Research Terms of Reference

Land displacement risk mapping using remote sensing

UKR2105
Ukraine

01 November 2021
Version 1.0

IMPACT Shaping practices Influencing policies Impacting lives

1. Executive Summary

Country of intervention	Ukraine					
Type of Emergency	**X**	Natural disaster	**X**	Conflict		
Type of Crisis	□	Sudden onset	□	Slow onset	**X**	Protracted
Mandating Body/ Agency	SDC					
Project Code	64EOH/64ARR					
Overall Research Timeframe	01/07/2021 to 31/05/2022					
Research Timeframe	1. Start collect data: 01/07/2021			5. Preliminary presentation: 30/11/2021		
	2. Data collected: N/A			6. Outputs sent for validation: 15/12/2021		
	3. Data analysed: 30/11/2021			7. Outputs published: 31/12/2021		
	4. Data sent for validation: N/A			8. Final presentation: 31/12//2021		
Number of assessments	X	Single assessment (one cycle) in 1 geography: Toretsk-Yenakiievo-Horlivka coalmining network				
	□	Multi assessment (more than one cycle)				
Humanitarian milestones	**Milestone**			**Deadline**		
	□	Donor plan/strategy				
	□	Inter-cluster plan/strategy				
	□	Cluster plan/strategy				
	X	NGO platform plan/strategy (3P Consortium)		30/11/2021		
	□	Other (Specify): High-level donor meetings		ongoing		
Audience Type & Dissemination	**Audience type**			**Dissemination**		
	X Strategic **X** Programmatic □ Operational			**X** General Product Mailing (e.g., mail to NGO consortium; HCT participants; Donors) **X** Cluster Mailing (DRR working group) **X** Presentation of findings **X** Website Dissemination (Relief Web & REACH Resource Centre) **X** Internal dissemination within 3P Consortium **X** Bilateral dissemination to local authorities		
Detailed dissemination plan required		Yes	**X**	No		
General Objective	To develop a better understanding of land subsidence and land displacement risks in coal mining region of Eastern Ukraine					
Specific Objective(s)	1. To map land displacement within Toretsk and Horlivka communities over the 2017-2021 using Interferometric Synthetic Aperture Radar (InSAR)[1] remote sensing technique					

[1] Interferometric Synthetic Aperture Radar (InSAR) is the technique, which uses the time series of synthetic aperture radar (SAR) images to generate maps of land surface deformation based on the differences in the phase of the waves returning to the satellite or aircraft.

	2. To analyze the relation between the largest subsidence and uplifting locations and the potential environmental processes driven by coal mines flooding in the area of interest. 3. To define populated areas and infrastructure locations which are possibly affected by the high rates of land displacement (land subsidence and upliftings).
Research Questions	1. What locations show consistent trend of land displacement over the last 5 years? a. What locations show high mean displacement velocity over the last 5 years? b. What locations show high total displacement in 2021? c. What is the agreement between applied SBAS algorithm and known locations of land displacement from other sources? 2. Which population and infrastructure are affected by intensive land displacement? a. Which populations are exposed to high risk of land subsidence or uplifting? b. Which buildings and infrastructure are potentially exposed to land displacement? 3. What factors might course the land displacement intensification? a. Which coal mines are in closest proximity to land displacement area, what is the status of these coal mines (operational, closed, uncontrolled)? b. What other possible environmental processes are known to drive the detected land displacement according to secondary data review and consultations with coal mine experts.
Geographic Coverage	Toretsk and Horlivka communities
Secondary data sources	Open Street Map, OCHA for neighborhood boundaries, Sentinel-1 images, SRTM DEM.

Population(s)	□	IDPs in camp	□	IDPs in informal sites		
	X	IDPs in host communities	□	IDPs [Other, Specify]		
	□	Refugees in camp	□	Refugees in informal sites		
	□	Refugees in host communities	□	Refugees [Other, Specify]		
	X	Host communities	**X**	Returnees		
Stratification	**X**	Geographical 1 #:_Population size per strata isknown? □ Yes **X** No	□	Group #: _ _ _ Population size per strata is known? □ Yes □ No	□	*[Other Specify]* #: _ _ Population size per strata is known? □ Yes □ No
Data collection tool(s)	**X**	Secondary data review				

	Sampling method	**Data collection method**
Structured data collection tool # 1	**N/A**	**N/A**
Structured data collection tool # 2	**N/A**	**N/A**
Semi-structured data collection tool (s) # 1	**N/A**	**N/A**
Semi-structured data collection tool (s) # 2	**N/A**	**N/A**
Target level of precision if probability sampling	**N/A**	**N/A**

Data management platform(s)	**X**	IMPACT	□	UNHCR		
	□	[Other, Specify]				
Expected output type(s)	□	Situation overview #: _ _	**X**	Report #: 1	□	Profile #: _ _
	□	Presentation (Preliminary findings) #: _ _	□	Presentation (Final) #: _ _	□	Factsheet #: _ _
	□	Interactive dashboard #:_	□	Webmap #: _ _	□	Map 1 #: _ _
Access	**X**	Public (available on IMPACT resource center and other humanitarian platforms)				
	□	Restricted (bilateral dissemination only upon agreed dissemination list, no publication on IMPACT or other platforms)				
Visibility	IMPACT, SDC, ACTED, R2P					

2. Rationale

2.1. Rationale

The Toretsk-Horlivka-Yenakievo coal mining network is one of the largest coal mining agglomerations in Eastern Ukraine and includes over 30 mines. With the energy sector reform started in the early 2000s, the long-lasting coal mine closure and conservation processes have begun and as of 2021 only three mines near the Toretsk area are operating officially.

The mine network is in a 25 km area crossing the "grey zone" along both sides of the contact line, exposed to shelling and landmines, rendering certain areas inaccessible and thus leading to a loss of management and technical oversight and control. As closed mines gradually flood, without adequate pumping and wastewater management, water becomes highly mineralized and polluted with industrial chemicals and spreads to underground and surface waters and can provoke land subsidence, affecting densely populated areas on both sides of the "line of contact" (LoC).

Monitoring is the basis for understanding the state of the environment and planning of measures to prevent natural and anthropogenic environmental disasters. However, due to the conflict, Ukrainian authorities have been unable to carry out appropriate monitoring of the coal mines, notably analyzing the chemical composition of water from the nearest wells and springs compared to the composition wastewater in mine release spots, the level of mines flooding, and the condition of soil and groundwater over minefields in non-government-controlled area (NGCA) etc.

Furthermore, with many mines located in NGCA interconnected with mines in government-controlled area (GCA), any action to change the structure and mode of operation of mines on either side will affect the other. However, the lack of operational information about actions taken in NGCA further inhibits a proper response in GCA.

Due to the conflict, the monitoring system covering the regional mine network is no longer operational. The lack of exchange of information between the two sides of the LOC on the issue further limits risk oversight and management, exposing settlements and populations on both sides of the LoC to a significant risk of disaster.

3. Methodology

3.1. Methodology overview

To detect the location exposed to land displacement over the last 5 years, IMPACT will apply the spaceborne Interferometric Synthetic Aperture Radar technique. Dense time series of radar Sentinel-1 images (with temporal resolution or time of revisitation, between 2 acquisitions in the same orbit direction is 12 days) allow to define temporally consistent locations with detectable changes in elevation. Each image consists of radiometric amplitude and phase, and interferometric algorithms are highly sensitive to the phase change due to the land displacement. Once land topographic phase is subtracted using freely available digital elevation models, displacement phase can be defined with a precision of a few millimeters.

Instead of simple interferometric comparison of single radar image pair, the most reliable approach of harnessing the long time series (> 20 images at once) should be applied. The most common methods (such as Persistent Scatterer Interferometry, PSI, or Small Baseline Subset, or SBAS) provide reliable results for the locations with high temporal coherence (i.e., temporal consistency of radar signal, which is typically achieved by built-up and bare soil locations, while vegetation and water bodies are not temporally coherent). For this study SBAS method is applied for its high flexibility when dealing with environments with abundant vegetation (agriculture, forests) like Toretsk-Horlivka area. SBAS method uses the locations (specific pixels) with negligible atmospheric (spatially correlated, but temporally decorrelated) and topographic (temporally consistent, but spatially decorrelated) noise. It builds time series of reliable displacement velocity for these pixels based on use of available set of radar image pairs. In this set, specific baseline image (master image) is the same across all available pairs.

It is intended to run SBAS algorithm using cloud-based and desktop software and a set of 79 radar Sentinel-1 images covering the entire Toretsk-Horlivka area. Images were downloaded from ONDA free archive and belong to the same descending-oriented orbit (relative number 94) and encompass at least the period from June 2017 to September 2021. Images for the

period November-March were not included into the analysis with aim to minimize the effects of snow cover and dense cloud cover which is typical for these latitudes in winter. SBAS method will be run on cloud-based GeoHazard platform. Only locations with mean displacement velocity larger 1 cm/year and high temporal coherence (70% and higher) will be used for further analysis.

To verify the remote sensing results, we will conduct a field visit and collect the land displacement evidence (signs of building wall breakage, measurements carried out in coal mines) or reported results of previous studies.

To define the population and infrastructure located in the area of high risk of land displacement the Open Street Map data will be used. The identified displacement hotspots will be overlapped with the industrial objects, roads and buildings and estimating the population living in these houses. Population will be estimated using a prior knowledge of household size (1.86 in Toretsk and periphery area according to REACH CVA and 2.32 in Yenakiyevo and periphery area according to the State Statistics office of Ukraine, 2021), and estimated number of apartments in multi-store buildings. Open Street Map data will be used to count the houses, with digitalizing the missing buildings using the available high-resolution images and assigning the number of floors using available photos in Google Earth and images collected during field visits and shadow size on high-resolution imagery. Additionally, there will be the assessment of critical infrastructure (health and education facilities) affected by detected land displacement hotspots (in close spatial proximity to displacement locations) and the number of unstable spoil tips affected by land displacement.

To analyze the factors which drives the land displacements, we will explore the available scientific papers and media sources to examine whether other, wider existing geological or other environmental/anthropogenic (except flooding of coal mines) can drive detected land displacement patterns in built-up areas. The preliminary maps of the areas with recently high rate of land displacement (> 1 cm per year) will be shared with coal mines representatives, mining experts and Toretsk city environmental department. The evidence-based actions and factors, which are in play, will be discussed with the coal mining and environmental experts.

3.2. Population of interest

The population of interest in this study includes host community members, IDPs and returnees in the one core area encompassing Toretsk community (GCA) and Horlivka (NGCA) community. These areas were selected due to be linked to the Toretsk-Yenakiievo-Horlivka coal mining network, being intersected by the line of contact (directly conflict-affected zone)

3.3. Secondary data review

The main freely available data source is an open Sentinel-1 image archive. As all Single-Look Complex (SLC, a data format needed for radar interferometry) images older than 3 months from current date are available only upon a request on the Sentinel-HUB platform, the ONDA archive is intended to be used to obtain the data.

Elevation and slope data will be obtained from SRTM (2000) digital elevation model available at Google Earth Engine or high resolution elevation model if available. Vector data on the line of contact, administrative boundaries, network, infrastructure, living buildings will be obtained from various sources, including OpenStreetMaps, OCHA data set, IMPACT sources, digitalized from high-resolution imagery available in Google Maps, etc.

It is expected to use evidence of local experts (ecological department of local authority, coal mine management, local ecology activists) and the report on geological and hydrological consequences of coal mine flooding prepared by state enterprise 'Donetskgeologiia' for ACTED to define other processes which can cause the land displacement alongside with mine flooding.

Table 1. List of open data sources to be utilised

Data source	Short description	Area	Available data and comment
ACLED Conflict incidence	Conflict incidence 2018-present time	Ukraine	Conflict incidents as recorded by ACLED
SRTM DEM	Global DEM	Global	DEM
Sentinel-1	RS	Global	Radar imagery (10 meters)

OCHA Settlement Boundaries	Administrative boundaries	Ukraine	Admin boundaries
OSM buildings network	Vector layer	Global	raw OSM
OSM road, electricity, water supply network	Vector layer	Global, Ukraine	raw OSM, Toretsk ABRA

3.4. Primary Data Collection

No primary data collection will be conducted as part of this assessment.

3.5. Data Processing & Analysis

We rely on the SBAS method which processes radar Sentinel-1 images as the main source of data for this analysis. It builds a set of georeferenced points with measured land displacement velocity (in cm/year) and with a high temporal coherence, or consistency (of radar signal). Then, we suggest defining the main hotspots around clusters of such points with similar land displacement rates (considering only points with at least -1 cm or +1 cm velocity). These hotspots in form of polygons can be used to link the land displacement areas to the closest coal mines (searching for possible reasons of land displacement), spoiling tips (showing those objects which are affected by land displacement), other available ground/remote sensing-based land displacement measurements (verification of results). As well, we plan to estimate the affected population living in land displacement risk areas by estimating the household size and approximated number of the apartments in the buildings. The infrastructure data will be extracted from various sources (OSM) in vector format, the missing buildings will be digitalized from the recent high-resolution Geo-Eye images. Elevation and slope from available DEM will be used to examine the possible water flows and surface flooding considering the network of interconnected coal mines located at different elevations.

Table 2 outlines the way in which geospatial data will be processed and analyzed within the framework.

Table 2. Summary of data processing and analysis.

Section name	Process/analysis
Land displacement (Sentinel-1 images, SBAS method)	Application of SBAS method on GeoHazard platform using all available images of Sentinel-1 satellite acquired over the last 5 years. The minimum temporal coherence for each location (pixel 20x20 m) is 70%.
Elevation and slope	Raster data calculated from Shuttle Radar Topographic Mission (2000) digital elevation model or high resolution elevation model is available
Critical infrastructure objects (health and education facilities)	Internal IMPACT data base for GCA, external sources for NGCA (e.g., Google Places)
Conflict incidence (INSO, ACLED)	INSO, ACLED conflict incidence data for June 2017 – December 2021 in the proximity of area of interest.
Living houses and other buildings	Cleaned and displayed OSM data, other IMPACT sources, high-resolution satellite Geo-Eye imagery acquired in September 2021
Coal mines, spoil tips, tailing dams	Vector layer from IMPACT data base, with indicated interconnections and depth of coal mines taken from report of State Enterprise 'Donetskgeologiia'

4. Roles and responsibilities

Table 3. Description of roles and responsibilities

Task Description	Responsible	Accountable	Consulted	Informed
Research Design	GIS Officer	Country Coordinator	3P Consortium partners, GIS/Database Manager, IMPACT Research Design Unit	
Secondary Data Review	GIS Officer, DRR Unit Lead	DRR Unit Lead	Country Coordinator, IMPACT Research Design Unit, IMPACT Data Unit	3P Consortium partners
3rd Party Data Requests	GIS Officer	DRR Unit Lead	Country Coordinator	
Data Processing (Checking, Cleaning)	GIS Officer	DRR Unit Lead	IMPACT Data Unit	
Data Analysis	GIS Officer	DRR Unit Lead	IMPACT Data Unit	
Map Production	GIS Officer	DRR Unit Lead	IMPACT GIS Unit	
Report Writing	GIS Officer	DRR Unit Lead	IMPACT Research Unit	3P Consortium partners
Report Translation	GIS Officer	DRR Unit Lead		
Report Design	GIS Officer	DRR Unit Lead	Country Coordinator, IMPACT Research Unit	3P Consortium partners
Dissemination	GIS Officer	Country Coordinator	3P Consortium partners	
Monitoring & Evaluation	GIS Officer	Country Coordinator		IMPACT Research Unit
Lessons Learned	GIS Officer	GIS Officer		IMPACT Research Unit

Responsible: *the person(s) who executes the task*
Accountable: *the person who validates the completion of the task and is accountable of the final output or milestone*
Consulted: *the person(s) who must be consulted when the task is implemented*
Informed: *the person(s) who need to be informed when the task is completed*

5. Data Management Plan is Available upon Request

6. Monitoring & Evaluation Plan

IMPACT Objective	External M&E Indicator	Internal M&E Indicator	Focal point	Tool	Will indicator be tracked?
Humanitarian stakeholders are accessing IMPACT products	Number of humanitarian organisations accessing IMPACT services/products Number of individuals accessing IMPACT services/products	# of downloads of x product from Resource Centre	Country request to HQ	User_log	**X** Yes
		# of downloads of x product from Relief Web	Country request to HQ		□ Yes
		# of downloads of x product from Country level platforms	Country team		□ Yes
		# of page clicks on x product from REACH global newsletter	Country request to HQ		□ Yes
		# of page clicks on x product from country newsletter, sendingBlue, bit.ly	Country team		□ Yes
		# of visits to x webmap/x dashboard	Country request to HQ		□ Yes
IMPACT activities contribute to better program implementation and coordination of the humanitarian response	Number of humanitarian organisations utilizing IMPACT services/products	# references in HPC documents (HNO, SRP, Flash appeals, Cluster/sector strategies)	Country team	Reference_log	DRR Working Group publications
		# references in single agency documents			
Humanitarian stakeholders are using IMPACT products	Humanitarian actors use IMPACT evidence/products as a basis for decision making, aid planning and delivery Number of humanitarian documents (HNO, HRP, cluster/agency strategic plans, etc.) directly informed by IMPACT products	Perceived relevance of IMPACT country-programs	Country team	Usage_Feedback *and* Usage_Survey template	no
		Perceived usefulness and influence of IMPACT outputs			
		Recommendations to strengthen IMPACT programs			
		Perceived capacity of IMPACT staff			
		Perceived quality of outputs/programs			
		Recommendations to strengthen IMPACT programs			
Humanitarian stakeholders are engaged in IMPACT programs throughout the research cycle	Number and/or percentage of humanitarian organizations directly contributing to IMPACT programs *(providing resources, participating to presentations, etc.)*	# of organizations providing resources (i.e. Staff, vehicles, meeting space, budget, etc.) for activity implementation	Country team	Engagement_log	□ Yes
		# of organizations /clusters inputting in research design and joint analysis			**X** Yes
		# of organizations /clusters attending briefings on findings;			**X** Yes