

Open-Source GIS Applications for Flood and Landslide Assessment: Comparative Cases from Poland and Malaysia

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Research Article

Keywords: Geographic Information Systems, Copernicus, QGIS, flood mapping, landslide analysis

Posted Date: September 18th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11067914/v1>

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Additional Declarations: The authors declare no competing interests.

Open-Source GIS Applications for Flood and Landslide Assessment: Comparative Cases from Poland and Malaysia

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Abstract: Research on natural disasters requires analytical procedures that are fast, reproducible, and based on sound scientific principles. They must be accessible to institutions responsible for environmental monitoring, land-use planning, and natural disaster risk reduction. This study evaluated the practical use of publicly available geospatial data and open-source GIS tools. Two contrasting natural hazards were analyzed: the September 2024 flood in Lower Silesia, Poland, with a particular focus on the urban floodplain in Wrocław, and the December 2022 landslide in Batang Kali, Selangor State, Malaysia. The study utilized Copernicus Sentinel-2 MSI Level 2A satellite imagery, DEM data from the Copernicus program, OpenStreetMap vector layers, and spatial processing in QGIS. The methodology employed a pre- and post-event change detection scheme based on spectral indices. The Normalized Difference Water Index (NDWI) was used to map the extent of flooding, while the Normalized Difference Vegetation Index (NDVI) was used to identify vegetation disturbances associated with the landslide. To identify the areas affected by the events and assess their relationships with built-up areas, hydrographic features, and terrain morphology, raster classification, elevation analysis, vector layer overlay, and thematic mapping were used. To identify disaster-affected areas and assess their relationships with built-up areas, hydrographic features, and terrain morphology, raster classification, elevation analysis, vector layer overlay, and thematic mapping were used. The results show that the Copernicus Data Space ecosystem and QGIS software provide a robust, transparent, and cost-effective analytical environment for the preliminary assessment of natural disaster impacts. In the case of Wrocław, the NDWI index helped identify flooded areas and infrastructure potentially at risk. In the case of Batang Kali, the differentiation of the NDVI index helped identify patterns of disturbed vegetation associated with the landslide trace. The study confirms that open-source geospatial tools can support repeatable analysis of natural disasters, educational practices, and early-stage decision support for natural disaster risk reduction.

Keywords: Geographic Information Systems; Copernicus; QGIS; flood mapping; landslide analysis.

1.0 Introduction

Natural disasters increasingly require analytical methods that are clearly grounded in a spatial context and technically reproducible. These methods must be accessible to institutions responsible for mitigating natural disaster risks, environmental monitoring, land-use planning, and emergency response (Smith et al., 2023).

Floods and landslides are among the most destructive natural hazards. They result from complex interactions between atmospheric factors, topography, land cover, hydrological conditions, and human presence in vulnerable areas. Their impacts are rarely limited to the immediate physical extent of the event. Typically, they affect entire infrastructure networks, urban structures, environmental systems, and the ability of local authorities to ensure public safety. Analysis of natural disasters cannot, therefore, be limited to descriptive reporting. It requires the integration of geospatial data, remote sensing, topographic information, and spatial interpretation within a coherent and continuous analytical framework. Risks associated with natural disasters currently stem from both environmental and human-induced factors. Factors such as extreme rainfall, changes in runoff conditions, urban expansion, and changes in land use increase the vulnerability and susceptibility of river valleys, floodplains, slopes, and suburban areas to natural disasters. The United Nations Office for Disaster Risk Reduction emphasizes that the impacts of disasters are becoming increasingly systemic, triggering a domino effect across various sectors and regions (United Nations Office for Disaster Risk Reduction [UNDRR], 2022). In this context, spatial data analysis is not only a technical operation but also a key element of risk management. Data analysis supports the identification of vulnerable areas, the interpretation of hazard mechanisms, and disaster preparedness, based on analysis-driven preventive measures.

Floods are one of the major hydrological hazards in Europe, particularly in low-lying river valleys and densely built-up urban areas. Their occurrence and severity are influenced by rainfall intensity, catchment response, river channel capacity, floodplain morphology, and the distribution of buildings and infrastructure. In Poland, flood risk remains a persistent problem, especially in areas located along major river systems, including the Odra River basin. The September 2024 flood in southwestern Poland, including the Wrocław region, once again demonstrated the importance of rapid spatial assessment in urban flood risk analysis. Phenomena of this kind require the designation of flood zones, the identification of buildings at risk, and an assessment of the relationship between floods and elevation above sea level. Previous studies on flood risk in Europe have emphasized that changing flood regimes and socio-economic vulnerability make spatial data-driven analysis essential for planning measures aimed at risk reduction and adaptation (Kundzewicz, 2012).

Landslides constitute a distinct but equally serious category of natural hazards. The formation of landslides (or mudslides) is influenced by: slope topography, lithological and soil conditions, groundwater and rainfall infiltration, vegetation cover, land-use pressure, and local engineering works.

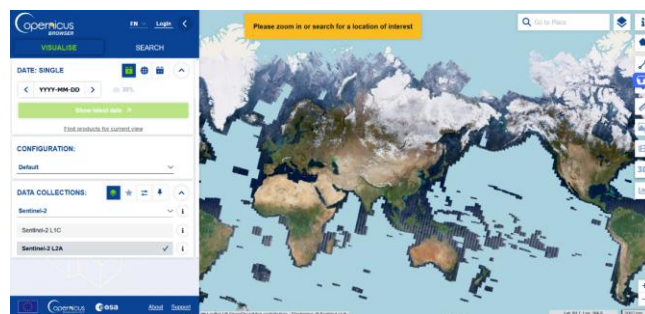
In tropical regions, heavy rainfall is one of the most significant factors triggering landslides, mudslides, debris flows, and rockfalls. The catastrophic landslide in Batang Kali, Selangor, Malaysia, which occurred in December 2022, illustrates the destructive potential of rain-induced landslides in a humid tropical environment. This event resulted in loss of life and underscored the need to develop methods for identifying landslides, interpreting topography, and documenting spatial data before and after the event. Since field access to such sites can be

difficult, dangerous, or delayed, remote sensing and GIS methods provide a robust and valuable foundation for the initial assessment of this phenomenon.

Geographic Information Systems (GIS) are now a key component of analyses and research on natural hazards. They enable the collection, management, processing, analysis, and visualization of spatially related information. GIS allows for the integration of raster and vector datasets: satellite imagery, digital elevation models, hydrographic layers, road networks, buildings, administrative boundaries, and land cover data. This integrative capability of GIS systems is particularly important in disaster analysis, where the phenomenon itself, its environmental determinants, and its consequences for the anthropogenic environment should be interpreted collectively. The scientific foundations of GIS systems emphasize spatial relationships, scale, topology, data quality, and the reproducibility of analysis as key elements of geographic reasoning (Longley et al., 2015).

Satellite remote sensing significantly expands the analytical capabilities of GIS systems by providing repeatable, synoptic, and spatially continuous observations of the Earth's surface. Multispectral images are particularly useful for detecting environmental changes before and after extreme events. The approach based on comparing pre- and post-event conditions belongs to the classic family of digital change-detection methods. Differences between two or more observations taken at different points in time are used to identify changes in land cover, moisture conditions, vegetation structure, or surface exposure (Singh, 1989). In natural disaster research, this approach is well-founded. It allows for the separation of the event signal from the previous landscape state, provided that data quality, cloud cover, seasonality, and the geometry of data acquisition are appropriately accounted for (Figure 1).

Spectral indices are among the most commonly used tools in satellite-based environmental analysis. The Normalized Difference Water Index (NDWI) is widely used to distinguish open water bodies and to aid in the identification of water-covered areas in remote sensing images (McFeeters, 1996). In flood analysis, the NDWI can be used to identify surface water and potential flooded areas. It is particularly effective when combined with threshold classification, terrain interpretation, and vector overlay. The NDVI, originally developed for vegetation monitoring, remains one of the most important indicators of vegetation status and land-cover disturbances (Rouse et al., 1974). In landslide analysis, variations in the NDVI can serve as an indirect indicator of vegetation removal, exposed soil, deposition of landslide material, and disturbances along the landslide path. Interpretations of landslides based on the NDVI should be treated with caution, as changes in vegetation may also result from seasonality, weather conditions, agricultural activities, or other processes unrelated to landslides, particularly in tropical climates.



(1)



(2)

Figure 1: Overview of the Copernicus Browser (1) and QGIS (2) systems. Sources: Copernicus Data Space Ecosystem and QGIS.org (2026a).



(1)



(2)

Figure 2: Relief and rescue operations in flood-stricken Wrocław (Poland, 2024) (1) and at the Batang Kali landslide site (Malaysia, 2022) (2). Photo sources: Global Empowerment Mission Europe (2024) and Malay Mail (2022).

The growing availability of open Earth observation data has transformed the practical aspects of natural disaster analysis. The Copernicus program, and in particular the Sentinel-2 multispectral satellite imagery, serves as a powerful data source for environmental monitoring, land cover analysis, vegetation assessment, and inland water monitoring. The Copernicus Data Space Ecosystem and the Copernicus Browser (Copernicus Data Space Ecosystem) facilitate access to satellite imagery and support the search, visualization, and download of relevant products pertaining to specific areas of interest. This is particularly important for research teams, public institutions, and educational projects that require transparent and cost-effective access to Earth observation data.

At the same time, QGIS (QGIS.org, 2026a) provides a mature, free, and open-source GIS environment for spatial analysis, raster processing, vector layer overlay, map creation, and repeatable geospatial workflows.

The combination of Copernicus data and QGIS thus creates a technically accessible analytical environment for disaster risk research, without the need for commercial GIS software.

Despite the widespread availability of GIS and satellite data, there remains a methodological need to demonstrate and validate how open geospatial processes can be applied to various types of hazards under diverse geographical and environmental conditions. Floods and landslides differ significantly in terms of spatial distribution. Floods generate direct water-related spectral signals and are largely determined by low-lying terrain and hydrographic connections. Landslides, on the other hand, often require indirect interpretation through vegetation disturbances, exposed soil, slope morphology, and landslide propagation patterns determined by topography. Consequently, the same general remote sensing and GIS framework must be adapted to the physical nature of each of these processes.

This analysis addresses this need by presenting a comparative use of publicly available geospatial data and open-source GIS tools. These were applied in two case studies on natural disasters: the September 2024 flood in Lower Silesia, Poland, with a particular focus on the urban context and floodplains of Wrocław (Global Empowerment Mission Europe, 2024), and the December 2022 landslide in Batang Kali, Malaysia (Malay Mail, 2022). The analysis utilized Copernicus Sentinel-2 satellite imagery (e.g., Jensen, 2015), DEM data from the Copernicus program, OpenStreetMap vector data, and spatial processing based on the NDWI index, differentiation of the NDVI index to detect vegetation disturbances associated with the landslide, interpretation of terrain features, and overlaying vector layers with selected infrastructure elements.

2.0 Study Area

The analysis was designed as a comparative geospatial study of two areas affected by natural disasters, representing different hazard mechanisms, climatic conditions, topography, and analytical requirements. The first study area is located in Wrocław, Lower Silesia, Poland, and was selected for analysis of the September 2024 flood along the Odra River. The second study area is located in Batang Kali, Selangor, Malaysia, and was selected to analyze the December 2022 landslide at Father's Organic Farm.

This dual-case-study structure allows for testing the open geospatial workflow under two fundamentally different environmental conditions: on a low-lying urban floodplain in Central Europe and on a tropical, forested slope in Southeast Asia. These two study areas were defined as the primary spatial basis, and the analysis specified the use of open-source satellite data, DEMs, and vector data for both locations.

2.1 Wrocław and Lower Silesia, Poland

The area covered by the flood analysis is located in the city of Wrocław, in the Lower Silesian Voivodeship in southwestern Poland (Fig. 3). Wrocław is situated in the Odra River valley, where the urban structure, floodplains, levees, canals, bridges, transportation infrastructure, and riverside areas form a complex hydrological and anthropogenic system.

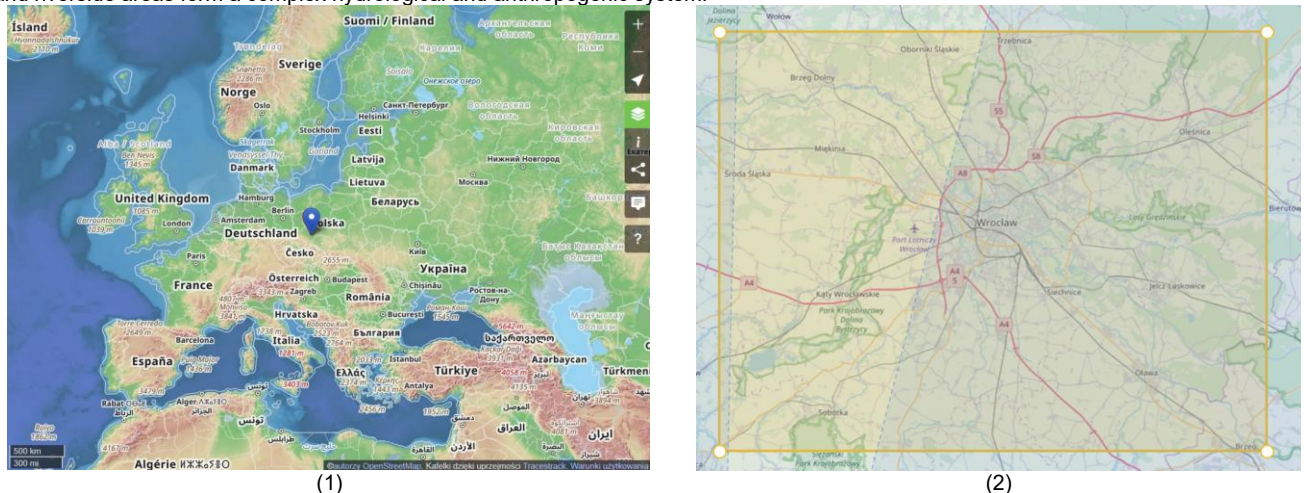


Figure 3: The geographical location of the city of Wrocław (1) and an example study area map (2). Sources: OpenStreetMap contributors and Tomiczek (2026).

For the purposes of a detailed GIS analysis, the area of interest (AOI) was limited to a compact urban-river section of Wrocław, roughly bounded by latitudes from 51.09525° N to 51.11121° N and longitudes from 17.04911° E to 17.06739° E. This area included the main river corridor, adjacent low-lying areas, built-up areas, and infrastructure elements relevant to the assessment of flood exposure. The selected scale was appropriate for creating maps based on Sentinel-2 data, overlaying vector layers in QGIS, and interpreting the effects of flooding on buildings and urban land cover. This area was designated as Lower_Silesia_flood_AOI and characterized as an urban and riverside area analyzed using Sentinel-2 data, DEM, and OpenStreetMap.

From the perspective of physical geography, the study area in Wrocław constitutes a lowland river valley environment, where flood risk depends on: river flow, floodplain morphology, local elevation differences, hydraulic connections, and the degree of urbanization. The relatively flat terrain favors the accumulation of water in depressions and riparian zones, and dense urbanization increases the potential impacts of even spatially limited flooding. Elevation values in the area of interest (AOI) range approximately from 113.5 m to 150 m above sea level. Areas below approximately 120 m above sea level were interpreted as particularly prone to flooding in the adopted DEM-based procedure.

The flood in September 2024 in southwestern Poland posed a serious hydrological threat to Wrocław and other parts of Lower Silesia. In response to the flood situation, the Polish government declared a state of natural disaster in parts of the Lower Silesian, Opole, and Silesian provinces. Reports at the time indicated that in the second half of September 2024, Wrocław was hit by a massive flood wave on the Oder River (Office of the Prime Minister, 2024). In the case of Wrocław, the study area was not selected as an abstract test site, but as a real urban environment at risk of flooding. The extent of the flooding, the low-lying terrain, the distribution of buildings, and the proximity of watercourses were spatially interrelated. This area was suitable for testing water detection based on the NDWI index, interpreting elevation data using a DEM model, and overlaying vector data from OpenStreetMap regarding buildings.

The study area map covered the area of interest (AOI) in Wrocław, including the Odra River, urbanized areas, major watercourses, and selected reference infrastructure. The map included: a coordinate grid, a north arrow, a scale, a legend, and a clearly defined border around the area of interest (AOI). The coordinate reference system (CRS) used was WGS 84 for geographic presentation and a projected coordinate reference system (CRS) for area calculations in the metric system.

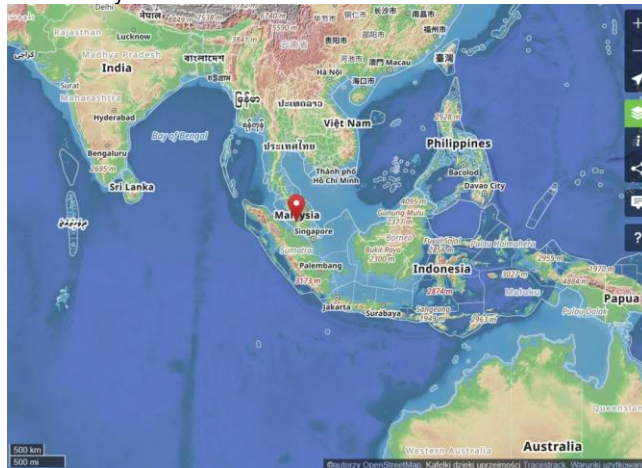
2.2 Batang Kali, Selangor, Malaysia

The landslide study area is located along the Jalan Batang Kali–Genting Highlands road in the Hulu Selangor region of Malaysia (Figure 4), between the towns of Batang Kali and Gohtong Jaya, on the grounds of the Father's Organic Farm campground. This site is located approximately 50 km north of Kuala Lumpur and is part of a tropical environment on the edge of a plateau. It is characterized by steep slopes, dense vegetation, heavy rainfall, and high geomorphological sensitivity to slope–water interactions. The Batang Kali area was identified as a steep, forested slope affected by a mass landslide that transformed into a mudslide and impacted built-up and agricultural areas located in the lower reaches of the river.

The Batang Kali disaster occurred on December 16, 2022. An official report published on a website dedicated to commemorating the victims and documenting the events in Batang Kali states that the landslide affected 92 people, 61 of whom were rescued, while 31 lost their lives. This accident was primarily caused by a natural phenomenon, which may have been influenced by rainfall and geological factors. A report by the Associated Press on the declassified government investigation also stated that the landslide caused the deaths of 31 people, including 13 children. Prolonged heavy rains recorded in the days leading up to the disaster were also cited as the main cause (Associated Press, 2023). These facts make the Batang Kali landslide an event with serious consequences, not only as a geomorphological phenomenon but also as a case of disaster risk. It has a direct impact on land-use planning, slope management, tourist safety, and emergency preparedness, particularly in tropical regions.

From a geomorphological perspective, the Batang Kali area differs significantly from the floodplain in Wrocław. It is a system of slopes where the occurrence of hazards is influenced by:

- slope gradient,
- properties of regolith and soil,
- groundwater conditions,
- disturbance of the vegetation cover,
- dynamics of soil flow.



(1)



(2)

Figure 4: The geographical location of Batang Kali (1) and an example study area map (2). Sources: OpenStreetMap contributors.

The source materials describe the landslide as a sequence of events comprising an initial slide, a temporary accumulation of landslide material, and a subsequent debris flow phase that affected the lower sectors of the campsite.

The estimated volume of displaced material was approximately 450,000 m³. The landslide area was determined based on the interpretation of geospatial data. These conditions are suitable for detecting vegetation disturbance based on the NDVI index, interpreting slope morphology using a DEM model, and spatially delineating the initiation, transport, and deposition zones of the landslide.

Tropical environmental conditions had direct methodological implications. Frequent cloud cover, rapid vegetation regrowth, high humidity, and complex terrain can limit the interpretability of optical satellite imagery. These limitations are particularly significant in the case of post-event analysis based on Sentinel-2 satellite imagery.

Under such conditions, loss of vegetation cover can be detected by differentiating the NDVI index. Landslide boundaries should be interpreted in conjunction with terrain morphology, visible signs of exposed soil, field or report-based knowledge, and additional spatial data. This is one of the reasons why the Batang Kali case is of cognitive value. It demonstrates both the usefulness and the limitations of open-source optical remote sensing in the assessment of tropical landslides.

The maps of the study area for Batang Kali included the area of interest (AOI) around Father's Organic Farm, the approximate source area, the sediment transport route, the deposition zone, the nearby road corridor, and the local topographic context. When the maps were

prepared, each included a coordinate grid, a north arrow, a scale bar, a legend, and a clear distinction between the interpreted landslide-affected area and the surrounding forested terrain.

2.3 General Qualitative Comparison of Research Areas

Taken as a whole, the two study areas provided a deliberately contrasting basis for methodological comparison. Wrocław represented a lowland, urban environment vulnerable to river flooding. The main subject of spectral analysis was surface water, and the primary analytical indicator was the NDWI.

Batang Kali was a tropical environment on a hillside, where the main visible signs following the event were damage to vegetation and exposed soil. As a result, differentiating the NDVI index proved more appropriate than directly mapping water indices. The contrast between these cases confirmed the main objective of the analyses: to assess whether publicly available data from the Copernicus program and QGIS-based processes can provide a reproducible, scientifically interpretable basis for the preliminary assessment of natural disaster impacts, taking into account various types of hazards and geographic conditions.

3.0 Materials and Methodology

3.1 Materials

The analysis utilized an integrated set of publicly available geospatial data, including satellite imagery, elevation models, and vector data. This enabled a comprehensive analysis of two different types of natural disasters. The analysis was conducted for two study areas: the Lower Silesia region in Poland (the 2024 flood) and Batang Kali in Malaysia (the 2022 landslide), whose locations were presented in the previous chapter of the article.

The main data source was satellite imagery from the Copernicus program, specifically Sentinel-2 data (MSI, processing level 2A). These data provide high spatial resolution and access to detailed information about the Earth's surface. They were selected due to their wide availability, regular updates, and high utility in analyzing environmental changes. The study utilized images taken before and after the event, which enabled a differential analysis and the identification of environmental changes (for an example of the toolset, see Table 1).

In the case of the flood in Wrocław, the Sentinel-2 image taken before the event was captured on August 24, 2024, and the image taken during the event was captured on September 18, 2024. In the case of the landslide in Batang Kali, the main pre-event Sentinel-2 image used in the design process was captured on July 7, 2022, and the post-event image was captured on March 9, 2023. The image from December 22, 2010, was treated solely as a historical reference point, which proved useful for contextual interpretation.

Based on data from the Sentinel-2 satellite, the spectral indices NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) were calculated. The NDVI index was used to assess vegetation condition and identify areas where degradation has occurred. The NDWI index was used to detect water bodies and determine the extent of flooding in the event of a flood. The use of these indices enables effective differentiation of land cover types and analysis of changes resulting from extreme events.

Table 1: Datasets and analytical tools used in the study

No.	Material or tool	Source	Spatial role in the study	Main application
1.	Sentinel-2 MSI Level-2A imagery	Copernicus Data Space Ecosystem	Multispectral raster data	NDWI, NDVI, pre-event and post-event change detection
2.	Copernicus DEM	Copernicus Data Space Ecosystem	Elevation raster data	Terrain elevation, slope context, geomorphological interpretation
3.	Building, road, and hydrographic vectors	OpenStreetMap contributors	Vector exposure data	Overlay with hazard masks and infrastructure interpretation
4.	QGIS 3.40	QGIS.org (2026a)	GIS analytical environment	Raster processing, vector analysis, classification, cartography
5.	Google Earth Engine	Gorelick et al. (2017)	Cloud geospatial processing environment	Satellite data screening, index calculation, workflow verification

Table 2: Characteristics of the analyzed study areas

No.	Study area	Location	Type of disaster	Year of event	Main analytical methods
1	Wrocław / Lower Silesia	Poland (Central Poland)	Flood	2024	NDWI, GIS spatial analysis, elevation analysis
2	Batang Kali / Selangor	Malaysia (Southeast Asia)	Landslide	2022	NDVI, pre-event/post-event difference analysis, GIS surface analysis

To account for topographic conditions, the Copernicus DEM elevation model was used, which enables the analysis of terrain elevation and slope. This data is particularly important in the context of identifying areas prone to flooding and mass movement processes. In the case of flooding, the DEM model allowed for the identification of low-lying areas, while in the landslide analysis, it enabled the identification of steep-sloped areas, which are more prone to destabilization.

An additional source of information was vector data obtained from the OpenStreetMap database, covering infrastructure elements such as buildings and road networks. This data was used to assess the impact of the analyzed phenomena on the anthropogenic environment, in particular to identify objects located in hazard zones. The integration of vector data with the results of remote sensing analysis enabled a more detailed spatial analysis and an assessment of potential losses.

Data processing and spatial analysis were conducted using two main analytical platforms. Google Earth Engine (GEE) (Gorelick et al., 2017) was used to process large satellite datasets and calculate spectral indices, while QGIS (version 3.40) was used to visualize results, conduct spatial analyses, and create thematic maps. The use of open-source tools made it possible to carry out the entire process in a straightforward, repeatable, and reproducible manner for use in other studies.

To clearly define the location of the analyzed study areas and ensure their spatial traceability, the geographic characteristics of the selected study areas are summarized in Table 2. This traceability ensured the precise location of the study areas and may facilitate future comparisons with other analyses conducted under similar environmental conditions.

3.2 Methodology / Framework / Theory

The methodology used in the analysis combines observational data obtained from satellite platforms with spatial analyses to provide a comprehensive assessment of the impacts of selected natural disasters. This approach is universal and repeatable, allowing it to be applied to the analysis of various types of environmental hazards, regardless of their specific characteristics and geographic location.

The research process has been divided into several basic stages, including:

1. Data acquisition.
2. Preprocessing.
3. Calculation of spectral indices.
4. Analysis of changes over time.
5. Classification of at-risk areas.
6. Spatial analysis.
7. Visualization of results.

The methodological framework was developed as a structured process for detecting geospatial changes before and after an event. This approach is widely used in remote sensing because it allows for the identification of spatial changes by comparing images acquired before and after a given event (Singh, 1989). In this analysis, this process was adapted to two different mechanisms of natural disaster formation. The flood (Wrocław, Lower Silesia, 2024) was treated as a problem of direct water detection, in which the spectral signature of surface water constitutes the primary diagnostic feature. A landslide (Batang Kali, 2022) was treated as a problem of indirect disturbance detection, in which vegetation loss, exposed soil, and terrain topography serve as the main indicators of mass movement.

(1) The first methodological step was to define the area of interest (AOI) and perform spatial standardization. In both cases, the AOI was digitized or imported as a polygon layer and then verified using satellite imagery and reference base maps. The AOI in Wrocław covered the urban-river area along the Oder River, while the AOI in Batang Kali covered the landslide initiation zone, its path of movement, and the deposition area near Father's Organic Farm.

All datasets were first checked in the WGS 84 geographic coordinate system. To calculate the metric area and overlay spatial layers, they were transformed into the appropriate projected coordinate reference systems.

This step was essential. Incorrect handling of coordinate reference systems can generate false spatial offsets between raster and vector layers, particularly when integrating satellite data, DEM data, and OpenStreetMap features.

(2) The second stage involved the selection and preprocessing of satellite data. Level 2A Sentinel-2 images were selected based on acquisition date, coverage of the area of interest (AOI), cloud cover, and suitability for visual interpretation. The spectral bands were imported into QGIS and cropped to the AOI. The raster layers were checked for cell size, extent, alignment, and NoData values.

When necessary, the rasters were resampled to a common 10-meter grid before calculating the indices. Pixels obscured by clouds were interpreted with caution. Areas with visible clouds or shadows were initially excluded from quantitative interpretation if this could affect the result. This was particularly important in the case of tropical Batang Kali, where persistent cloud cover posed a serious limitation for optical remote sensing.

(3) The third step was to calculate the spectral index. The NDVI index was calculated as follows (Formula 1):

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

For the Sentinel-2 satellite, the NIR band corresponds to channel B08, and the red band to channel B04. The NDVI index was used primarily to analyze the landslide in Batang Kali and, to a lesser extent, to determine the land cover context in the analysis of the flood in Wrocław.

High NDVI values indicate dense and healthy vegetation, while low or significantly reduced values may indicate exposed soil, disturbed vegetation, built-up areas, water, or debris.

The concept of the NDVI index stems from early research on vegetation remote sensing and remains a fundamental indicator for assessing vegetation condition (Rouse et al., 1974).

The NDWI index was calculated according to McFeeters (1996) as follows (Formula 2):

$$NDWI = \frac{Green - NIR}{Green + NIR} \quad (2)$$

For the Sentinel-2 satellite, the green band corresponds to channel B03, and the NIR band corresponds to channel B08.

The NDWI index was used as the primary indicator for creating flood maps in Wrocław because it highlights open water features while minimizing the influence of vegetation and dry soil.

This approach is based on the theoretical foundations proposed by McFeeters (1996), who introduced the NDWI index to identify areas of open water in remote-sensing images. In this analysis, the NDWI index was calculated separately for images taken before the event and for those taken during the event.

(4) The fourth stage involved temporal differentiation and the determination of index thresholds. As part of the flood analysis, raster maps of the NDWI index from before and during the event were compared to identify areas where the water signal intensity had increased.

A binary water mask was created using an NDWI threshold of 0.05. This threshold was calibrated through visual comparison with Sentinel-2 images in true color and false color, a mapped hydrographic network, low-lying areas identified based on a DEM, and expert analysis in QGIS. Since no independent field validation data were available, the flood mask was treated as a preliminary result at the initial selection stage, rather than as a final, official inventory of flooded areas.

Pixels with NDWI values equal to or greater than 0.05 were classified as water or potential flooding, while pixels below this value were classified as non-water.

Permanent water bodies were identified based on a pre-event water mask, while newly detected water bodies or increased moisture were assessed using a mask from the event period and a differential NDWI layer. The purpose of this procedure was to distinguish between water spread caused by flooding and pre-existing river channels and permanent water bodies.

For the landslide analysis, the main diagnostic grid was the NDVI difference layer (Formula 3):

$$\Delta NDVI = NDVI_{post} - NDVI_{pre} \quad (3)$$

Negative $\Delta NDVI$ values were interpreted as potential vegetation loss or land cover disturbance. For the final mask of landslide-induced disturbances, a conservative threshold of $\Delta NDVI \leq -0.20$ was applied. It was then visually verified based on a post-event Sentinel-2 image, terrain morphology, elevation above sea level, visible patterns of exposed soil, and the known location of the Batang Kali landslide. This interpretation was not based solely on the NDVI index, as tropical vegetation can regenerate quickly, and a decrease in NDVI values may also result from cloud cover, seasonal changes, agricultural activity, or other changes in land cover unrelated to landslides.

(5) The fifth stage involved refining the results after classification.

Binary raster masks were cleaned up to reduce the number of isolated pixels and minor artifacts. Noise reduction was performed through raster filtering, the application of the minimum mapping unit logic, and visual inspection.

The cleaned raster masks were then converted into vector polygons, as area calculations and layer overlap analysis required vector geometry.

The polygon boundaries were verified against the original Sentinel-2 images, terrain features derived from the DEM, and contextual layers. This verification step was necessary to avoid misinterpretation of mixed pixels, cloud-covered areas, urban shadows, and spectrally ambiguous surfaces.

(6) The sixth step involved integrating the hazard maps with data on topography and infrastructure.

For the city of Wrocław, building outlines, roads, and hydrographic features from OpenStreetMap were overlaid onto the classified flood map. This made it possible to identify buildings located within or near a potential flood zone and to interpret the spatial relationships between the occurrence of flooding, proximity to the river, and low-lying terrain.

For Batang Kali, the mask of disturbed vegetation was interpreted together with information on terrain slope and elevation above sea level to distinguish the source zone, transport corridor, and sedimentation area. The interpreted extent of the landslide was compared with available visual documentation of the landslide.

(7) The final methodological step involved preparing maps and documenting the results.

The final maps were created in QGIS and included:

- the boundaries of the area of interest (AOI),
- classified hazard zones,
- an appropriate base map (or satellite layers),
- scale,
- a north arrow,
- coordinate information,
- a legend,
- information on data sources.

The maps were designed not only as illustrations but also as visual analytical products.

The proposed workflow is presented conceptually in Figure 5.

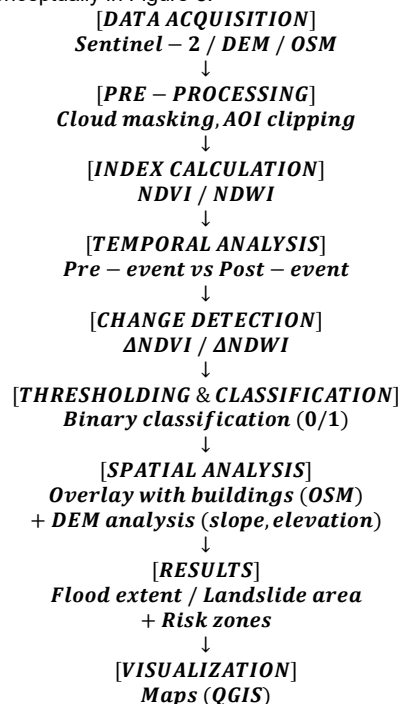


Figure 5: General methodological framework used for both case studies. The workflow includes data acquisition from Copernicus and OpenStreetMap, preprocessing in QGIS or Google Earth Engine, spectral index calculation, pre-event/post-event change detection, binary classification, DEM-supported interpretation, vector overlay, map preparation, and final spatial interpretation.

The adopted methodology should be regarded as a geospatial assessment rather than a substitute for hydrodynamic modeling, geotechnical slope stability analysis, or detailed field surveys.

Its main advantage lies in the rapid, transparent, and repeatable identification of areas affected by natural disasters using publicly available data and tools.

This is particularly important in the context of education, preliminary planning, and early disaster risk reduction, especially where access to commercial software or proprietary high-resolution data is limited.

It should be emphasized that the methodology used was developed based on project materials produced by students under the supervision of their academic advisors, as well as our own analyses, and constitutes a coherent, comprehensive approach to the use of geospatial data in research on natural hazards.

4.0 Results

4.1 Flood Mapping Results for the Wrocław Study Area

The flood analysis for the study area in Wrocław provided a spatial representation of areas covered by water and areas potentially at risk of flooding within the selected urban-river study area. The use of MSI imagery from the Sentinel-2 satellite in the Level 2A standard made it possible to compare the surface conditions before and during the event. The workflow in QGIS allowed for the integration of spectral analysis

results with elevation data and vector data on infrastructure. The main result of this part of the study was the generation of a binary water and flood mask based on the Normalized Difference Water Index (NDWI). The calculations were performed using the green and near-infrared bands of the Sentinel-2 satellite (Figure 6).

The NDWI raster for the study period showed a clear concentration of positive values associated with water along the Odra River corridor and in selected adjacent lowland areas. A binary classification based on an NDWI threshold of 0.05 separated pixels interpreted as water bodies or water-influenced areas from non-water land cover classes. The resulting mask reflected the main hydrographic structure of the area of interest (AOI) and identified localized zones. The spectral response was consistent with surface water or flood-related moisture. The most distinct water signatures occurred in the immediate vicinity of the river channel, secondary water bodies, and low-lying parts of the floodplain. Even in a relatively small and urbanized AOI, Sentinel-2 data support the detection of spatial patterns associated with flooding, particularly when interpreted in conjunction with topography and land-use context.

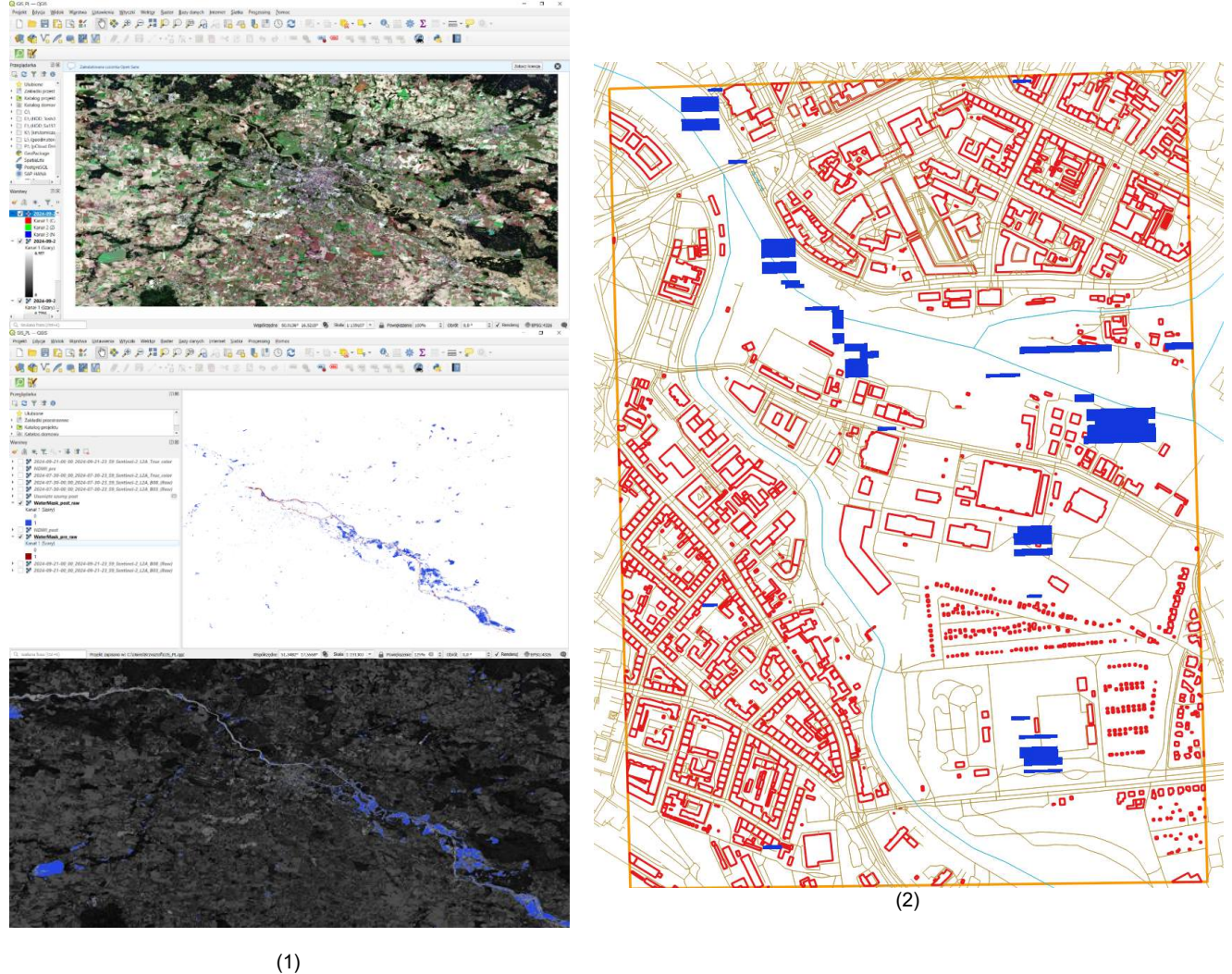


Figure 6: Location of the study area in Wrocław / Lower Silesia, Poland, used for flood analysis (1) and identification of potentially flood-exposed buildings (2). Sentinel-2/OpenStreetMap/QGIS workflow.

A photograph taken before the event, on August 24, 2024, served as a reference point for distinguishing permanent bodies of water from areas where an increased water signal was recorded during the flood. In the image from the time of the event, taken on September 18, 2024, increased cloud cover was visible, which limited full spectral reliability in some parts of the area of interest (AOI). The image retained sufficient useful information for preliminary mapping of water-covered areas following spatial cropping, visual quality control, and interpretation in QGIS. The difference between pre-event and event-period NDWI values indicated an increase in surface moisture in selected parts of the floodplain and riparian zones. These areas were interpreted as hydrologically likely flood-affected areas, as their location corresponded to the river corridor and low absolute elevation.

An analysis of terrain elevation based on the Copernicus DEM served as an independent geomorphological verification of the NDWI classification. Elevations in the study area ranged from approximately 113.5 m to 150 m above sea level. The lowest terrain features were concentrated near river sections and floodplains within the study area. Areas located below approximately 120 m above sea level showed the greatest susceptibility to water accumulation. Overlaying the mask derived from the NDWI index onto the DEM data revealed that the identified pixels affected by the presence of water were not randomly distributed. The previously reported value of approximately 70 km² was not included because it referred to an earlier, larger area of interest (AOI) of an exploratory nature and was inconsistent with the compact, coordinate-defined area of interest in Wrocław used in this article. Consequently, the final interpretation presents the localized water-affected areas within the local area of interest (AOI).

The analysis also demonstrated the importance of combining raster classifications with vector data on exposure. Building outlines from OpenStreetMap were cropped to the area of interest (AOI) and overlaid on the water and flood mask. A total of 1,388 buildings were identified in the study area. The highest level of vulnerability was observed in zones located directly along the river corridor and in selected parts of the central, northern, eastern, and southeastern areas of interest (AOI), where residential, industrial, and warehouse buildings are situated near low-lying areas. This analysis should not be interpreted as a definitive list of building damage. It represents a spatial selection of buildings located within or near identified flood-affected zones and indicates areas where more detailed verification, field inspections, or higher-resolution data would be necessary.

The distribution of buildings potentially at risk of flooding confirmed that flood impact assessments cannot be limited solely to delineating the boundaries of the floodplain.

In an urban environment, the value of a flood map depends on how it relates to built-up areas, transportation corridors, land use, and local topography.

The case of Wrocław demonstrated that a relatively simple process based on the NDWI index, combined with DEM and OpenStreetMap layers, can produce a useful first-order vulnerability map. The most important result was therefore not only the identification of water pixels, but also demonstrating how open-source tools like Copernicus and QGIS can combine flood detection with urban vulnerability assessment.

4.2 Landslide Mapping Results for the Batang Kali Study Area

The analysis of the Batang Kali area enabled a spatial interpretation of the zone affected by the landslide. It was based primarily on variations in the NDVI index, an analysis of the terrain, and a comparison with the known location of the disaster site at Father's Organic Farm. Unlike the case of the flood in Wrocław, where the phenomenon depicted on the map was directly visible due to the presence of surface water, the landslide case required indirect interpretation. The main remote sensing indicator was the decline in vegetation vitality and continuity following the slope failure, expressed by negative values in the differential NDVI layer.

The NDVI comparison revealed a distinct zone of vegetation disturbance along the interpreted, clearly visible landslide corridor. This zone contrasted with the surrounding forested area, which retained higher NDVI values and exhibited relatively stable, mature vegetation cover. The negative NDVI anomaly spatially corresponded to the transition from dense vegetation to exposed soil, ground, and disturbed substrate. The visual pattern corresponded to the expected spectral response of a soil runoff path or landslide in a tropical forested environment. Under such conditions, a landslide removes or buries vegetation and exposes mineral soil material at the surface.

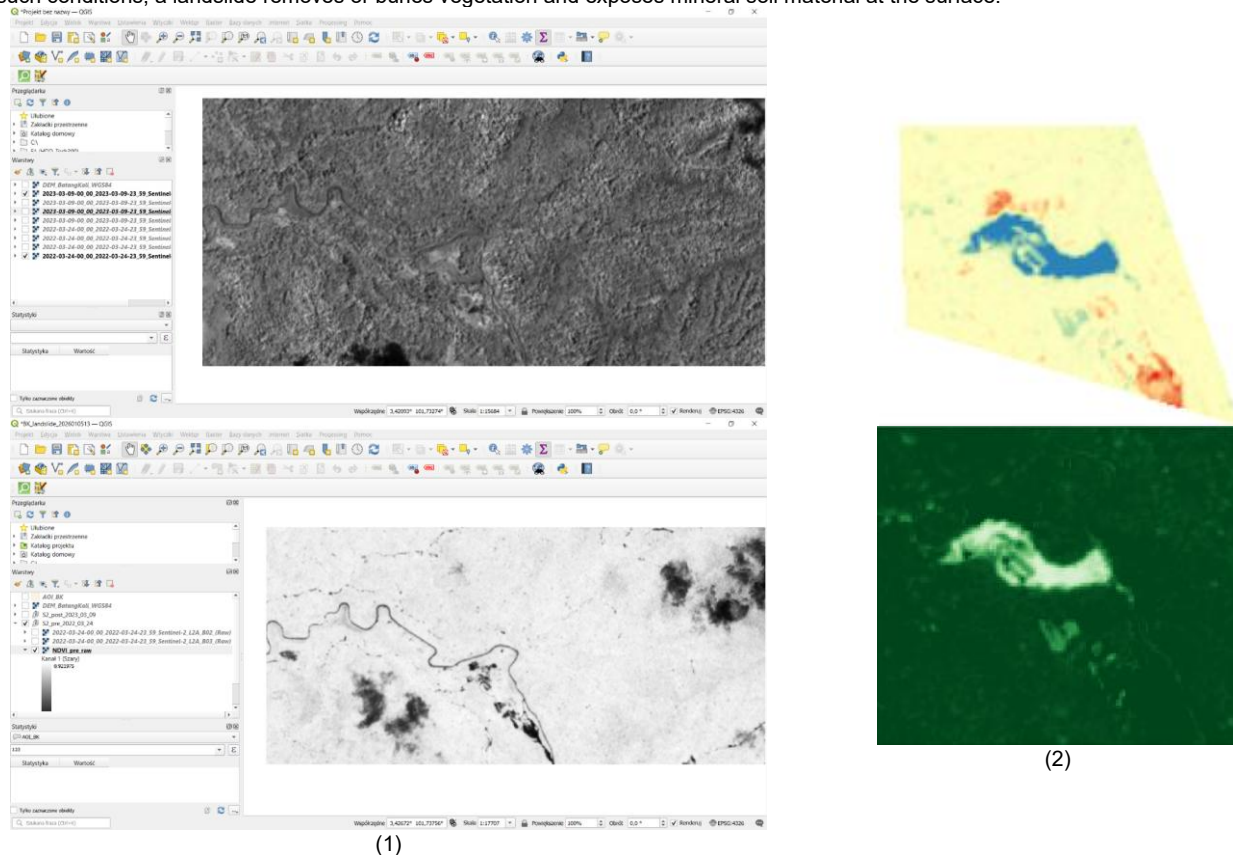


Figure 7: Location of the Batang Kali-Selangor study area used for landslide analysis (1) and an example of the landslide disturbance mask generated from Δ NDVI threshold classification (2).

The area of the landslide, estimated based on an analysis of Sentinel-2 data, was approximately 1.24 km². This estimate was obtained by comparing the pre-event reference image, taken on July 7, 2022, with the post-event image, taken on March 9, 2023, using a conservative Δ NDVI threshold of ≤ -0.20 for the disturbed vegetation class. This value should be treated as an estimate based on the disturbed surface areas visible in selected post-event images, rather than as a definitive value derived from engineering measurements. In tropical conditions, the result depends on the date the image was taken, cloud cover, vegetation regrowth, spatial resolution, and the threshold used to distinguish disturbed areas from undisturbed areas.

In tropical environments, vegetation regrowth can occur rapidly, which may limit the detectability of the original landslide boundary in images taken several weeks or months after the event. For this reason, the mapped landslide area is best interpreted as a (cautious) geospatial estimate of visible disturbances within the selected area of interest (AOI).

An analysis based on DEM data showed that the landslide occurred on steep, forested terrain, where elevation differences and slope geometry determined the path of the landslide material. The available data indicate a change in elevation from approximately 150 m at the upper part of the slope affected by the landslide to approximately 113.5 m in the lower zone where the material accumulated. The spatial distribution of the NDVI anomaly followed the expected direction down the slope, from the initiation area toward the zone where the landslide material deposited (Figure 7). This confirmed that the pattern of vegetation changes was not an isolated spectral artifact but corresponded to the movement of landslide material determined by the topography.

The landslide mechanism, interpreted based on geospatial data and available documentation, was consistent with a sequence of gradual failure. Failure in the upper part of the slope initiated the movement of the main landslide mass, which subsequently transformed into a larger debris flow, reaching the lower parts of the campsite. The estimated total volume of displaced material was approximately 450,000 m³, and the initial volume of the landslide was estimated at approximately 47,000 m³. These values indicate that the final scale of the event was strongly influenced by phenomena such as entrainment, sediment accumulation, and secondary flow transformation. From a GIS analysis perspective, the final extent of the landslide encompassed not only the initial area but also the transport and deposition zones.

Although the NDWI layer played a secondary role in the Batang Kali analysis, it provided additional information about water-saturated or moisture-affected areas within the landslide corridor.

An NDWI threshold value of 0.05 was applied in accordance with the flood analysis procedure; however, its interpretation differed in the case of landslides. The NDWI was not used to map flooding as the primary hazard. Instead, it helped identify moisture-related features that may be associated with saturated soils, local drainage, or water-affected ground surfaces. This interpretation remains cautious, as optical indices do not determine pore water pressure, subsurface saturation, or geotechnical strength parameters (Bandira et al., 2024).

The results from Batang Kali showed that publicly available satellite imagery and QGIS software can help identify landslide-affected areas in forested regions after an event occurs. At the same time, they indicated that landslide mapping is inherently more interpretive in nature than flood mapping. The method of differentiating the NDVI index allows for the identification of external manifestations of the event, primarily vegetation loss and exposed soil. However, it does not allow for the direct measurement of landslide depth or any geotechnical aspects, such as the geometry of the internal slip surface, soil properties, rainfall infiltration, and stability conditions. Therefore, the final interpretation of a landslide should ultimately be treated (only) as the result of geospatial analysis. For geotechnical analysis purposes, the ultimate goal would be to obtain field verification using high-resolution imagery, engineering-geological data, and precipitation data.

4.3 Comparative Results of the Two Case Studies

A comparative analysis showed that the same workflow using an open-data GIS system can be applied to various natural hazards, provided that the interpretation is adapted to the mechanisms of each of these processes. In Wrocław, the NDWI proved to be the most effective indicator, as the analysis focused on surface water. In Batang Kali, the difference in NDVI values proved to be more reliable, as vegetation and land-cover disturbances caused by the landslide rather than the water itself were the key indicators.

Both cases also differed in terms of the role of topography in the analysis. In Wrocław, elevation above sea level determined flood susceptibility and helped identify low-lying areas near the river corridor. In Batang Kali, the terrain morphology determined the initiation of the landslide, its movement down the slope, and its deposition. These differences confirm that information from the DEM is essential for both types of hazards, although its analytical significance depends on the mechanics of the specific process.

The comparison also showed that QGIS plays a key role in transforming remote sensing results into interpretable geospatial products. The Copernicus system provided the primary satellite and elevation data, while QGIS enabled raster cropping, index calculation, binary classification, vector layer overlay, area calculation, and final cartographic preparation. As a result, the workflow remained transparent and repeatable, while avoiding dependence on commercial GIS software. This is significant for education in disaster risk reduction and preliminary hazard assessment, especially where commercial tools are unavailable or their purchase is not cost-effective.

The quality of the results was limited by the constraints of optical satellite imagery. In Wrocław, cloud cover during the event period reduced the reliability of interpretation in some parts of the area of interest (AOI). In Batang Kali, tropical cloud cover, regrowing vegetation, and complex terrain increased the uncertainty in delineating landslide boundaries. These limitations do not undermine the validity of the process; they merely define its appropriate scope of application. This method is suitable for preliminary mapping, comparative analysis, educational training, and early spatial interpretation. It should not be used as a substitute for hydrodynamic modeling, detailed geotechnical studies, or official damage assessments.

5.0 Discussion

The results confirm that publicly available satellite data and open-source GIS software can provide a scientifically sound basis for the preliminary assessment of the impacts of natural disasters. The two case studies differ in terms of hazard mechanisms, environmental conditions, spectral characteristics, and interpretation logic. Both examples demonstrate that a properly organized process based on Copernicus Sentinel-2 satellite imagery, digital elevation model (DEM) data, OpenStreetMap vector data, and processing in QGIS can aid in identifying disaster-affected areas and determining their relationships with topography and infrastructure. This result is of great significance in the context of natural disaster risk reduction, where rapid, repeatable, and cost-effective spatial information is often needed, especially before detailed field survey results or specialized engineering analyses are available.

The case of the flood in Wrocław confirms the high practical value of NDWI-based mapping in identifying surface waters and areas potentially at risk of flooding. The theoretical basis for this result is consistent with the work of McFeeters (1996), who demonstrated that the NDWI index highlights open water features by contrasting the reflection of green and near-infrared light. In this analysis, the water mask generated based on the NDWI index reflected the main hydrographic structure of the area of interest (AOI) and enabled the identification of additional water-covered areas near the Odra River corridor. This confirmed that the analysis of spectral indices is useful not only for regional flood mapping but also for small urban-river areas, provided that the results are interpreted in conjunction with local topography, pre-event conditions, and land-use patterns.

At the same time, the results from Wrocław showed that creating flood maps in urban areas is more complex than simply extracting water features from satellite images. Built-up areas, shadows, narrow canals, wet roofs, roads, and mixed pixels can generate ambiguous spectral responses. Therefore, the NDWI index should not be interpreted mechanically. In the area of interest (AOI) under analysis, combining NDWI classification with the Copernicus Digital Elevation Model (DEM) and land cover data from OpenStreetMap significantly improved the interpretation of the results. The digital elevation model (DEM) helped verify whether the detected water-related pixels were located in low-lying areas, while the vector land cover data transformed the flood mask into a spatial product focused on vulnerability. The scientific value of flood mapping therefore depends not only on the spectral index itself, but also on the quality of the spatial integration performed in the GIS.

The landslide in Batang Kali required a different interpretive approach. This phenomenon was not represented by a direct spectral target, such as open water, but by indirect signs of mass movement on the ground surface. The main diagnostic indicator was a decrease in the NDVI index associated with the removal of vegetation, soil exposure, sediment deposition, and disturbance of the slope surface. This interpretation is consistent with the well-established use of the NDVI as an indicator of vegetation condition and surface disturbance in vegetation monitoring studies (Rouse et al., 1974). In forested tropical areas, a marked decrease in the NDVI index following a landslide can serve as an effective preliminary indicator for detection, particularly where access to the terrain is limited or hazardous.

Detecting landslides using the NDVI index requires greater caution than detecting floods using the NDWI index. A decrease in the NDVI value may reflect vegetation loss associated with a landslide, but it may also result from many other factors, such as cloud shadows, image acquisition conditions, seasonal vegetation variability, agricultural clearing, deforestation, or rapid post-event vegetation regrowth. This is particularly important in tropical countries, including Malaysia, where persistent cloud cover and rapid vegetation regrowth can obscure the original boundaries of the landslide. Therefore, interpretations such as those for Batang Kali cannot ultimately rely solely on a differential raster. They must combine NDVI anomalies with geotechnical and geomorphological reasoning, terrain context derived from the DEM, the known location of the event, the slope direction, and available documentation of the landslide mechanism. This confirms a broader methodological principle: spectral indices are not definitive interpretations, but diagnostic layers requiring process-based analysis.

Comparative results confirm the classic assumption in remote sensing that change detection is most reliable when the observed spectral change is physically linked to the process under study (Singh, 1989). In the case of floods, the relationship between the presence of water and the response of the NDWI index is direct. In the case of landslides, this relationship involves the displacement of the slope and a decrease in the NDVI index value. This index detects the impact of a landslide on land cover, rather than the landslide itself or the mechanical phenomenon. This distinction explains why flood mapping yielded a more unambiguous binary classification, while landslide mapping required greater expert interpretation.

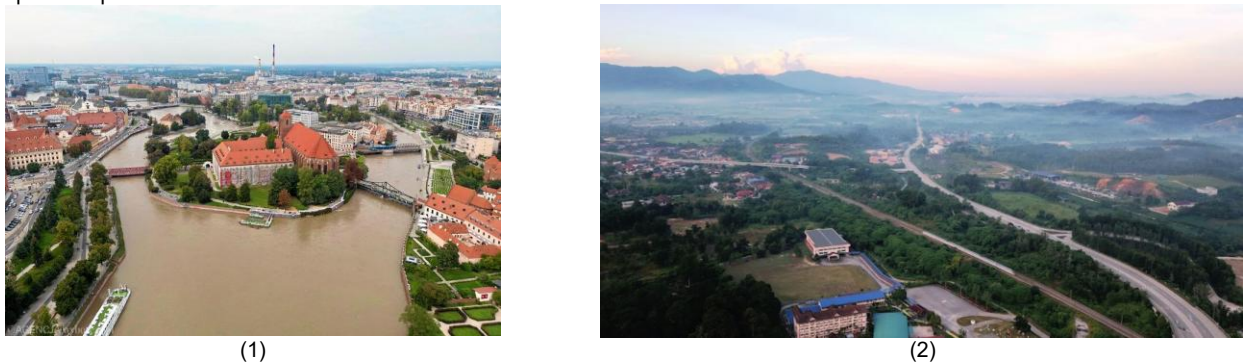


Figure 8: General views of areas affected by natural disasters: the city of Wrocław and the Batang Kali region. Photo sources: TOK FM/PAP (2024; permission required for publication) and Zackhaikaltarmizi (2022; CC BY-SA 4.0).

A universal GIS workflow should not be confused with a universal classification rule. The workflow may be general, but the choice of indicator, threshold-setting strategy, and validation logic must be tailored to the hazard process.

DEM data played a key role in both case studies, although their significance varied from case to case.

In Wrocław, terrain elevation determined the likelihood of flooding and helped identify low-lying areas prone to water accumulation. In Batang Kali, terrain morphology influenced slope instability, downslope sediment transport, and debris accumulation. This demonstrates that elevation and slope gradient layers should be treated as fundamental interpretive data in disaster analysis, rather than merely as supplementary information. In flood studies, DEM data support the assessment of hydrological probability. In landslide studies, DEMs provide a geomorphological framework for interpreting initiation, transport, and deposition zones. The integration of terrain data with spectral indices is therefore one of the strongest elements of this analysis.

The analysis also demonstrated the operational value of QGIS as a central analytical environment. QGIS enabled the harmonization of coordinate reference systems, raster clipping, calculation of indicators, binary classification, conversion of rasters to vectors, overlaying of spatial layers, area calculation, and preparation of a cartographic layout. This functionality is crucial because disaster analysis requires not only calculations based on remote sensing data but also spatial inference using multiple layers. QGIS also supports the reproducibility of results, as the analytical process can be documented, repeated, modified, and applied to other research areas. There are also no financial barriers associated with commercial GIS software (QGIS.org, 2026b).

The Copernicus system plays an equally important role. Sentinel-2 provides multispectral data with bands suitable for calculating NDVI and NDWI indices, and the Copernicus data infrastructure facilitates access to repeatable Earth observation products (Copernicus Data Space Ecosystem, European Space Agency). In this study, data from the Copernicus program served as the empirical basis for both case studies, while QGIS transformed this data into interpretable spatial products. The combination of the Copernicus program and QGIS is therefore not only technically convenient but also methodologically significant, as it enables transparent, cost-effective, and reproducible analysis of natural disasters.

The limitations of this study should be clearly noted:

- (1) First, optical imagery from the Sentinel-2 satellite is sensitive to cloud cover, cloud shadows, haze, and atmospheric conditions. This limitation may be significant in both tropical climates and urban areas.
- (2) Second, the spatial resolution of Sentinel-2 is sufficient for certain types of analysis. It may be too low for a precise assessment of damage at the scale of individual buildings, small canals, narrow dirt paths, or minor landslides.
- (3) Third, threshold-based classification is inherently simplified. A single NDWI or NDVI threshold may not perform equally well across different land cover classes, lighting conditions, soils, vegetation types, or urban areas.
- (4) Fourth, OpenStreetMap data is valuable and widely available, but its completeness and positional accuracy may vary slightly depending on the location being analyzed.

These limitations do not diminish the value of the proposed methodology; rather, they define its proper practical and scientific status. This method should be treated as a preliminary geospatial screening assessment, suitable for rapid interpretation, educational use, support in the creation of hazard maps, and early-stage decision-making. It should not be used as the sole substitute for hydrodynamic modeling, hydraulic simulation, geotechnical slope stability analysis, high-resolution photogrammetry, LiDAR measurements, or official final damage assessments.

For floods, future comprehensive studies should additionally include: SAR imagery from the Sentinel-1 satellite, hydrological data, water level observations, hydraulic modeling, and geotechnical analyses to improve the interpretation of flood depth and dynamics. In the case of landslides, future comprehensive studies should include: rainfall data, engineering-geological profiles, soil parameters, geotechnical calculations with a specific focus on slope stability analysis, and higher-resolution imagery. This will allow for a better determination of the mechanism of landslide initiation and progression, as well as the volume of displaced soil.

Despite these limitations, the analysis represents a valuable methodological contribution. It demonstrates that open geospatial processes can bridge the gap between raw satellite imagery and the practical interpretation of catastrophic events. The case of Wrocław illustrates how the NDWI index, DEM data, and building outlines can be combined to support the assessment of urban flood vulnerability, while the case of Batang Kali shows how differentiating the NDVI index and interpreting terrain features can help identify areas affected by landslides in a tropical environment.

The results also confirmed that disaster analysis should be multi-layered, account for processes, and be grounded in a geographic context. The proposed approach is useful as a technical process, as well as a teaching and research framework for developing geospatial competencies (including among students) in the field of Disaster Risk Reduction (DRR).

6.0 Conclusions

The study demonstrated that publicly available geospatial data and open-source GIS tools can serve as a reliable, transparent, and reproducible basis for the initial analysis of natural disasters. Two case studies—the September 2024 flood in the Wrocław region of Lower Silesia, Poland, and the December 2022 landslide in Batang Kali, Selangor, Malaysia—were characterized by different hazard mechanisms, environmental conditions, and analytical challenges. Despite these differences, both cases confirmed that a structured process based on Copernicus Sentinel-2 satellite imagery, DEM data from the Copernicus program, OpenStreetMap vector layers, and spatial processing in QGIS can aid in the identification and interpretation of areas affected by natural disasters.

The flood analysis confirmed the usefulness of the NDWI index for detecting areas covered by water and potentially at risk of flooding in an urban-river environment. When combined with elevation data and building outlines, the flood mask developed based on the NDWI index was more than just a simple representation of the extent of floodwater; it became a spatial product focused on exposure assessment, which helped identify areas where buildings and infrastructure were located in or near flood-prone zones. The example of Wrocław thus demonstrated that open geospatial processes can support rapid analysis of urban flooding, especially when spectral information, terrain morphology, and vector data are interpreted together.

An analysis of the landslide in Batang Kali confirmed that variations in the NDVI index can serve as an effective preliminary indicator of vegetation disturbance associated with mass movement processes. This method allowed for the identification of areas where vegetation removal, exposed debris, and disturbed soil were consistent with the interpreted landslide path. This case also demonstrated that interpretation based on the NDVI index requires greater geomorphological caution than the creation of flood maps. In tropical regions, cloud cover, rapid vegetation regrowth, and the complexity of land cover can reduce the reliability of interpretations. Therefore, NDVI results should always be evaluated in conjunction with topography, event documentation, and, where possible, high-resolution field or reference data.

The main conclusion of the analyses is that Copernicus and QGIS provide a technically accessible and scientifically useful analytical environment for reducing the risks associated with natural disasters. Copernicus provides consistent and freely accessible Earth observation data, while QGIS enables data integration, spatial analysis, raster and vector processing, and professional cartographic visualization. This combination is particularly valuable for universities, research teams, local authorities, and educational projects that require repeatable workflows without relying on commercial software.

The proposed approach should be viewed primarily as a method for preliminary assessment. It does not replace hydrodynamic modeling, engineering-geological studies, geotechnical stability analysis, LiDAR-based mapping, or a final, detailed, and official damage assessment.

The advantages of the presented methodological approach include: rapid implementation, methodological transparency, low costs, and adaptability to different regions and types of hazards.

In detailed follow-up studies, the scope should be expanded to include data from: Sentinel-1 SAR, higher-resolution optical imagery, precipitation data, hydrological observations, and geotechnical data collected in the field. This will improve the accuracy and interpretation of the results.

In summary, the analysis confirmed that open geospatial methods can effectively support disaster impact assessment, spatial planning, environmental monitoring, and disaster risk reduction. The procedure developed for Wrocław and Batang Kali can be applied to other regions prone to floods and landslides. In such cases, local terrain conditions, data quality, and the physical mechanisms of the hazards must be carefully taken into account.

Acknowledgement

The research was conducted as part of an international student PBL project carried out jointly by the Silesian University of Technology and Universiti Sains Malaysia under the Silesian University of Technology's IDUB program—the Initiative of Excellence. Project topic: Practical application of geographic information systems (GIS) in the research, analysis, and management of the effects of natural disasters, as illustrated by the floods in southwestern Poland (2024) and the landslide in Batang Kali, Malaysia (2022). Primary advisor: Krzysztof Marian Tomiczek, winter semester of the 2025/2026 academic year, Silesian University of Technology, Gliwice, Poland, EU.

Conflicts of Interest

The authors declare that there are no conflicts of interest in this study.

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