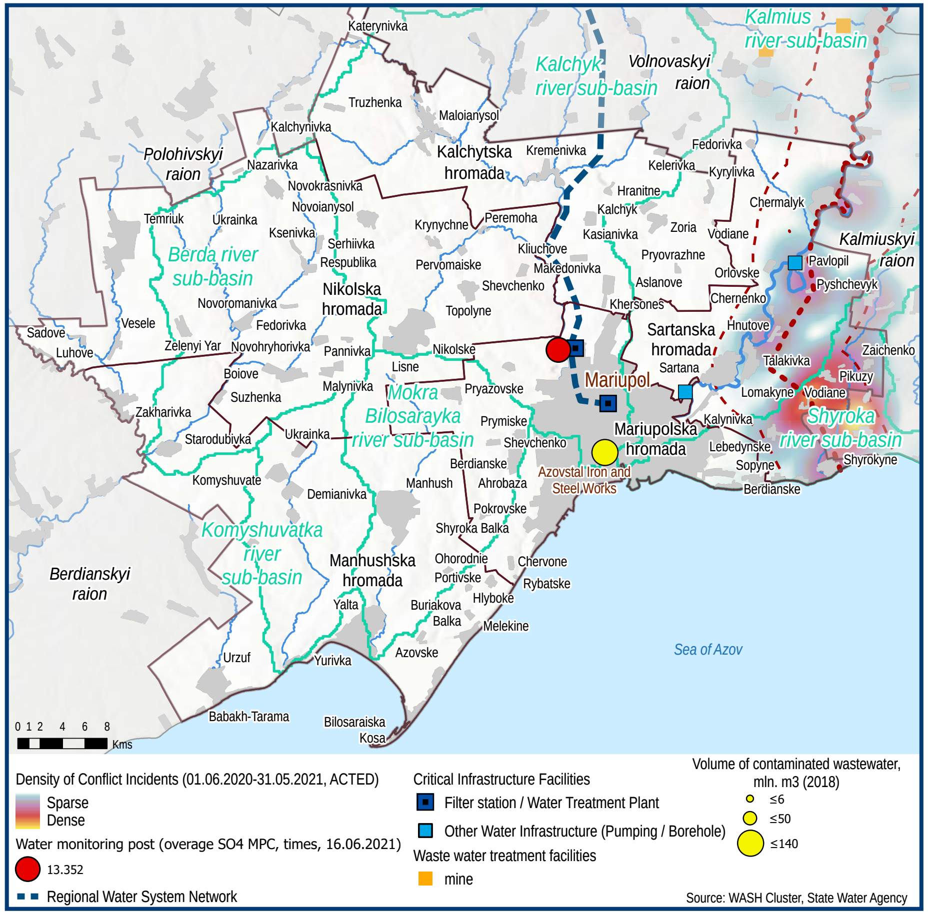
Table 15.1. Infrastructure within 5km of CL

Infrastructure	Within 5km of CL
Oil and gas pipelines	~27km
Electricity powerlines	~60km
Electricity sub-stations	2
Water pumping stations	1
Communication towers	49
Roads	~80km

Suggested mitigation approaches

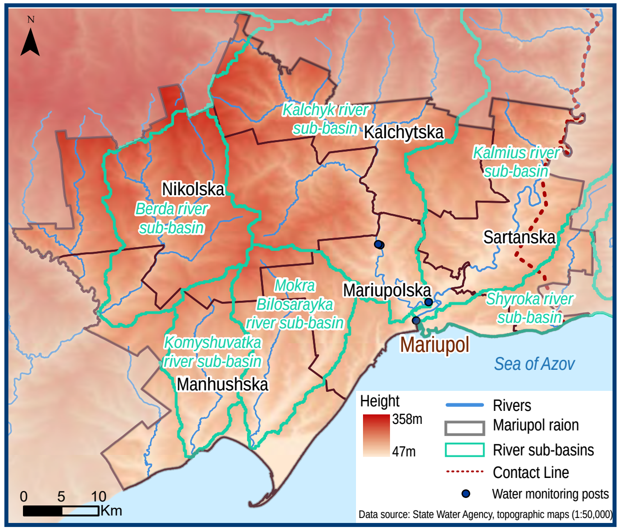
- Diversification of power sources or improved connection for communities to the Ukrainian network would minimize the risk of large-scale power outages
- Considering linkages between electricity and utility networks, and potential cascading effects, conduct risk assessments for response planning.
- Consider alternative communication methods during emergencies (radio, public switched telephone network)

Map 16.1. Wastewater management in Mariupolskyi Raion



Wastewater is broadly defined as water that has been contaminated by human use. UN Water identifies the following sources of wastewater: domestic water for sanitation, water from commercial establishments, water from industrial and agricultural activities, storm-water, and other urban run-off. Wastewater management can be potentially hazardous as flammable liquids, acids, and solvents are often used in such facilities[76] and inadequate treatment can lead to contamination of groundwater.

Map 16.2. Water sub-basins in Mariupolskyi Raion



Mariupol water supply scheme is part of the centralised water supply system in the Donetsk region serviced by Municipal Enterprise “Water of Donbass”. The total water intake for Mariupol as of 2019 was 574 million m^3. Returned wastewater into surface water bodies accounted for 559 million m^3. 57% of the returning water to Kalmius river was classified as polluted, compared to 7% discharged into the Kalchyk river.

As of 2019, monitoring posts in **Kalchyk and Kalmius rivers showed high mineralisation of the water bodies, exceeding three times the maximum permitted concentration (MPC). There is also more than two times overrun of MPC for sulfates and chlorides, particularly for Kalmius river (Table 16.1).** Updated data taken two posts from June 16, 2021, at the Kalchyk River (18 and 23 km on the river near Starokrymske reservoir) shows revealing the overage of sulfates MPC (up to 13.4 MPC) and dissolved oxygen (up to 2.1 MPC)[77].

Annually, Mariupol enterprises discharge ~800 thousand tons of harmful substances into the Sea of Azov[78]. In 2020, there were two cases of high pollution by nitrite nitrogen: on January 14 at station 34 (northwestern part of Taganrog Bay, the mouth of the river Kalmius) concentration reached 0.25 mg/dm³ (12.5 MPC), and on December 15 - 0.2 mg/dm3 (10 MPC)[79].

Substances include heat exchange waters and industrial wastewaters (industrial effluents from blast furnace, gas, crimping and rail-beam productions). As of 2019, discharge did not meet the standards for fishery reservoirs on the following indicators: **petroleum products (6.8 MPC), total iron (14 MPC), nitrites (3.8 MPC) and ammonium nitrogen (5.2 MPC)**. According to water monitoring from the Mariupol Hydrometeorological Observatory, the MPC for petroleum products, total iron, nitrites and ammonium nitrogen are often recorded.

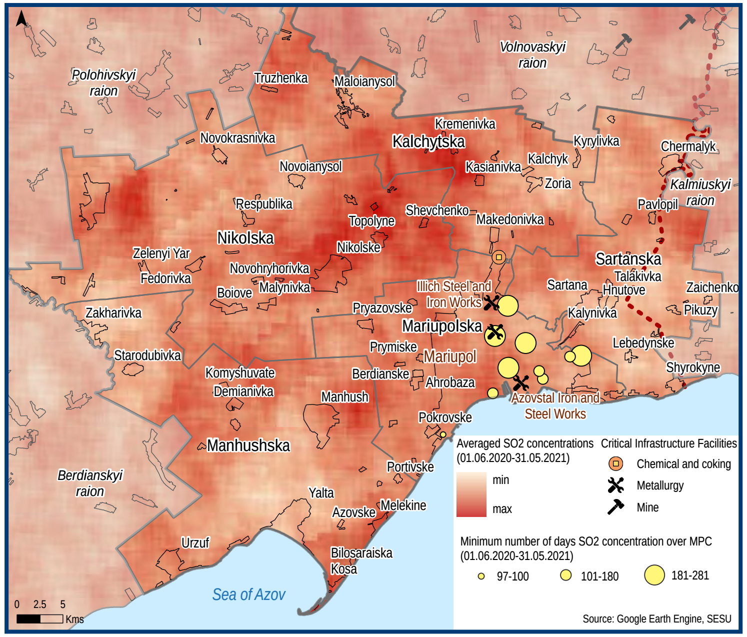
Table 16.1. Average annual concentrations of substances in monitoring posts of water bodies, 2019 (in units of multiplicity of the MPC)[80]

	Mineralisation	Sulfates	Chlorides	Ammonium	Petroleum	Other
R. Kalchyk, near Old Crimean Reservoir	2.9	2.7	0.5	0.1	0.3	Fe – 0.9 Mn – 1.0
R. Kalchyk, mouth	3.1	2.5	1.2	0.7	0.6	Fe - 1.3 Mn - 1.1
R. Kalmius, mouth	3.4	2	2.8	0.2	0.6	Fe - 1.6 Mn - 1.2

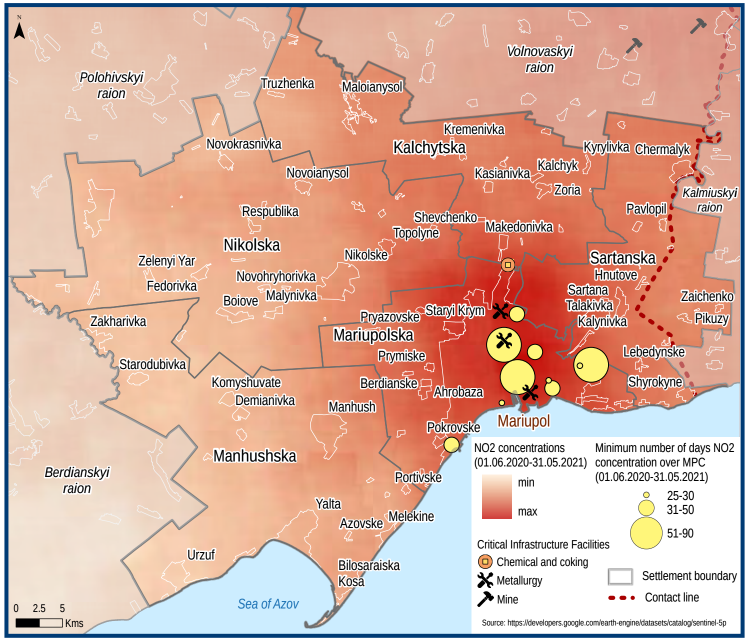
Suggested mitigation approaches

» Establish the monitoring of water quality at all stages of the water system to ensure that contaminated water does not jeopardize access to water or harm the environment.

Map 17.1. Average SO2 concentrations, Mariupolskyi Raion



Map 17.2. Average NO2 concentrations, Mariupolskyi Raion



Air pollution is identified as one of the country's key environmental challenges[81]. According to WHO, air pollution poses a major threat to health and climate[82], leading to around seven million premature deaths annually. Increased mortality primarily results from stroke, heart disease, chronic obstructive pulmonary disease, lung cancer and acute respiratory infections.

Sources of air pollution include gases, such as ammonia, carbon monoxide (CO), sulfur dioxide (SO2), nitrous oxide (NO2), methane (CH4) and chlorofluorocarbons; particulates, including both organic and inorganic; and biological molecules. Both human activity and natural processes can generate air pollution.

Within Mariupolskyi Raion, Mariupol City and surrounding areas generate and are affected by the highest levels of air pollution. In 2020 Mariupol topped the list of Ukrainian cities with a "very high" level of air pollution. The city had an integrated air pollution index (API) of 15.7 in 2020 (the normal rate of API is 5.0 mg / m3), as shown in Chart 17.1.

The increase in API observed in the chart is associated with an increase in the average annual atmospheric concentration of dust, nitrogen dioxide, phenol, and of formaldehyde in particular, which exceeds 6.7 mg/m3 in Mariupol (the maximum permitted concentration of formaldehyde is 0.035 mg/m3)[83].

Mariupol alone is responsible for 13% of Ukraine`s total emissions deriving from stationary pollution sources, including industrial plants and power stations (2459.5 thsd.t)[84]. According to Ukrstat, 99.6% of these emissions derived from major metallurgical facilities in the city in 2019.

Chart 17.1. Air pollution index, Mariupol (2013-2020)[87]

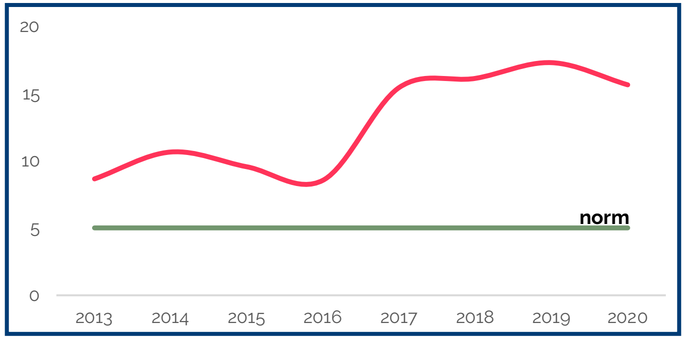
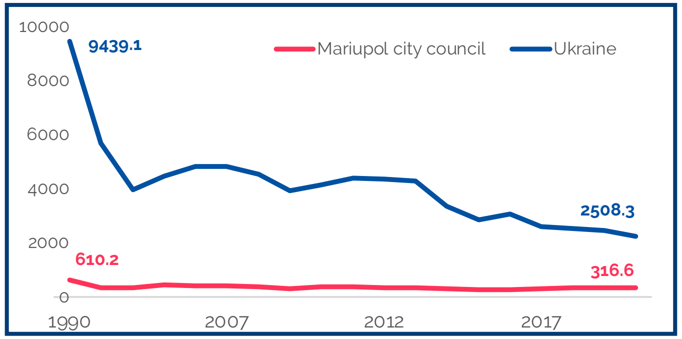
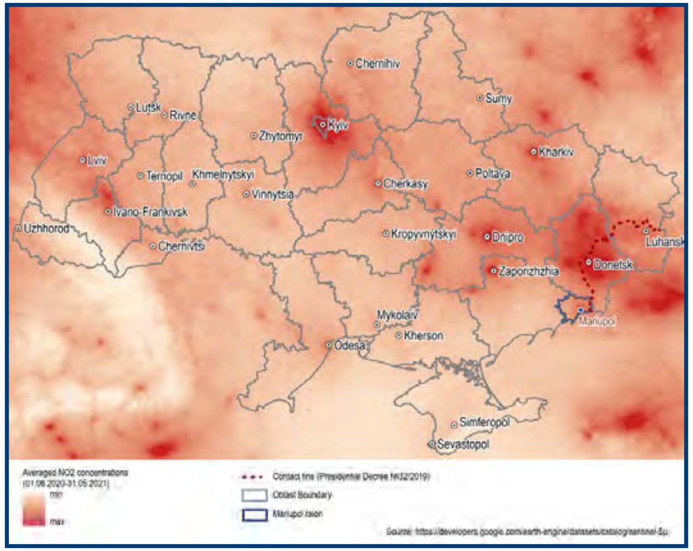


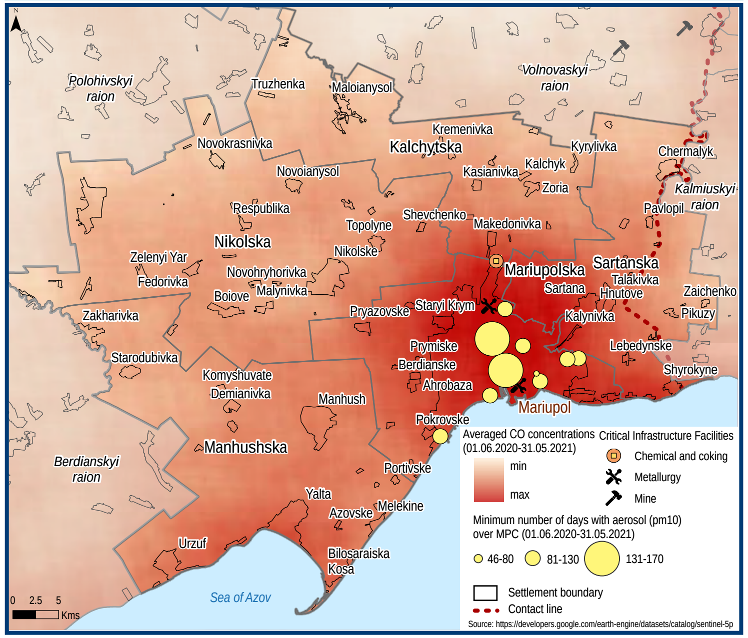
Chart 17.2. Emissions from stationary pollution sources[88]



Map 17.3. Average NO2 concentrations in Ukraine



Map 17.4. Average CO concentrations, Mariupolskyi Raion



Map 17.5. Average aerosol concentrations, Mariupolskyi Raion

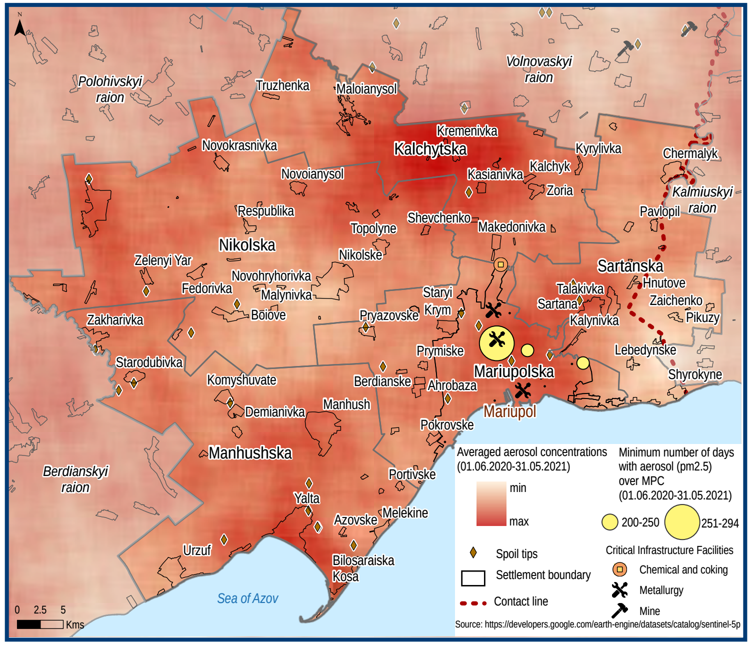


Chart 17.2 demonstrates that excluding a sharp initial drop after independence, emissions from stationary pollution sources in Mariupol have remained relatively stable over the past 20 years, compared to the overall descending trend in Ukraine as a whole.

Maps 17.1-17.5 show the distribution of air pollution in Mariupolskyi Raion. NO_2 emissions are mostly concentrated within Mariupol City around the biggest metallurgic plants, and at reduced intensity in the eastern hromadas of Sartanska and Kalchytska (Map 17.2). **Across the country as a whole (Map 16.3), it is clear that Donetsk Oblast is a major hotspot for NO_2 concentrations.**

The maximum concentration of carbon monoxide (CO) is clearly concentrated within Mariupol City, and to a lesser extent in the coastal area of Manhushska Hromada. CO is produced from the combustion of fossil fuels, biomass burning, and atmospheric oxidation of methane and other hydrocarbons. The gas also has an important role in forming smog.

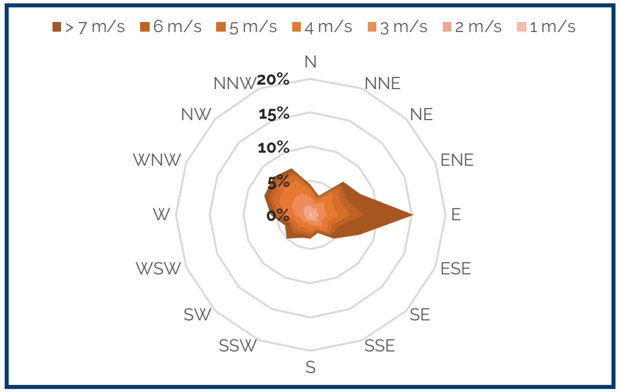
Sulfur dioxide (SO_2) is formed from the burning of fuels such as coal or petrochemical products. It is also produced from industrial processes such as fertiliser production and smelting sulfur-containing metal ores. Concentrations are highest in the north of the raion, between Kremenivka and Malynivka, as well as in Starchenkove in the northwest of the raion. In Mariupol City, the maximum permitted concentration (MPC) was exceeded on up to 280 days in some areas between June 2020 and May 2021. Note that SO_2 is seasonal, peaking in February and March.

The highest concentration of aerosols (pm 2.5) occurs near spoil tips and quarries across Mariupolskyi Raion (Map 17.5). The most exposed is Kalchytska Hromada due to the location of Kalchytsia quarry, where syenites are mined, south of Mahushska and all of Mariupolska Hromada. In Mariupol City pm 2.5 particle concentration exceeds MPC on a minimum of 250-300 days per year and pm10 particles on at least 180 days per year.

On average, the PM2.5 WHO 24-hour Air Quality Guideline (AQG) value is exceeded in Mariupol on more than 200 days per year[85]. The World Health Organization's (WHO) AQG states that long-term exposure for those living above an annual average PM2.5 concentration of 10 μg/m^3 (micrograms per cubic meter) are at higher risk of cardiopulmonary, lung cancer mortality and increased risk of premature death. Recent studies indicated the adverse effects of PM2.5, on the central nervous system (CNS) and brain health[86].

As recorded at Mariupol weather station, predominant wind directions in the area are from the east (Chart 17.3). This will have implications on populations close to pollution sources, as pollutants will often be carried downwind, disproportionately affecting communities in this direction.

Chart 17.3. Primary wind directions and speeds at Mariupol weather station (2005-2020)

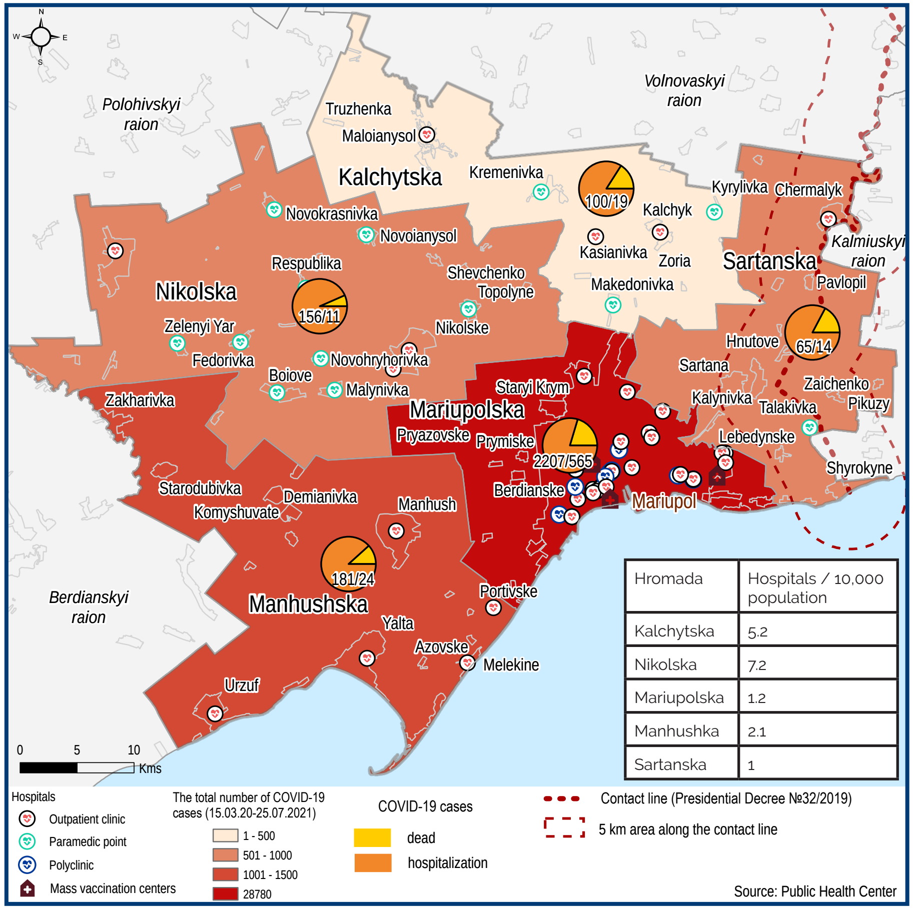


Suggested mitigation approaches

- Increase capacities to monitor air quality and widen network of monitoring stations.
- Install or repair air filtration systems in all hazardous facilities
- Utilise nature-based solutions and green spaces in urban areas

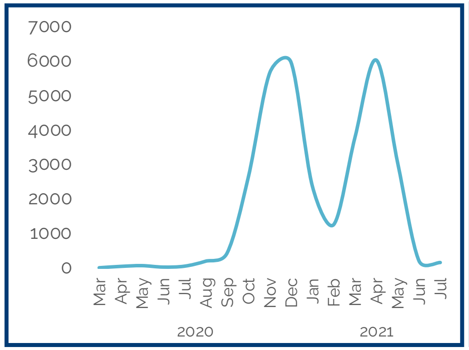
The effect of Covid-19

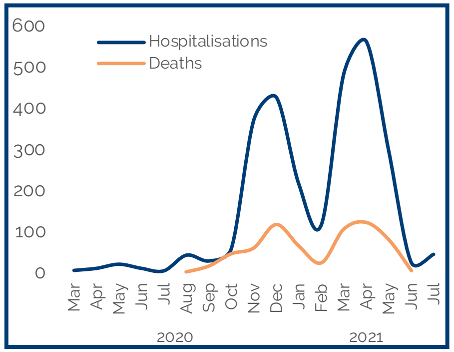
Map 18.1. Healthcare infrastructure in Mariupolskyi Raion



Hromada	Hospitals / 10,000 population
Kalchytska	5.2
Nikolska	7.2
Mariupolska	1.2
Manhushka	2.1
Sartanska	1

Charts 18.1-2 Monthly COVID-19 cases, deaths and hopsitalisations, Mariupolskyi Raion[89]

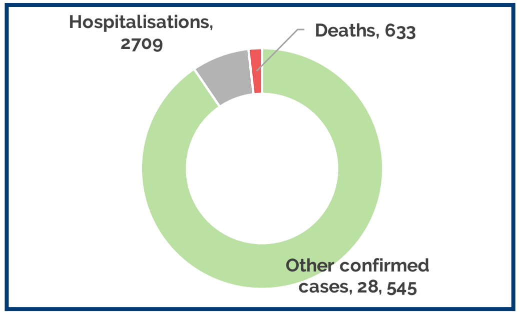




COVID-19 has clearly demonstrated the importance of addressing global health hazards. The first COVID-19 case in Ukraine was recorded in February 2020. By 30 July 2021, the National Health Service of Ukraine had recorded 2.25 million cases, including 52,930 deaths (2.4%).

By 25 July 2021, 31,887 laboratory-confirmed cases had been registered in Mariupolskyi Raion (28,388 in Mariupol City). Among these, 633 (2%) died[93], a slightly lower death rate than the Ukraine average.

Chart 18.3. COVID-19 cases by outcome and by age group, Mariupolskyi Raion[93]



During the first wave in December 2020, daily hospitalisations and deaths peaked at 425/116 per month respectively in Mariupolskyi Raion. The second wave was more severe, with 561 hospitalisations/121 deaths in April 2021[93].

Age and gender distribution of confirmed COVID-19 case statistics align with national and global trends. Among confirmed cases, 58% were female. The highest number of confirmed cases fell within the 36-59 and 60-85 age bracket, accounting for 45% and 31% of cases respectively. However, the death rate was considerably higher, reaching 12% for the 86+ age group.

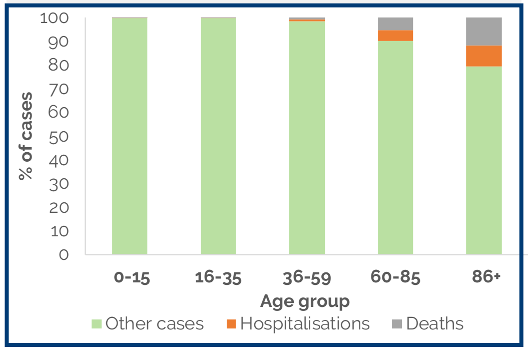
Map 18.1 shows that Mariupolska Hromada had the highest number of cases (90% of raion total) due to its high population. Manhushska Hromada was second most affected by COVID-19, with the highest number of cases in each age group and the highest number of fatalities, compared to Kalchytska, Nikolska and Sartanska Hromadas.

Whilst the national vaccination campaign began in February 2021, Ukraine still experiences the lowest vaccination rate in Europe[90]. As of 29 July 2021, 30,139 people (7% of Mariupol city`s population) had received at least one dose. Currently three public vaccination centres are operating in Mariupol city, as shown on the map.

Apart from turbulences in the health sector, COVID-19 and lockdown restrictions particularly impacted Mariupolskyi raion due its proximity to the CL and movement constraints. **This resulted in limited service access, including to pensions, education, employment and healthcare. Donetsk Oblast also experienced the highest increase in unemployment from March-April 2020 (53% vs. 31% nationwide)[91].** Additionally, farmers were unable to travel to their fields to plant crops, resulting in spikes in food prices and decreases in income, not only for farmers but also for small traders relying on their produce[92].

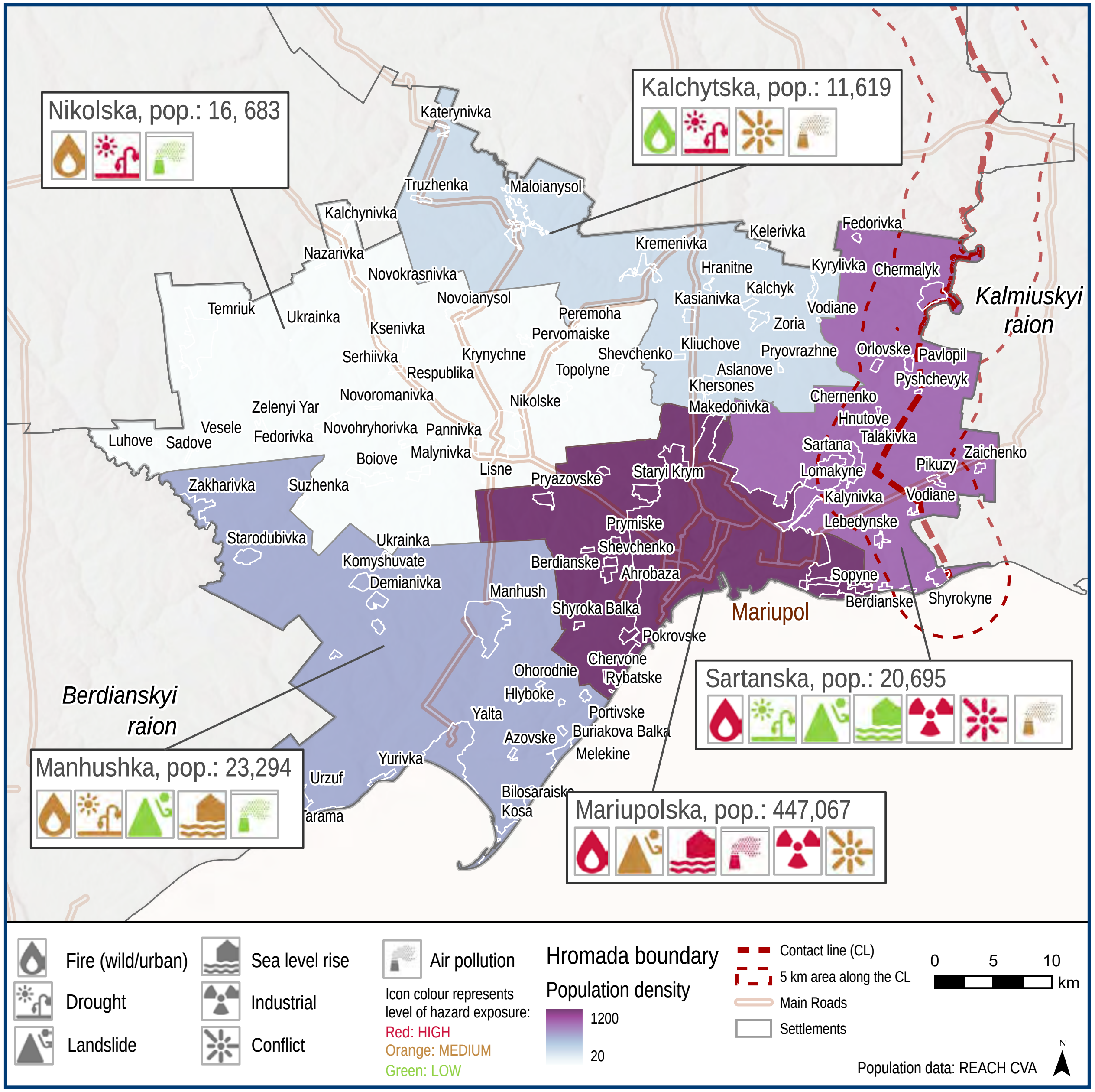
Due to high exposure to air pollution, Mariupol's population also faced higher risk of serious progression of COVID-19. This is because air pollution causes inflammation of the respiratory, pulmonary, and cardiovascular tracts[93].

Chart 18.4. COVID-19 cases by outcome and by age group, Mariupolskyi Raion[93]



Multi-hazard exposure

Map 19.1. Multi-hazard exposure, showing main hazards affecting different hromadas, as well as hromada population density, Mariupolskyi Raion



Map 19.1. and Table 19.1. show predominant natural and anthropogenic hazards affecting hromadas in Mariupolskyi Raion, plus population density (population exposed). This map aims to serve as a tool to indicate the distribution of hazards across the raion and aid in prioritisation of risk mitigation processes. In future, it would be useful to incorporate vulnerability data to gain a full understanding of the risk profile. As mentioned, this information was not available except for the city.

Each hazard has been colour-coded by hazard intensity and exposure of the population, environment and infrastructure. Note that land degradation, soil salinity, biodiversity loss, and heat and cold waves have not been included as they occur throughout the raion.

Observing the map, **it is clear that Mariupolska and Sartanska are exposed to the most hazards.** They are also the two hromadas with the greatest population density and critical infrastructure. Due to proximity of the CL, Sartanska Hromada is most exposed to conflict, with shelling and other attacks putting populations and critical infrastructre at risk. Attacks on hazardous facilities could also result in environmental issues.

Whilst less densely populated in comparison, drought and air pollution are significant hazard concerns in Nikolska and Kalchytska hromadas. Due to the large rural population, drought could be a concern to farmers. Coastal hromadas mean while are affected by landslides and abrasion, whilst sea level rise will pose an increasing risk as global climate change continues.

Table 19.1. Multi-hazard exposure for each hromada, showing level of hazard intensity and exposure to populations, infrastructure and the environment

Hromada	Fire	Drought	Landslide	Sea level	Industrial	Conflict	Pollution
Kalchytska							
Nikolska							
Mariupolska							
Manhushska							
Sartanska							

Section 2: Risks in Mariupol City

A deeper dive into the risks affecting the city

Mariupol City - Overview

Map 20.1. Mariupol City overview map

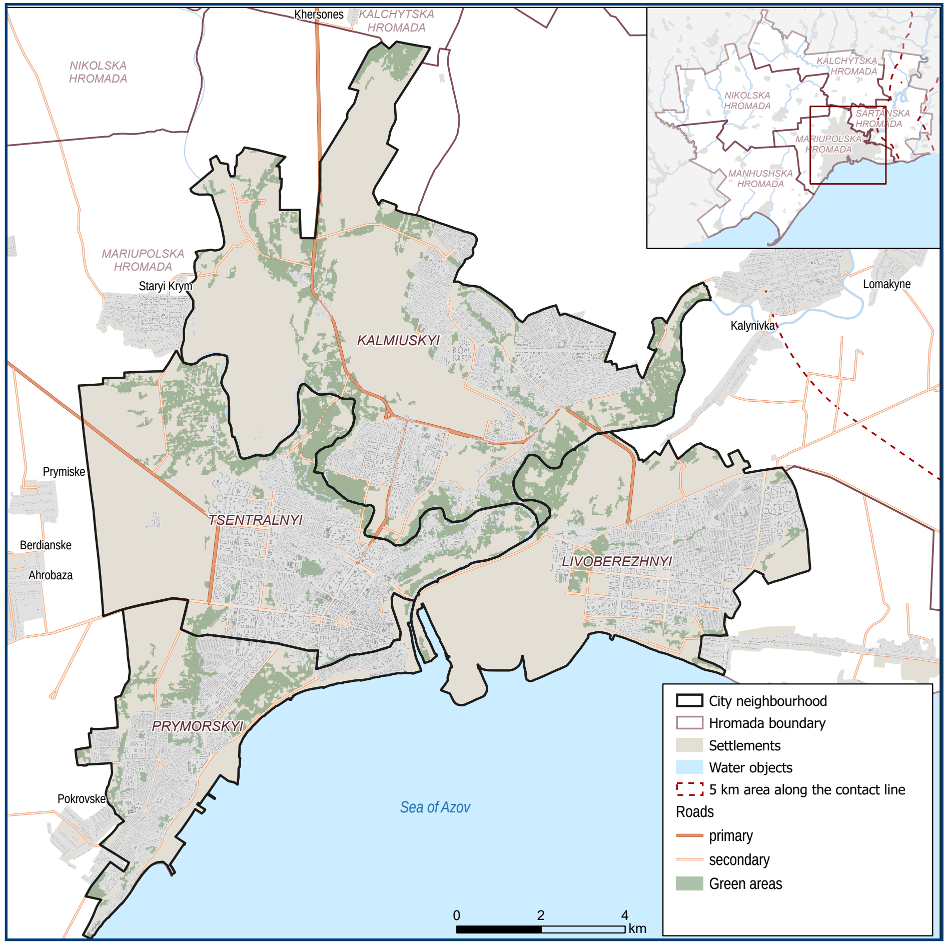
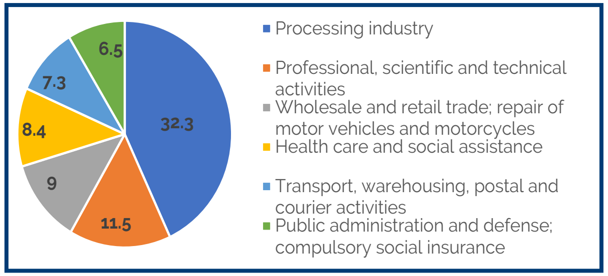


Table 20.1. Population by district, Mariupol City[97]

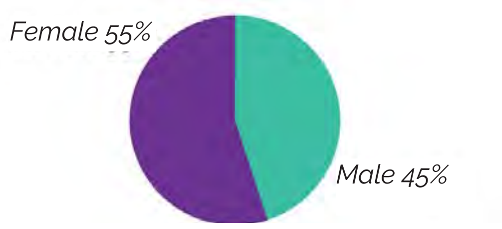
District	Population
Kalimiuskiy	122,455
Tsentralnyi	138,970
Livoberezhnyi	124,900
Prymorskyi	67,700

Chart 20.1. Employed population by sector of employment (%), Mariupol City [98]



The city of Mariupol is the administrative centre of Mariupolskyi Raion. It is the 10th largest city in Ukraine, and the second largest in Donetsk Oblast. The city is located on the north coast of the Sea of Azov at the mouth of the Kalmius river. Mariupol City is divided into 4 administrative-territorial units (districts) - Kalmiuskyi, Tsentralnyi, Prymorskyi and Livoberezhnyi.

As of 2021, the population of Mariupol City accounts for 454,023 inhabitants. The most populous district is Tsentralnyi as shown in Table 20.1. Demographically, females represent 55% of the total population. 22% of the total population is elderly (65+ years)[94]. Mariupol is a multinational city and there are around 120 nationalities.



There are around 200,000 people in employment in Mariupol City, amounting to ~40% of the total population. Of these, the largest proportion (32%) is employed in processing industry and 11.5% are involved in professional, scientific and technical activities. 8,4% of population work in a public sector, namely health care and social assistance.

The industrial potential of the city serves as a foundation of the economy. 34.2% of tax revenues are generated by industrial facilities, the largest of which are the metallurgical enterprises of the Metinvest group ("PJSC Azovstal Iron and Steel Works " and the "Ilyich Iron and Steel Works).

The largest machine-building enterprise in Ukraine - Azovmash, is also located in the city, whose products make up a significant part of Ukraine's exports. The share of Mariupol in the industry of Ukraine is about 7%.[95]. As of July, 2020, there are more than 20,000 enterprises of various forms of ownership registered in the city[96].

In addition, the city also has a chemical industry as well as a diversified agricultural production industry.

Mariupol is a point of intersection of the transport routes of international, national and regional significance. The territory is crossed by highways connecting Mariupol, Zaporizhia, Berdyansk and highways of different levels.

Mariupol railway junction serves as a connecting link between the Mariupol Commercial Sea Port, the city and the territory of the whole country.

The Mariupol Commercial Sea Port is the largest port in the Sea of Azov and one of the largest in Ukraine. It`s share in the total Ukrainian marine export accounts of 7% and in import – 4%. Ferrous metals, metal rolling, construction, and grain loads are the main cargos exported from the port while the main import cargos are coal and construction.

Finally, Mariupol is also a cultural centre of the Azoz Sea. Because of its location on the coast, as well as presence of historical and architectural monuments, the city does hold great potential for the tourism industry.

Mariupol City - Industrial Hazards and Air Pollution

Map 21.1. Summarised MPC of selected pollutants

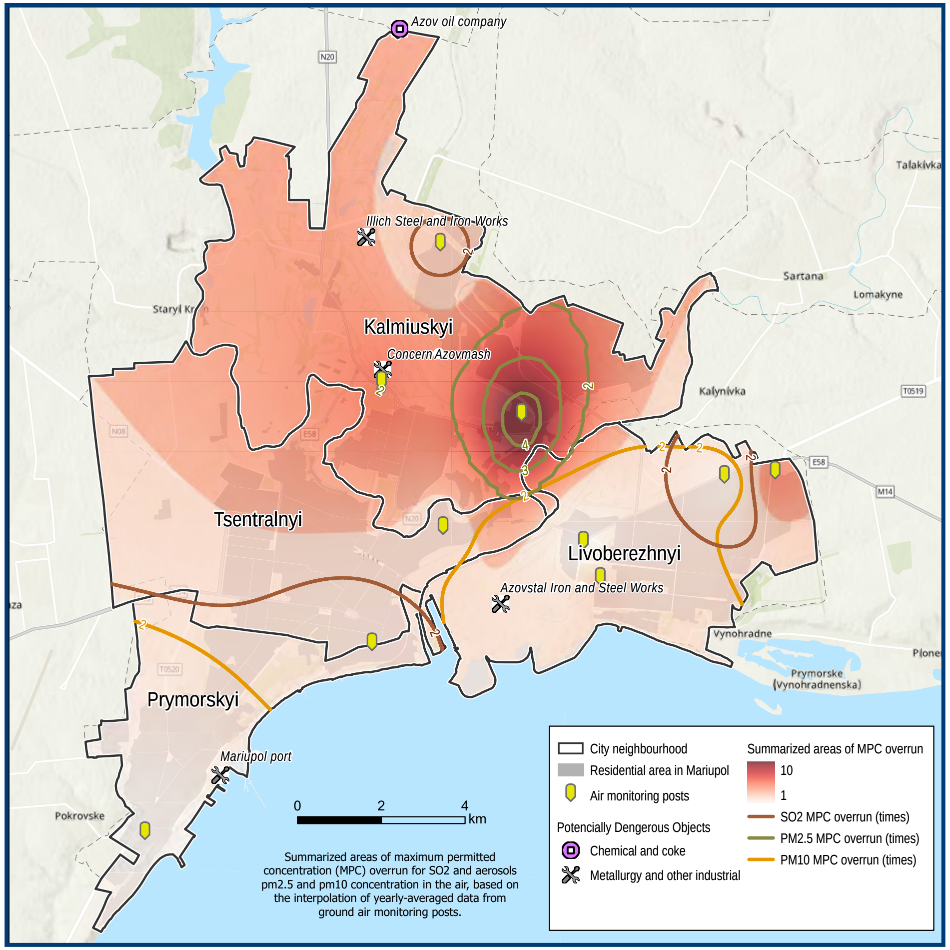


Chart 21.1. No. days with max. permitted concentration (MPC) overage (Jun '20 - May '21)[103]

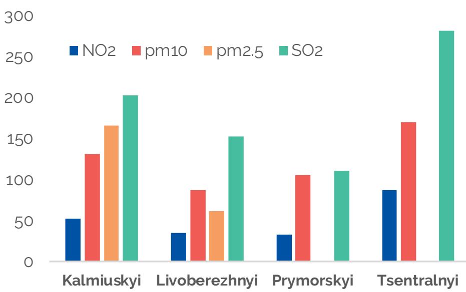
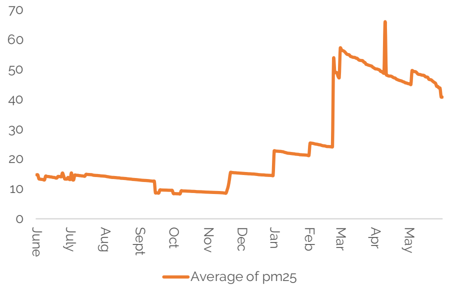


Chart 21.2. pm2.5 (particulate matter) concentration, Mariupol (Jun '20 - May '21) [107]



28% of the urban area of Mariupol City is classified as industrial. The main facilities are Azovstal and Illch iron and steel works. Azovstal produces coke, manufactures pesticides and steel casting, whilst Ilyich predominantly manufactures metallurgical products. Other major facilities include PJSC Azovmash, a producer of freight cars, tanks and machinery.

The principal health threat posed by industrial facilities is air pollution. During a 2021 IMPACT survey, 77% of households cited air pollution as a primary environmental concern. Air pollution also poses an environmental threat, and contributes significantly to Ukraine`s greenhouse gas emissions,

Within Mariupol City, ferrous metallurgy ranks second in total emissions, after energy production. Emissions from the metallurgical industry mainly consist of carbon oxides (67.5%), aerosols (15.5%), sulfur dioxide (10.8%) and nitrogen oxides (5.4%)[99]. Map 21.1 shows summarised exceedance of maximum permitted concentrations (MPC) of key pollutants.

Chart 21.1, based on air pollution monitoring data, shows all pollutants in Kalmiuskyi and Livoberezhnyi exceeded MPC in June 2020-May 2021. SO2 was most frequently over limit, accounting for 200 days in Kalmiuskyi and 150 days in Livoberezhnyi districts.

Aerosols pm 2.5 and pm 10 were also above norm in these districts with the longest period exceeding pm 2.5 MPC in Kalmiuskyi District (150+ days). This can be explained by proximity to the Illyich plant. In contrast, in Prymorskyi and Tsentralnyi districts, pm2.5 exceedance was not observed. However, pm10 over MPC in Tsentralnyi District lasted 150+ days. In Tsentralnyi District, the highest number of days with SO2 and NO2 over MPC was observed, at 280 and 160 respectively.

Chart 21.2 shows the pm2.5 trend in June 2020-May 2021 in the city. A dramatic rise is observed in Spring 2021, possibly due to meteorogical conditions, such as wind and snow melt, which affect pollutants.

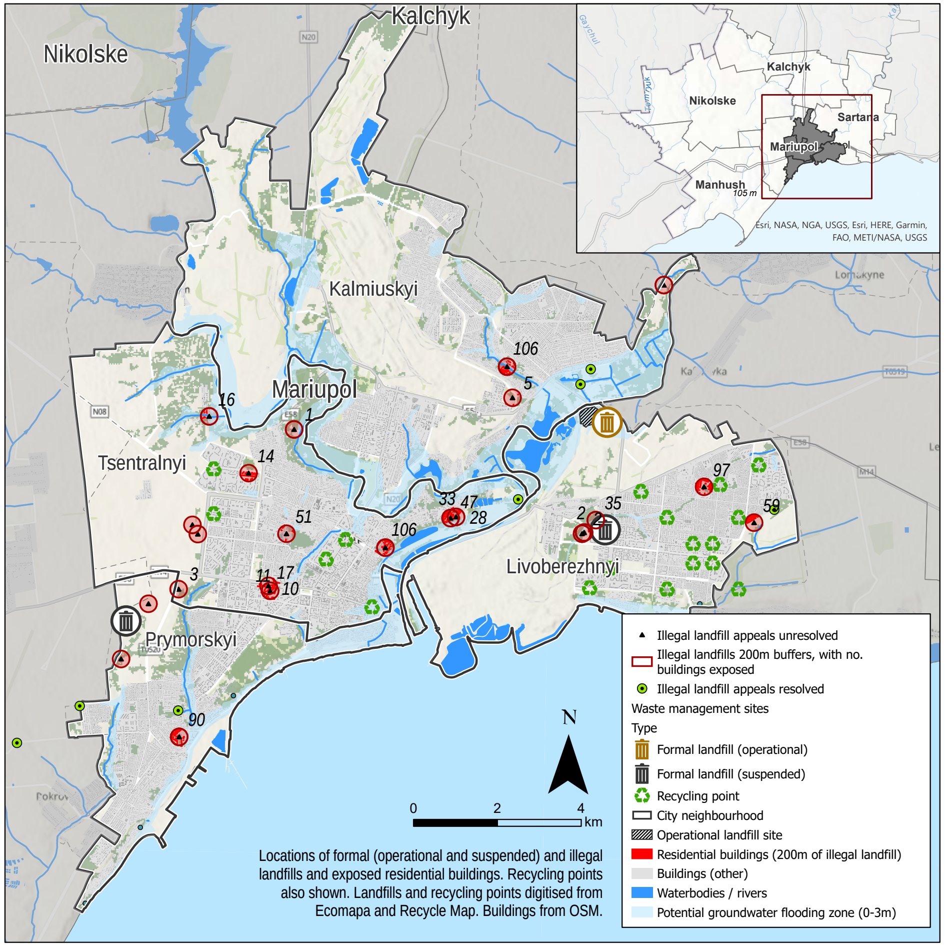
Metinvest Group invested $344 million in environmental projects in the past decade and are committed to invest an additional $433 million by 2025[100]. In May 2021, the overhaul of a blast furnace was completed at Illyich plant, plus installation of new aspiration equipment. The commissioning of new filters will reduce dust emissions by 90% and sulfur emissions by 46%[101].

Another issue relates to water pollution. There is a shortage of good quality water resources, causing water supply issues in the city. The existing water supply scheme is part of the centralized Donetsk water supply system (p. 24). The sea area is subject to significant anthropogenic pressure due to industrial activities on the coast. The technology of domestic and industrial wastewater treatment in the city needs to be improved (see p. 29).

The majority of wastewater discharged from metallurgical plants in the city is thermal, released into the River Kalmius and Sea of Azov according to special permits[102]. Whilst not polluted, these heated waters raise the temperature of natural water bodies and affect flora and fauna.

There are also a number of tailing dams and spoil tips (p. 23) that could cause surface and groundwater contamination. A detailled FEAT analysis (p. 22) outlines exposure pathways and potential impacts of targeted conflict incidents.

Map 22.1. Waste management facilities in Mariupol City



Locations of formal (operational and suspended) and illegal landfills and exposed residential buildings. Recycling points also shown. Landfills and recycling points digitised from Ecomapa and Recycle Map. Buildings from OSM.

Table 22.1 Waste management facilities, by district

District	No. of formal landfills[97]	No. of illegal landfills[104]	No. of recycling points[105]
Kalmiuskyi	0	3	3
Prymorskyi	1 (susp.)	3	4
Tsentralnyi	0	12	17

Large amounts of household and industrial waste are produced in the city, with the largest industrial waste producers being the metallurgical industries (almost 9000 thsd. tons produced in 2019)[106].

Household waste is often disposed of illegally. During a 2021 IMPACT survey, 23% of interviewed households in Mariupol City were aware of illegal landfills in the vicinity of their homes, of which residents` primary concern was visual impact (56%), followed by soil contamination (53%). Note that although high, awareness of illegal landfills was lower than in other parts of the region, such as Berdianskyi and Prymorskyi (49%).

Map 22.1. shows waste management facilities and illegal landfills across the city. Illegal landfills were mapped using citizen appeal data from Ecomapa. As shown, although many of these appeals have been addressed, 23 remain, with the highest concentration in Tsentralnyi and Livoberezhnyi (Table 22.1). Residential buildings within 200m, which could be exposed to visual and odour impacts, as well as local environmental contamination, are also shown.

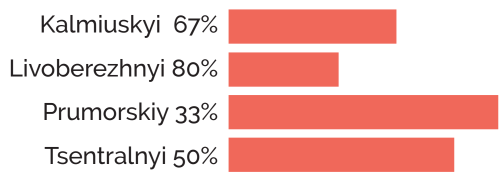
Whilst 85% of households claimed to take waste to landfill (IMPACT 2021 survey), only 1 of the 3 formal landfills in the city, located in Livoberezhnyi District, is currently operational. This district also has the highest concentration of recycling points, highlighting an opportunity for waste collection authorities to also pick up recyclables when colecting general waste..

The survey indicated that 100% of respondents would use recycling services if available locally. However, only 24% were aware of such services, of which 57% reported to use these currently. Cost and lack of available services were cited as key barriers.

Between 2010 and July 2020, > 17 million m3 of biogas was generated at the (suspended) Primorsky landfill. Biogas generation at Livoberezhnyi landfill began in 2019. This biogas plant has a capacity of 1.2 MW and generates > 10 million kWh of electricity annually[107].

Associated hazards include fires and flooding. For example, a 300 m2 fire broke out in June 2021 at the Livoberezhnyi landfill. Extinguishing the fire was complicated by lack of water supply; the nearest fire hydrant is 3 km away[108]. As Chart 22.1 shows, the majority of illegal landfills are within 200m of the 0-3 metre groundwater floodzone, presenting an increased risk of surface water and environmental contamination.

Chart 22.1 % illegal landfills <200m of 0-3m groundwater floodzone



Suggested mitigation approaches

- Prioritise cleanup of illegal landfill close to water sources / floodzones
- Raise community awareness of available recycling services
- Provide incentives to recycle and reduce waste sent to landfill

Mariupol City - Flooding and landslides

Map 23.1. Floods and landslide exposure, Mariupol City

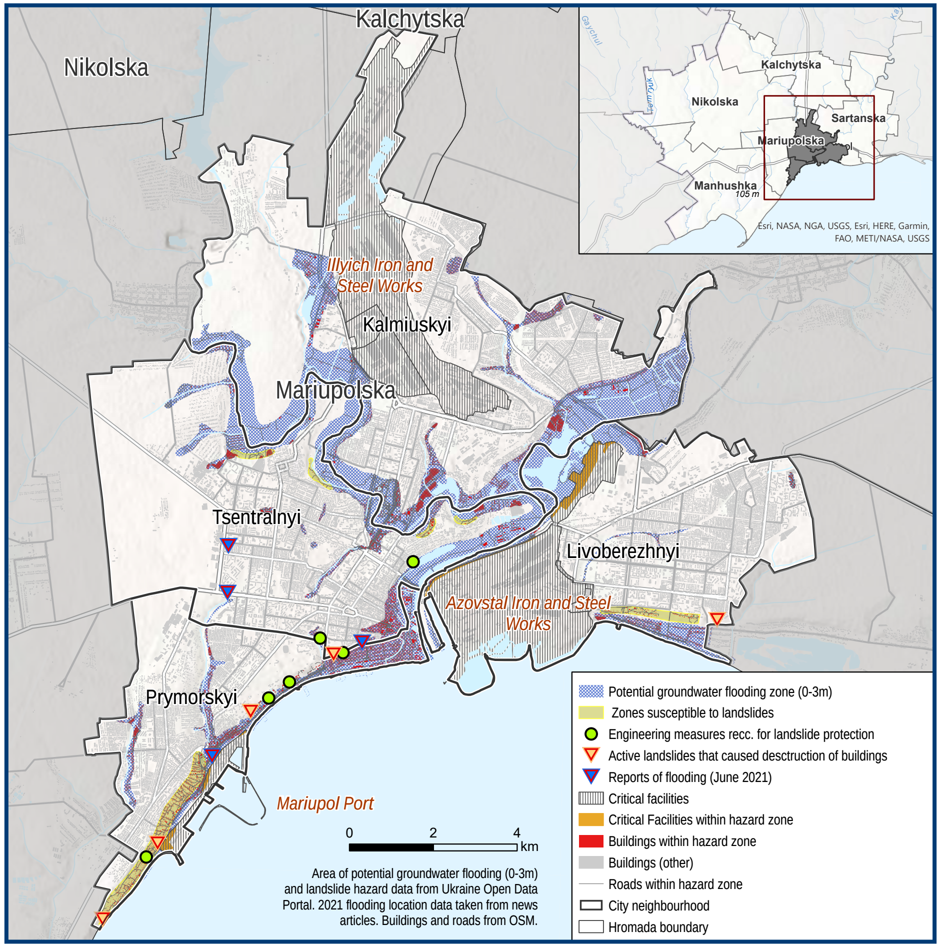
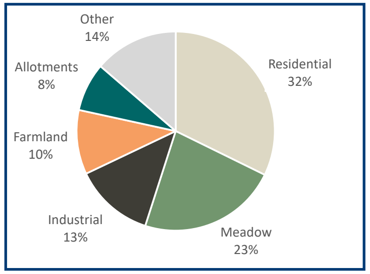


Table 23.1 Infrastructure potentially exposed to groundwater flooding (0-3m in depth), Mariupol City

Infrastructure type	Affected assets
Buildings (total no.)	7715
Roads (km)	380
Railways (km)	109
Power lines (km)	43

Chart 23.1. Land use in the ground-water floodzone shown on map



Flooding

Floodplains in all districts of Mariupol City are susceptible to coastal, fluvial and groundwater flooding[109]. Coastal and fluvial flooding affects the Azov coast, the mouth of the river Kalmius and valleys of the rivers Kalmius, Kalchik and tributaries.

Groundwater flooding also poses a risk to coastal areas and river floodplains, as indicated in Map 23.1. Chart 23.1 shows the predominant land use in zones susceptible to groundwater flooding. It is clear that residential areas make up a large proportion of this zone, indicating that a large population is potentially exposed. The zone includes over 7000 buildings and almost 400km of roads (Table 23.1).

On the 8th-9th June 2021, flooding occurred in Mariupol City, including the areas around Gromova Street (Tsentralnyi District), Lunin Avenue (Prymorskyi District), Pidhirna Street (Tsentralnyi District) and Kuprina Street. These areas are marked on Map 23.1. Some of the reported locations were outside the mapped area of groundwater flooding, indicating this zone may be underestimated. The flooding events clearly coincide with intense rainfall[110] (Chart 23.2.).

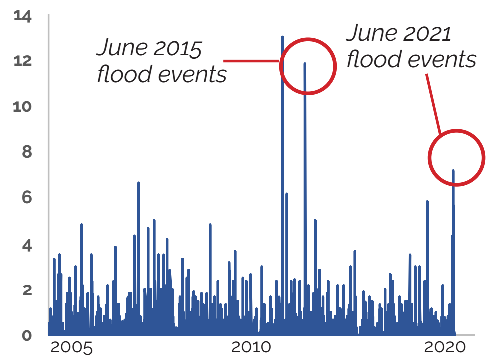
On June 17 2021, Starokrymskoye reservoir overflowed after heavy rains, flooding 32 households and damaging a road bridge. The structure was not able to handle the exceptionally high volumes of rainfall[111]. Additionally, sinkholes were reported throughout the city during the same period, including on Nakhimov Avenue in Prymorskyi District, and along Metallurgov Avenue in Tsentralnyi District[112].

Landslides

Many parts of the city are also prone to landslides, including areas of Prymorskyi, Tsentralnyi and Livoberezhnyi districts. As indicated on the map, the coastline from the southwestern tip of Prymorskyi District to the eastern side of the port is particularly susceptible, as well as sections of the right bank of the Kalchyk river and the area adjacent to Morskyi Bulvar in Livoberezhnyi District.

Between the village of Pischane in the western outskirts of Mariupol and the village Rybatske, a landslide of length 40-100 m is present, as well as one of 300m length to the west of the village[113]. The area south of this to Melekene is particularly prone to landslides due to the clay soils (see p. 17).

Chart 23.2 Max. daily rainfall intensity, Mariupol City (mm/day)



Suggested mitigation approaches

- Carry out engineering measures for landslide and flood protection
- Utilise nature-based solutions
- Avoid further development in flood and landslide hazard zones
- Utilise early-warning systems, including satellite-based tools.

Mariupol City - Urban Heat Islands

Map 24.1. Avg. July land surface temperature and urban heat islands (2020)

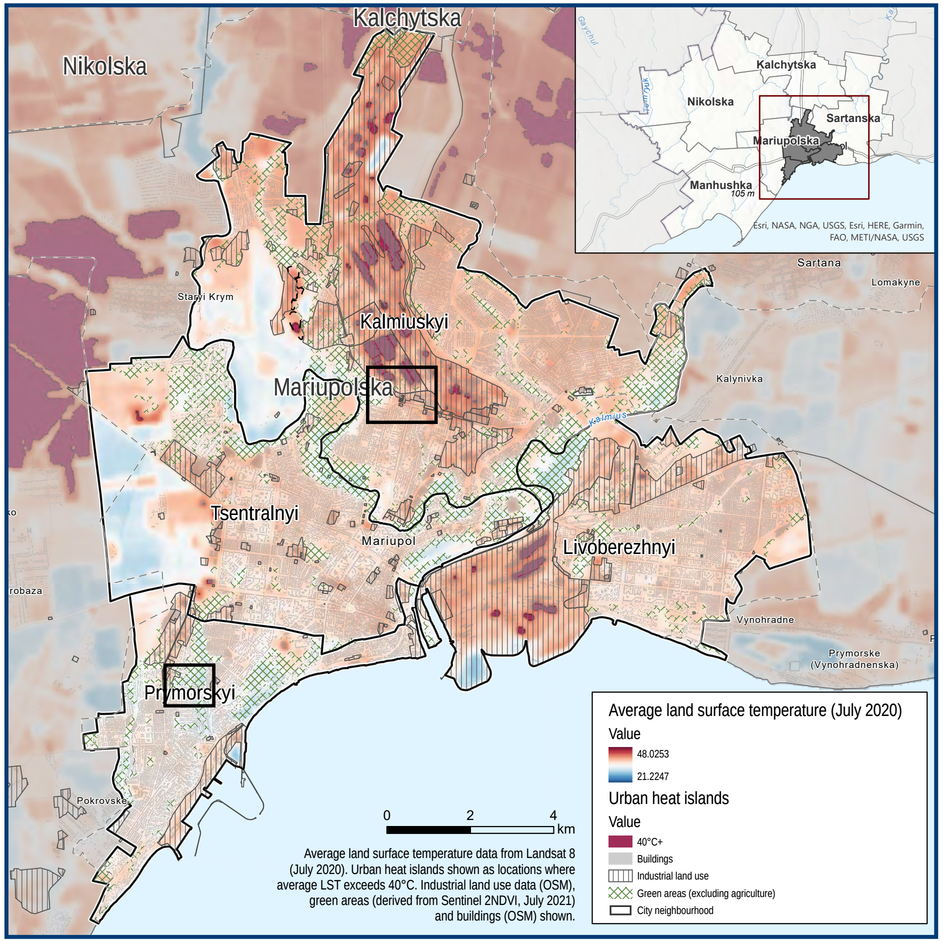


Table 24.1. Avg. and max. land surface temperature by land cover type (July 2020)

Land use type	Average LST (˚C)	Maximum LST (˚C)
Urban (residential) areas	33	48
Urban (industrial) areas	35	48
Green areas (excluding agriculture)	32	39
Agricultural areas	33	45

Urban heat islands (UHIs) occur when there is a denser concentration of pavements, buildings and other surfaces that absorb and retain heat[114]. They can lead to uncomfortable and potentially dangerous conditions for citizens, particularly for the elderly and vulnerable.

On the other hand, urban planning involving trees, vegetation, parks and green roofs for example, known as "green infrastructure," helps to reduce the UHI effect through creating shade, reflecting solar radiation and releasing moisture into the atmosphere.

As Map 24.1 shows, **land surface temperature (LST) varied significantly across Mariupol City In July 2020. This is strongly related to land use,** and LST can vary greatly in very localised areas, as indicated in Table 24.1 and maps 24.2, which show zoom-ins of parts of the city. UHIs on the map are categorised as those areas with an average LST >40˚C[115].

Industrial areas had the highest LST, averaging 34.5˚C, whilst green areas such as forests and parks were significantly cooler, even when in close proximity to hotter areas, as shown in Map 24.1. This highlights the importance of green infrastructure in regulating temperatures within cities. In addition, studies have shown the positive effect it has on mental health[116], and its potential to reduce air pollution exposure when implemented strategically[117].

Prymorskyi District had the lowest LST, probably due to low proportion of industrial land and higher proportion of green areas, whilst Kalmiuskyi had the greatest average LST (almost 35˚C), due to high proportion of industrial and agricultural areas.

Average air temperature in Mariupol city was 24.8˚C in July 2020[118]. However, as indicated in the Climate Change chapter, air temperatures in the raion could increase by up to 3.5˚C within the next 40 years, meaning LSTs in the city will greatly exceed what is seen today.

Suggested mitigation approaches

- Encourage new developments to utilise green infrastructure
- Install green roofs, build parks and restore woodlands to mitigate UHIs.

Map 24.2. Zoom-ins highlighting local LST variations in Mariupol City

Mariupol City - vulnerability profile

Map 26.1. Vulnerability profile of districts within Mariupol City

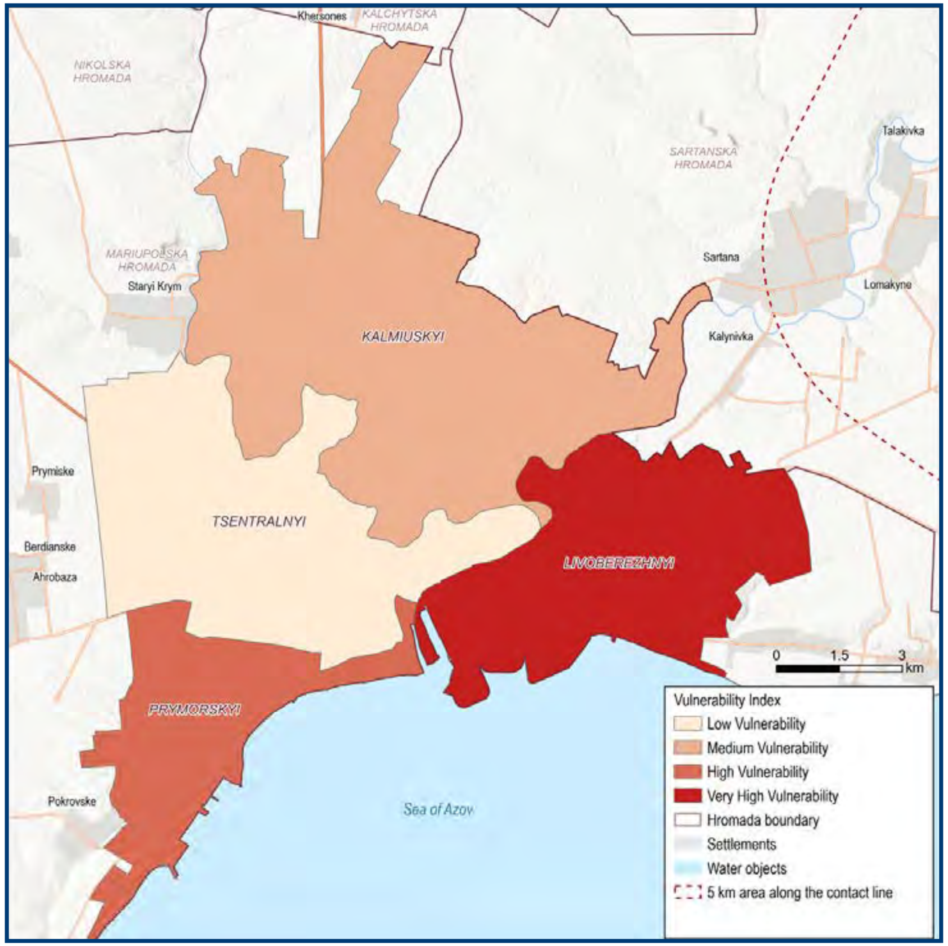


Chart 26.1. % of HHs by vulnerability profile of head of household (IMPACT UCVA, 2020)[121]

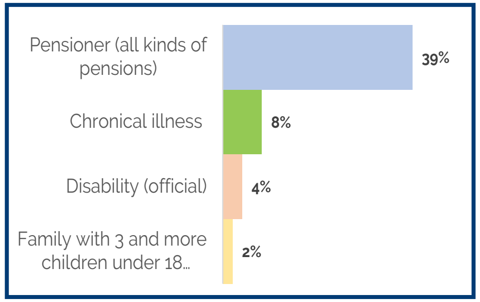
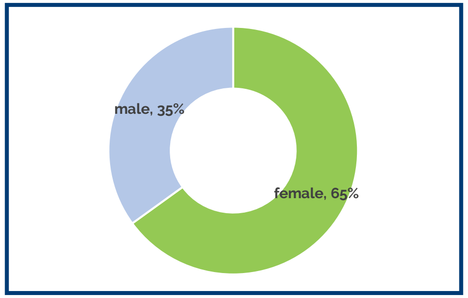


Chart 26.2. Gender distribution among population 65+ (IMPACT UCVA, 2020)[128]



Vulnerability and multi-hazard risk for Mariupol City was determined using a composite indicator analysis approach, with calculations based on variables from various secondary data sources. For more details on this methodology, see Annex 1.

As of 2021, the population of Mariupol is around 452,000, of which 55% are female and 45% are male. The gender balance gap is slightly higher among the elderly (65+), where 65% are female (Chart 26.2).

According to the IMPACT UCVA survey, undertaken in April 2020[128], **more than one third of households are headed by retired persons** (Chart 26.1.). A few households (8%) were also found to be headed by chronically ill individuals, another vulnerable group because of their dependency on health care facilities and general impact on quality of life.

Analysis of social vulnerability data obtained from Mariupol City Council, IMPACT UCVA and other data sources shows that **Livoberezhnyi District has very high vulnerability, whilst Prymorskyi District has high vulnerability** (Map 26.1).

Based on the **susceptibility** indicators, Livoberezhnyi District was found to have the highest number of IDPs per 10,000 people (2642), as well as the highest ratio of households with 3+ children per 10,000 people. This district also had the second largest proportion of people with one or more disability (276 per 10,000). This demonstrates that **Livoberezhnyi District has a high proportion of dependents with limited ability to successfully cope and recover from hazardous events.**

The population of Prymorskyi District showed higher susceptibility from the economic perspective, including having the highest ratio of respondents living with average income below the subsistence minimum (~158$ per month)[119]. Households interviewed under Azov Sea Area Socio-economic Resilience Assessment (2021), conducted by IMPACT[120], reported that in the last 2 years, COVID-19, as well as price increases, had the greatest influence on their financial situation. Primarily this was due to resultant job losses, unexpected disease, and related expenses.

Coping capacity is another component of vulnerability, related to how well a population is able to respond to an emergency, Availability of key services such as health facilities, social services, administrative services, education facilities, and official shelters enhance coping capacity. **Livoberezhnyi and Kalimiuskiy districts had the lowest number of social, administrative, and educational services** (see Chart 26.4). These districts also had low numbers of physicians in hospitals, which further contribute to their vulnerability by threatening the provision of timely and quality medical care.

Prymorskyi District has the lowest number of health care facilities per 10,000 people in the whole city. According to the socio-economic resilience assessment (SERA) undertaken by IMPACT in 2021, the **main concern of populations in Mariupol was access to and quality of healthcare services (reported by 33% and 63% of households, respectively).**

The most important health care priorities were reported as the following: 1. Reduction of prices for drugs and medications; 2. Reduction of prices for services; 3. Improvement of quality of equipment in health facilities. Respondents report that due to lack of funds, they must reduce essential health expenditures, which exacerbate their vulnerability further.

Adaptive capacity, such as proportion of green spaces and employment opportunities also have the lowest availability in Livoberezhnyi District (11%), as depicted in Chart 26.3. Adaptive capacity is also strengthened by access to psychosocial support services, as it enables people to build resilience and better cope with adversity in the future. Ukrainian Foundation for Public Health (FPH) and Malteser International provide psychosocial services for adolescents and adults in Mariupol City.

The full list of vulnerability indicators by city district is shown in Table 26.1.

Chart 26.3. % of district area covered by green space (excluding agricultural area)

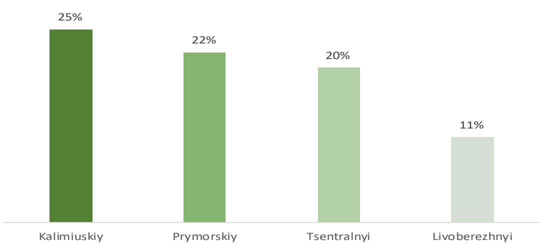


Chart 26.4. Services access by district (no. facilities available) - Mariupol UCVA, 2020

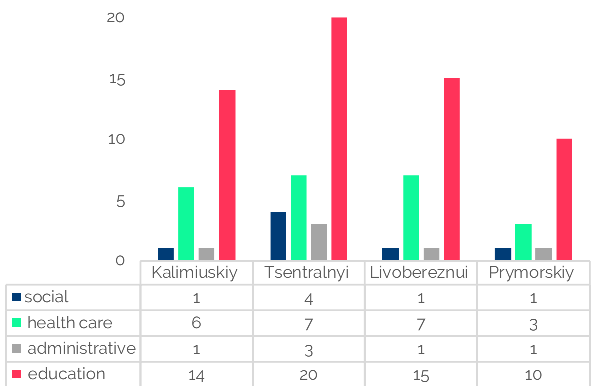


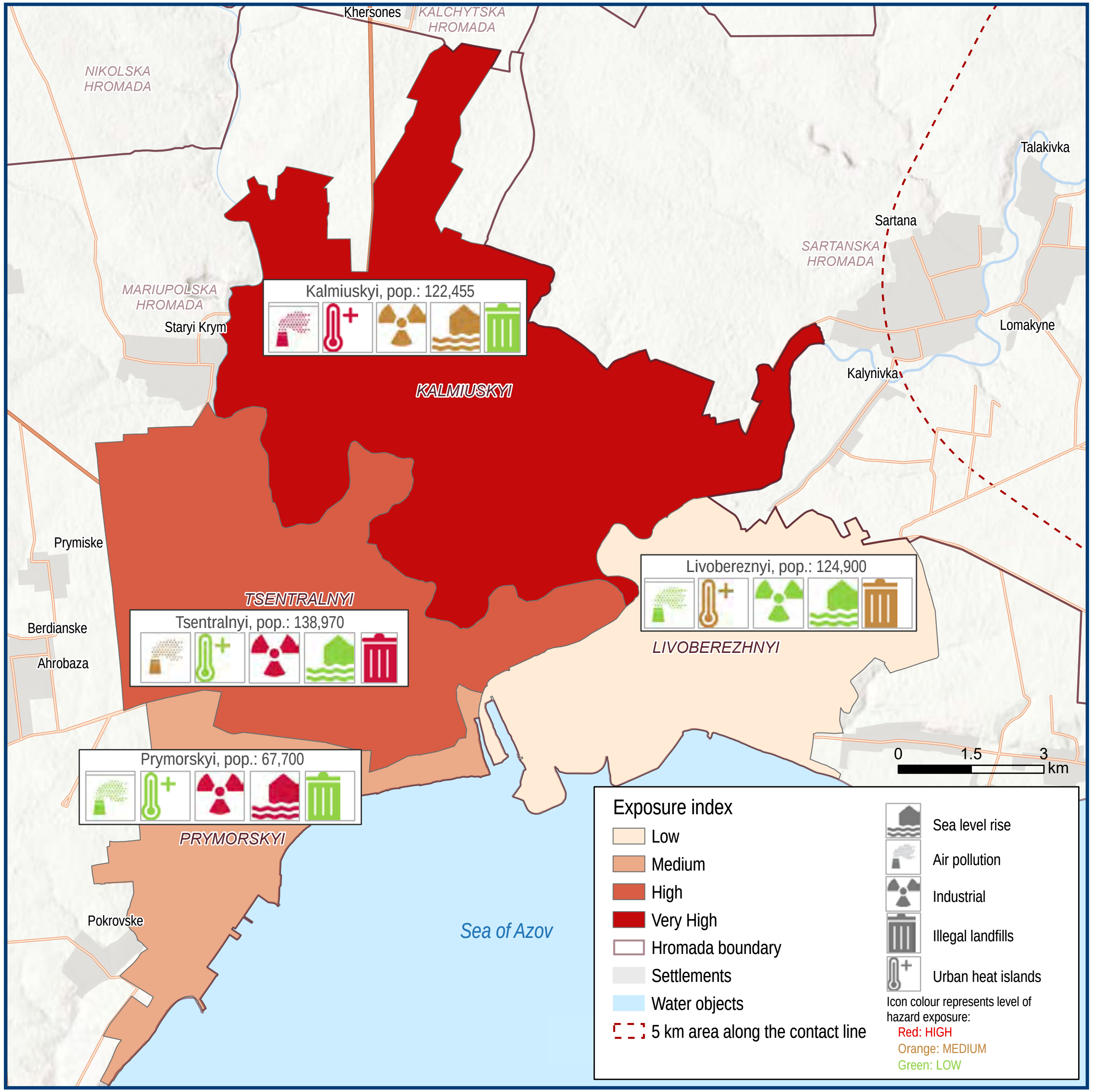
Table 26.1. Vulnerability indicators by district to 10,000 population, Mariupol City[a]

Vulnerability indicator	Kalimiuskiy	Tsentralnyi	Livoberezhnyi	Prymorskyi
Susceptibility				
1.1 People that are IDPs	2528.93	1475.64	2642.59	2315.07
1.2 Households with three or more children	27.52	20.58	29.46	26.74
1.3 People who are either a widow, a single parent, or single female HoH	112.86	101.39	95.60	102.51
1.4 People with one or more disability	194.93	317.62	276.46	174.45
1.5 People whose average income per capita fell below the actual subsistence minimum	74.48	94.7	78.86	98.97
Coping capacity				
2.1 Number of physician (general practicioners of family medicine)	1.47	2.16	0.88	1.33
2.2 Number of hospital beds	41.24	28.42	42.43	40.77
2.3 Social services facilities	0.08	0.29	0.08	0.15
2.4 Health care facilities	0.49	0.5	0.56	0.44
2.5 Ratio of admin. service centres	0.08	0.22	0.08	0.15
2.6 Ratio of education services facilities	1.14	1.44	1.2	1.48
2.7Ratioofemergency-relatedprotection facilities(shelters)	4.08	1.08	3.76	2.07
Adaptive capacity				
3.1 Percentage of green space as proportion of neighbourhood area (excluding agricultural land)	22	25	11	20
3.2 Formal and informal inclusive social facilities that promote well-being and prevent or reduce mental health and psychosocial problems	0.08	0.14	0.08	0
3.3 Employment opportunities	3.35	6.76	1.92	1.92

a data from multiple sources, including Mariupol City Council and IMPACT 2020 Urban CVA.

Mariupol City - Multi-hazard exposure profile

Map 27.1. Multi-hazard exposure by district, Mariupol City



The multi-hazard exposure analysis for Mariupol City was calculated from the combination of five hazard indicators 1.1 air pollution, 1.2 heat waves and urban heat islands 1.3 hazardous facilities, 1.4 flooding, 1.5 illegal landfills. These were calculated a outlined in Table 25.1 on page 39.

Map 27.1 and Table 27.1 show the overall multi-hazard exposure index for each district, whilst the main hazards and level of exposure are indicated by the relevant icons. For example, red icons indicate a higher level of population exposure to that specific hazard, whilst orange and green icons indicate progressively lower exposure1.

The map and table show that Livoberezhnyi has the lowest exposure to hazards, with heat waves and illegal landfills posing the greatest risks here. On the other hand, **Kalmiuskyi has the highest level of hazard exposure: populations here are most exposed to air pollution and heat waves.**

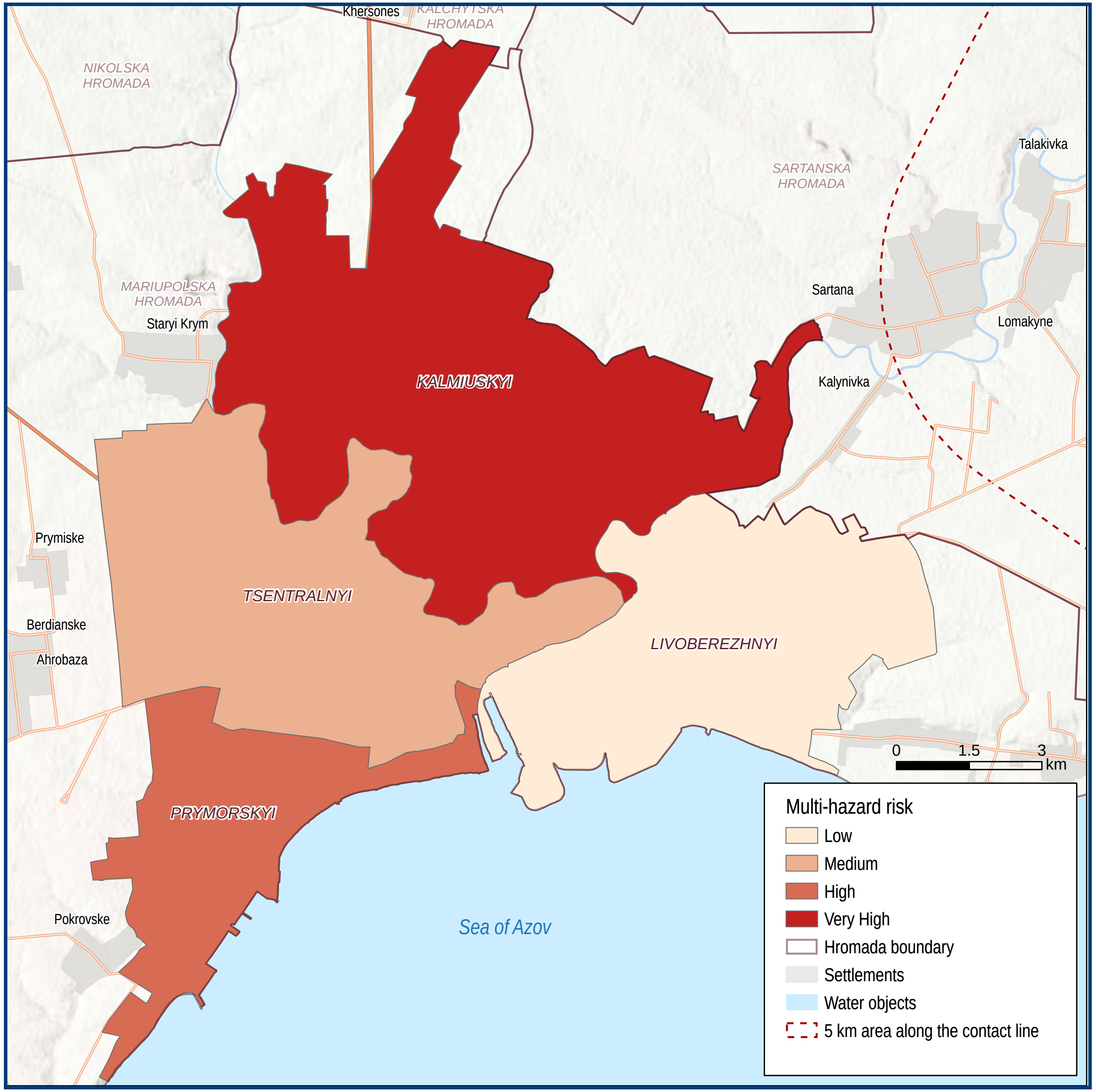
This map aims to serve as a tool to indicate the distribution of hazards across the city of Mariupol, and aid in the prioritisation of risk mitigation processes. Note that this map does not incorporate population vulnerability. This is included in the risk map on the following page, which combines both hazard exposure and population vulnerability.

Table 27.1. Multi-hazard exposure by district showing level of hazard intensity and exposure to populations, infrastructure and the environment

District	Heat wave	Flooding	Haz. facilities	Illegal landfills	Air pollution
Tsentralnyi					
Kalimiuskiy					
Livoberezhnyi					
Prymorskyi					

1 Note that green icons do not necessary indicate that the level of hazard is low in that district, just that there is low population exposure to this hazard.

Map 28.1. Multi-hazard risk by district, Mariupol City



Multi-hazard risk was calculated for the 4 official districts of Mariupol City using the risk equation, Multi-hazard Risk Index (MHRI) = Multi-hazard Exposure Index (HEI) x Vulnerability Index (VI), as indicated on p. 38. Specifically, the index was calculated based on the equal weighting of the five hazard exposure indicators of air pollution, heat waves / urban heat islands, hazardous facilities, flooding, and illegal landfills, multiplied by the societal vulnerability index. Values for each of these indexes for each district are shown in Table 28.1.

To be defined correctly as "Risk," the MHRI accounts for both exposure to hazard and societal vulnerability. Without societal exposure to a hazard, there is low risk, whilst where there is high exposure to a hazard but low societal vulnerability, there is also low risk.

Overall, Kalmiuskyi District has the highest hazard exposure and risk index within the city. The population in this district are highly exposed to air pollution and the urban heat island effect, whilst exposure to flooding and proximity to hazardous facilities is also relatively high. Table 28.1 shows that despite relatively low societal vulnerability, Kalimiuskiy District has the greatest risk in Mariupol City due to its high exposure to multiple hazards.

In contrast, although Prymorskyi District has relatively low exposure to the five selected hazards, the district is still the second-most at risk, primarily due to high vulnerability of the population here. Data from Livoberezhnyi District on the other hand clearly demonstrates that without significant exposure to hazards, risk remains low, despite the population living in this area being the most vulnerable.

Table 28.1. Multi-hazard exposure index (MHEI), vulnerability index (VI) & risk (MHRI) by district, Mariupol City

District	Population	VI	MHEI	MHRI
Kalimiuskiy	122,455	0.49	0.87	0.43
Tsentralnyi	179,582	0.40	0.57	0.22
Livoberezhnyi	124,900	0.77	0.23	0.18
Prymorskyi	67,700	0.71	0.40	0.28

3. Mariupol - Building a Resilient City

The objective of this chapter is to understand the level of resilience capacity[a] in Mariupol City and identify key areas of action for influencing and supporting resilience-building.

***Resilience* is defined as the ability of a system, community or society to resist, absorb and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions[122].**

In this ABRA, resilience is assessed by the following factors based on the **Operational Framework for Making Cities Resilient of the Sendai Framework at the Local Level**:

Identification and understanding of current and future risk scenarios
Understanding patterns of social vulnerability and societal capacity for resilience.
Assessing capacity and adequacy of critical infrastructure
Identifying ecosystem services and nature-based solutions within cities to enhance use for risk reduction and resilience building.

To build resilience, it is crucial to first identify and assess the most significant risks the city and its citizens face. This ABRA has consolidated maps and data related to a range of natural, socio-natural and anthropogenic hazards affecting the whole raion, and aims to serve as a tool for this very purpose.

According to the in-depth analysis conducted for Mariupol City for this ABRA, the five most common hazards identified were: **air pollution, flooding, heat waves (including urban heat islands), illegal landfills, and proximity to hazardous facilities**. Residential areas were taken as the exposed zones, given that this is where the population reside.

The assessment found that residential areas in Kalmiuskyi and Prymorskyi districts were the most at risk to these hazards. Residents of Kalmiuskyi District are the most exposed to the urban heat island effect and poor air quality, which determines the highest risk index here, despite the medium social vulnerability index. Prymorskyi District on the contrary, was found to have high vulnerability and medium hazard exposure. Interaction of these two factors culminates in high multi-hazard risk in this district.

The district with the lowest risk and lowest multi-hazard exposure was Livoberezhnyi. However, the population living in this district were found to have very high social vulnerability.

Resilience to climate change

Due to the continuous and increasing influence of **climate change**, intensity, frequency and duration of some hazards such as heat waves and flooding will continue to increase.

Resilience-building should therefore be an adaptive process, considering regional climatic trends and potential impacts on the behaviour of such hazards[123].

For example, as indicated in the Climate Change chapter, **maximum air temperatures in the raion could increase by up to 3.5˚C in the warmest months** within the next 40 years. Industrial areas in the city had the highest surface temperatures, averaging 34.5˚C in July 2020, whilst green areas such as forests and parks were significantly cooler at 31.6˚C.

The **urban heat island effect** is highly dependent on the ratio of green space to denser concentration of pavements, buildings and other surfaces that absorb and retain heat. **Livoberezhnyi District has the lowest proportion of green space**, accounting for only 11% of the district area, whilst industrial areas make up a staggering 41% of the territory.

To combat increasing threats of rising temperatures and heat waves, it is crucial to consider "green infrastructure" in resilience-building planning.

Green infrastructure is defined by the European Commission as *"a strategically planned network of high quality natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings. More specifically, being a spatial structure providing benefits from nature to people, it aims to enhance nature's ability to deliver multiple valuable ecosystem goods and services, such as clean air or water[124]."*

To prioritise areas that could contribute the most to risk reduction, it is important to firstly identify the most critical zones or ecosystems to develop

Source: EBRD Green Cities

a The potential for proactive measures to be taken in order to deal with shocks or stresses.


Source: Mariupol City Council

or restore. Cities such as Lviv and Bila Tserkva took part in a Community Safari[125], developed by the UNDP Innovative Development Laboratory in Ukraine. The two-day "quest" around the city aimed to bring together community members to collectively identify, discuss and test ideas to solve environmental challenges and coordinate follow-up actions, using nature-based solutions. As a result, digital maps were created which marked ~40 locations in Lviv and 25 in Bila Tserkva, which require nature-based solutions. Such an activity could also be beneficial for Mariupol City for awareness raising and community engagement.

Following the European cities` example, cities such as Rivne, Lviv and Kharkiv are developing ideas to implement so-called **"green corridors".**

Green corridors consist entirely of parks, forests, public water bodies and gardens united in a single network, linking different parts of the city in environmentally-friendly ways for pedestrians and cyclists.

Apart from their recreational benefit, green corridors serve as pools for rainfall accumulation to prevent flooding and inundation. Green areas will also improve the air quality and create a cooling effect during heat waves. Moreover, the presence of green spaces in urban areas is associated with better mental health and encourages residents to engage in more physical activity.

Resilience to urban flooding

Riverine and groundwater flooding present further risks to Mariupol City, which is intersected by both the Kalchuk and Kalmius rivers. Residential areas that are the most prone to flooding are located in Prymorskyi and Kalmiuskyi districts. According to IPCC, 2021, it is very likely that heavy precipitation events will intensify and become more frequent in the future, hence exacerbating the flooding hazard in the city[126].

Mariupol City is also highly exposed to **sea level rise.** Under future scenarios, the level of the Sea of Azov is expected to rise by between 0.36m and 0.46m by 2100 (see p. 18). Under the highest GHG emission scenario (rcp8.5), sea level rise may reach +82cm by 2100. Within Mariupolskyi Raion, these zones cover an area of 53.35km and could inundate industrial and residential coastline areas as well as exacerbate the effects of flooding within the city. This may lead to risk of cascading failures from one asset system to another, landslides, inundation of hazardous landfills and critical infrastructure.

To mitigate the damaging impact of flooding, city administration should incorporate both grey and green infrastructure measures to its city development plans. It is important to improve drainage system as well as reserve plots within the city for expansion of green areas. Green roofs and stormwater retention systems are other natural solutions for urban flood mitigation.[127] Some of these measures have been implemented elsewhere in Ukraine. For example, in the Dnipro City, a green roof was established on the shopping center "Cascade Plaza[128]".

Resilience to air pollution

Air pollution is another concerning hazard in the city, especially in Kalmiuskyi District. The intensity of this hazard is highly dependent on future policies and plans towards reduction of emissions released by industrial plants in Mariupol and surrounding areas. It is important to expand air quality monitoring capabilities to expand the evidence base for air quality control policy development. As identified in the Air Pollution section, two main metallurgic plants are the biggest contributors of pollutants in the area. However, emissions from transportation also contribute to air quality in the city.

Green space development is a valuable natural tool to build resilience to air pollution.[127] Trees, vegetation, and green roofs can help regulate building temperatures, reducing demand and therefore emissions from energy use associated with heating and cooling buildings. Vegetation also helps to absorb air pollutants.

In addition, investments in transportation system should encourage people to use more public transport, whilst investments in walking and cycling routes would encourage residents to travel in a more environmentally-friendly way.

To address environmental challenges, in May 2019, **Mariupol joined the European Bank for Reconstruction and Development (EBRD) Green Cities programme** which strives to tackle the challenges of air quality and solid waste management in the city.

Societal capacity for resilience

As described in the Vulnerability section, Livobereznyi and Prymorskyi districts were scored

Source: Mariupol City Council

as the most vulnerable, including high susceptibility of their residences and lack of coping and adaptive capacity.

Coping and adaptive capacities form the basis for assessment of disaster resilience. Coping capacities are the means by which people or organizations use available resources, skills and opportunities to face adverse consequences that could lead to a disaster. Coping capacity in this assessment was based on **availability and access to critical infrastructure and public services1 within Mariupol city.** This improves the response during and after a disaster and respectively decreases both human and economic loss.

According to the IMPACT UCVA survey in 2021, capacity and adequacy of critical infrastructure in Mariupol City vary depending on district. When considering ratio of public services per 10,000 of the population, **Livoberezhnyi and Kalimiuskiy districts display a clear deficit of administrative, educational and social services**, while **Prymorskyi District has a very low number of health care facilities** and low number of family doctors per 10,000 of the population. It also **lacks bomb shelters** in the case of mass evacuation, which is critical to cope with sudden onset hazards and conflict incidents.

Adaptive capacities are the arrangements and processes that enable adjustment through learning, adaptation and transformation. Capacity to adapt to the adverse impacts of climate change and intensifying hazards in the future was measured as a **proportion of green spaces** in the city. **Livoberezhnyi District has the lowest capacity in this regard (11% of the territory is green spaces)** and requires further adoption of nature-based solutions in the area.

Another useful measure of adaptive capacity is the presence and access to mental health and psychosocial support (**MHPSS) services**, which increases the ability of individuals to better cope with stress and faster recover and adapt to unusual situations caused by hazardous events. There are two centers providing the psychosocial support services in Mariupol City: Ukrainian Foundation for Public Health and Malteser International. In addition, the Ukrainian Red Cross Society provides free psychological support through the "Let's Talk" hotline, as well as conducts the first psychosocial aid trainings for instructors in Mariupol.

Some suggested actions for resilience building[a]:

Integration of the disaster risk reduction framework in the City's Master Plan
Develop Green City Action Plan (GCAP) in accordance with disaster risk mitigation strategies
Collectively identify problems and then explore possible nature-based solutions for Mariupol city via quest Community Safari[b] to increase expenditure on environmental protection and nature conservation in the city
Establish partnerships among key stakeholders, civil society organizations and private sector interested in improving the city's resilience

a This needs further discussion with experts working in the field of Disaster Risk Reduction
b Administrative centers, education, health care social, emergency-related protection facilities)

Source: Mariupol City Council

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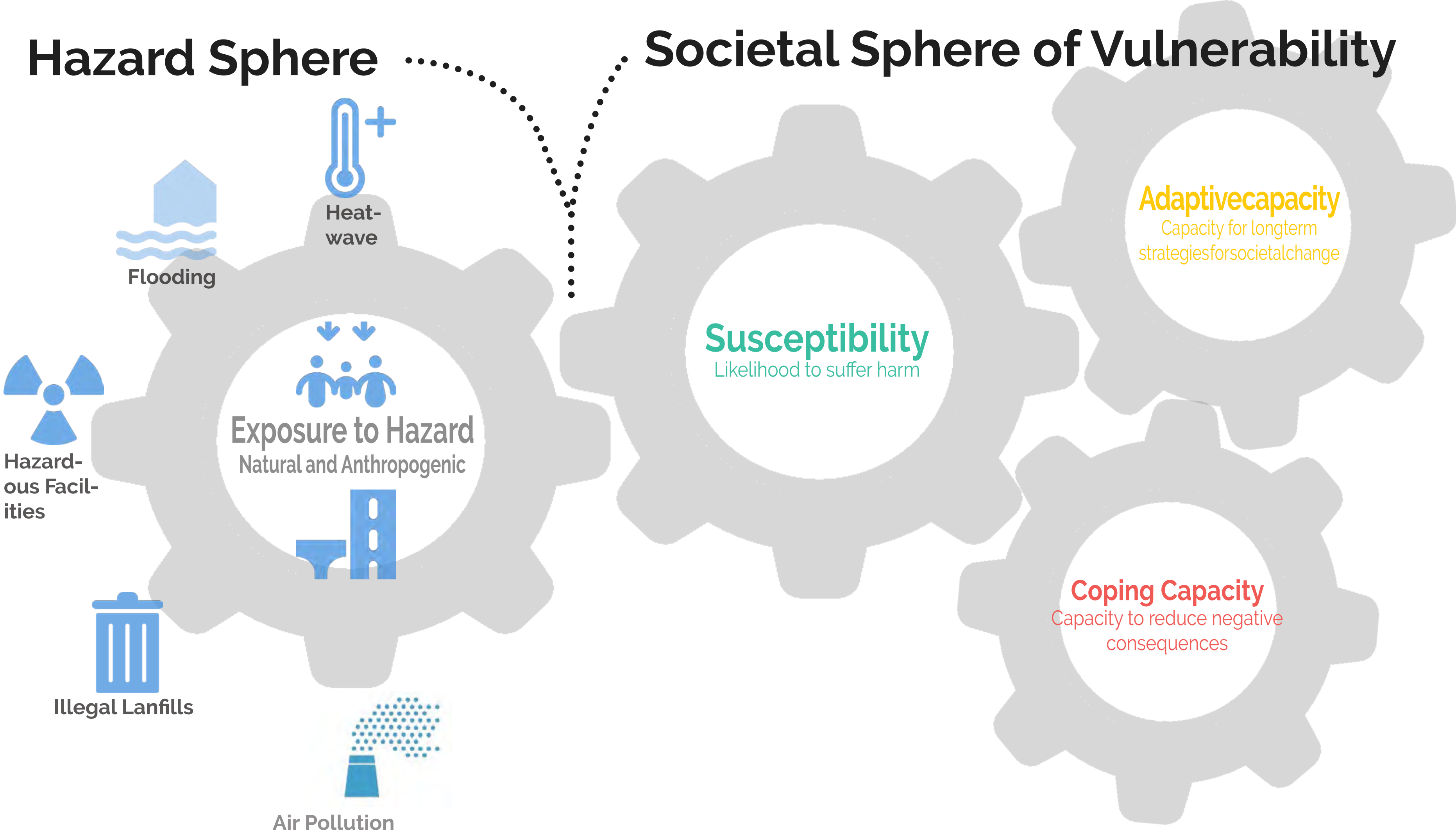
Annex 1 - methodology notes

Methodology for Mariupolskyi Raion, focus on hazards / hazard exposure to population and infrastructure

Hazard	Data sources	Methodology
Wildfires	NASA FIRMS (2001-2020). State Emergency Service of Ukraine (2015-2018). Conflict data from ACLED. Copernicus Proba-V Land cover (2019).	Wildfire map: data from NASA`s satellite-based Fire Information for Resource Management System (FIRMS) between 2001 and 2020 aggregated into 1 sq.km. bins, and mean frequency and intensity of fires per year calculated for each bin. Presumed vegetation fires were extracted. SESU unit travel time map was created based on data, provided by SESU department in Donetsk oblast.
Land degradation	Trends Earth (2001-2018).	Land degradation calculation run in Trends Earth for Mariupolskyi Raion.
Soil erosion	SRTM digital elevation model (2021). Copernicus Proba-V Land cover (2019) Global rainfall erosivity dataset (2017). Soil data: digitised from Ukraine Cadastre Map.	RUSLE model (Revised Universal Soil Loss Equation) was employed - calculates annual soil losses as a function of rainfall erosivity, soil erodibility, topography, landuse management, and soil conservation support practice. Rainfall erosivity factor was derived from the global rainfall erosivity dataset. Soil erodibility factor was elaborated from a soil map, and topographic factors were calculated based on the 30m SRTM elevation model. Landuse management factor was elaborated based on Copernicus land cover and OpenStreetMap datasets. A map of accumulated distances to forested shelterbelts (windbreaks) was developed and used as the soil conservation factor.
Drought	VCI data derived from MODIS EVI (2001-2020). Copernicus Proba-V Land cover (2019). Climatic data from Giovanni (GLDAS). Meteorological information for dry wind data from Rp5.	Overall drought hazard was calculated in Google Earth Engine based on accumulated vegetation condition index (VCI). Satellite-derived vegetation health data from spring and summer months between 2001 and 2020 (MODIS EVI) was used. Analysis was run for agricultural areas only, masked out using Copernicus land cover data. Methodology adapted from UN Spider. Drought hazard exposure calculated for each hromada by weighting the drought severity for each pixel (0.4-1 = 0, 0.3-0.4 = 1, 0.2-0.3 = 2, 0.1-0.2 = 3, 0-0.1 = 4), summing pixel values for each hromada, then multiplying this by the % population that is rural, approximated as exposed population, given that a large proportion of the rural population in Ukraine work in agriculture.
Heat waves	MODIS MOD11 (2000-2020).	Percentage of days with land service temperature above 37˚C in June, July and August (2000-2020), calculated from MODIS Land Surface Temperature and Emissivity (MOD11).
Cold waves	MODIS MOD11 (2000-2020).	Percentage of days with land service temperature below -15˚C in December, January and February (2000-2020), calculated from MODIS Land Surface Temperature and Emissivity (MOD11).
Biodiversity loss	Copernicus Proba-V Land cover (2019).	Percentage of the raion area with natural vegetation (grasslands, forest, wetlands, and water bodies) per square km.
Coastal landslides	Soil data: digitised from Ukraine Cadastre Map. Elevation data: SRTM digital elevation model (2000). Vegetation cover: calculated from Sentinel 2 MS imagery (2020).	Clay soils digitised from Ukraine Cadastre Map. Susceptibility index calculated for these zones based on equal weighting of slope angle (calculated from SRTM digital elevation model) and vegetation cover (higher slope angle = higher susceptibility + higher vegetation cover = lower susceptibility). Vegetation cover approximated from normalised difference vegetation index (NDVI), calculated from Sentinel 2 multispectral image.
Infrastructure exposure to conflict	Infrastructure data from OSM. Communication towers from OpenCellID. Conflict data from ACLED.	Density of conflict incidents between 1st June 2020 to 31 May 2021 extracted from ACLED database. Only events classified as explosions and remote violence were used. Density layer created which was overlaid with key infrastructure data extracted from OpenStreetMap. Proximity of conflict events to hazardous facilities was calculated in QGIS, along with lengths of networks within 5km of the contact line (CL) and incidents occurring in or near settlements.
Air pollution	Satellite air polution data from Sentinel-5P. Ground monitoring posts data from Save-Ecobot. Industrial facilities from Donbas Environment Information System.	Yearly-averaged raster datasets over the raion for main pollutants (NO_2, SO_2, CO and aerosols) were calculated using GoogleEarthEngine. Data from ground air monotoring posts was yearly-averaged and interpolated over the area of Mariupol city using Inverse Distance Weighting method in QGIS, then clipped by values over maximum permissible concentrations (MPC) for each of the pollutant. Over the area with MPC exceedance, it was calculated how many times the MPC was exceeded for each of the pollutant and summed.
COVID-19	COVID cases data from Ukraine Public Health Center and Cabinet of Ministers of Ukraine (2020-2021).	The map shows hromada-level findings, indicating all COVID-19 cases, hospitalisation and dead from 15.03.20 to 25.07.2021 (data were available for this time period). The total number of COVID-19 cases is indicated in color for the hromada, the number of deaths, and the number of hospitalizations shows on the chart for each hromada.
Multi-hazard exposure	Hazard datasets created above, excluding land degradation, soil salinity, biodiversity loss, heat waves and cold waves.	Hazards occurring in each of hromada identified and ranked based on high, medium or low level of hazard exposure.

Mariupol City - Multi-hazard risk concept

Multi-hazard Risk1 = Hazard exposure (heat waves + flooding + hazardous facilities + illegal landfills + air pollution) **x Vulnerability** (susceptibility + adaptive capacity + coping capacity)



1 This methodology was adapted by IMPACT based on the World Risk Index.

Mariupol City - hazard exposure calculation

Table 25.1. Hazard exposure indicators used for multi-hazard risk calculation

Hazard	Indicator	Methodology
Heat waves and heat islands	Percentage of days with land surface temperature above 37˚C in each district	Data on land surface temperature was acquired from MODIS satellite data (MOD11) in June, July and August over 2001-2020 using Google Earth Engine and calculated for each city district.
Flooding	Percentage of residential area covered by flood hazard zone	Percentage of residential zone (extracted from OSM data) covered by the 0-3m groundwater flooding zone (from Ukraine Open Data Portal) calculated for each city district.
Hazardous facilities	Mean distance of hazardous faciilties to buildings within residential areas (km)	Averaged distance from all buildings in residential areas (extracted from OSM data) to all hazardous objects calculated for each city district.
Illegal landfills	Number of buildings within 200m of an illegal landfill site	The number of residential buildings (extracted from OSM data) were counted within a 200m vicinity of incomplete illegal landfill appeals (digitised from Ecomapa) for each city district.
Air pollution	Yearly average concentra-tion of pm2.5, pm10 and SO2 in residential areas, in relation to MPC	Yearly average concentration of pm2.5, pm10 and SO2 in resi-dential areas interpolated from air pollution monitoring posts and clipped by the MPC values, summed into one raster and cal-culated for each city district.

Flooding in Mariupol City in Summer 2021

Source: InfoResist

Source: Radiosvoboda

Source: GMK Centre

Mariupol City - vulnerability index calculation

SUSCEPTIBILITY

Dependency

0.2 Ratio of people that are IDPs to 10.000 population

IDPs are dependent on their current "sheltered" status to receive public services. They also tend to have limited social networks in their new place of residence.

0.2 Ratio of households with three or more children to 10.000 population

Children have higher dependency on others and may be unable to protect themselves or evacuate if necessary.

0.2 Ratio of people who are either a widow, a single parent, or single female HoH to 10.000 population

Disproportionately affected by disasters due to their dependency on social security payments and potential lower income from only one family member.

0.2 Ratio of people with one or more disability to 10.000 population

Potential physical inability to evacuate during a disaster and reliance upon others or public services. to ensure their evacuation in safely maner.

Economic capacity

0.2 Ratio of people whose average income per capita fell below subsistence minimum to 10.000 population

Income level influences availability and access to different assets and therefore ability to prepare, respond, or recover from a disaster.

COPING CAPACITY

Health care facilities resources

Indicate the level of access to care and the provision of quality medical care, which are highly correlated with live-saving and health status.

0.25 Number of psysician (general practicioners of family medicine) to 10.000 population

0.25 Number of hospital beds to 10.000 population

Public service facilities

Availability of and access to social, health care, administrative, employment services and public assistance improves preparedness and response to disaster and respectively decreases both human and economic loss.

0.1 Ratio of social services facilities to 10.000 population

0.1 Ratio of health care facilities to 10.000 population

0.1 Ratio of administrative centres to 10.000 population

0.1 Ratio of education services faciliies to 10.000 population

0.1 Ratio of emergency-related protection facilities (shelters) to 10.000 population

ADAPTIVE CAPACITY

0.5 Percentage of green space as proportion of neighbourhood area (excluding agricultural land)

Green spaces in urban settings provide various ecosystem services and protect habitat. They also improve air quality, decrease the impact of heat waves and increase communities subjective well-being.

0.25 Ratio of formal and informal inclusive social facilities that promote well-being and prevent or reduce mental health and psychosocial problems to 10.000 population

Access to and usage of MHPSS services increases the ability of individual to better cope with stressul events and faster adapt to or/ and recover from disastrous events.

0.25 Ratio of employment opportunites to 10.000 population

Employment opportunities increase the economic capacity for preparedness and mitigation measures as well as the potential sustainable access to finances after the disaster.

Numerical figures represent indicator weighting to a total value of 1 for Susceptability, 1 for Coping capacity and 1 for Adaptive capacity. Additng these three components together divided by 3 result in Vulnerability index.

Vulnerability = (Susceptability + Coping Capacity + Adaptive Capacity)/3

Cascading Risks

Diagram shows potential cascading risks in Mariupolskyi Raion and Mariupol City. Many hazards and risks are interconnected. For example, heat waves and droughts, exacerbated by climate change, lead to the conditions suitable for wildfires. Conflict-related shelling may cause fires to ignite, whilst landmines hinder access in the response. Damage to critical infrastructure caused by wildfires further complicates response and increases vulnerability of the population.