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ENVIRONMENTAL SPECIFIC NEEDS OF A GRAVEL PIT – CASE STUDY SOMEȘ RIVER

Dorel GUȘAT[1,4], Ioan BUD[2,4], Dinu DARABA[3,4]*

[1]Technical University of Cluj Napoca, North University Center of Baia Mare, Romania, Dorel.Gusat@irmmm.utcluj.ro
[2]Technical University of Cluj Napoca, North University Center of Baia Mare, Romania, Ioan.Bud@irmmm.utcluj.ro
[3]Technical University of Cluj Napoca, North University Center of Baia Mare, Romania, Dinu.Daraba@imtech.utcluj.ro
[4]European University of Technology, European Union

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Abstract: *The evaluation and management of environmental impacts in gravel pit operations are essential for ensuring compliance with Romanian environmental regulations and promoting sustainable mining practices. Remote sensing technologies, particularly those utilizing data from the Copernicus Satellite Program, offer innovative methods for monitoring and assessing these impacts. This study examines the integration of high-resolution satellite imagery and environmental data to quantify the environmental footprint of gravel pits in accordance with national legislation. By analyzing land use changes, vegetation loss, and water quality, remote sensing provides a comprehensive framework for impact assessment. The results emphasize the potential of Copernicus data to support regulatory compliance, rehabilitation planning, and informed decision-making in extractive industries, in line with Romanian legal requirements.*
Keywords: *Gravel pit, Remote sensing, Environmental footprint, Copernicus Satellite*

1. Introduction

To extract gravel, a company must apply and comply to the Environmental Protection Agency requests. This process is governed by multiple legal provisions, including Government Decision no. 1000/2012 on the reorganization and operation of the National Agency for Environmental Protection and its subordinate institutions, GEO no. 195/2005 (approved by Law no. 265/2006) on environmental protection, as subsequently amended, and Law no. 219/2019, which modifies and supplements Article 16 of GEO no. 195/2005. Additionally, compliance with Order MMAP no. 1150/2020, which regulates the procedure for the annual endorsement of environmental and integrated environmental authorizations, as well as MMDD Order no. 1798/2007 on the issuance of environmental permits, is required. The company must meet several specific requirements to obtain the necessary approvals.

Also provides for the following activities: CAEN code: Rev2: 0812 - gravel and sand extraction; clay and kaolin extraction is a need.

The exploitation of sand and gravel will be done within the established perimeter, in compliance with the conditions imposed by the valid exploitation permit issued by **National Regulatory Authority for Mining, Petroleum and Geological Storage of Carbon Dioxide (NRAMPGSC)** [1].

Also the exploitation of sand and gravel will be done within the established perimeter, in compliance with the conditions imposed by the valid Water Management Authorization.

Here, to monitor the environmental impact of the exploitation, the new Earth Observation methods, provided by the *Copernicus Satellite* ([2]) included in a powerful software like ArcGIS Pro ([3]) (license acquired and existed in the Faculty of Engineering of the Technical University of Cluj Napoca) has been applied.

2. Methods of data interrogation

Using the ARCGIS Pro license, we can significantly support gravel extraction operations (extraction, water level monitoring, rehabilitation process) by providing advanced geospatial tools for site selection, resource assessment, environmental impact analysis, and compliance with regulations. Several steps are here highlighted:

* Corresponding author: Dorel Gusat, Assoc.prof. eng. Ph.D, Technical University of Cluj Napoca, North University Center of Baia Mare, Romania, Dr. Victor Babes Street 62/A, Baia Mare, https://users.utcluj.ro/~gusatd/, Dorel.Gusat@irmmm.utcluj.ro

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1. Site Selection & Resource Assessment

- Geological & Hydrological Mapping: ArcGIS Pro helps visualize and analyze geological formations and hydrological features to identify optimal gravel extraction sites. Using the geological maps acquired from the Geological Institute of Romania ([4]) several digital maps has been created to support the resources identification. ArcGIS Pro consolidates geological and hydrological datasets to identify extraction sites while minimizing ecological disruption.

Using the cloud computing of the CLOUDUT system of the Technical University of Cluj Napoca ([5]), we are able to access huge amounts of data in a verry sort time, to download and visualize several maps already created or data sets needed for our assessments.

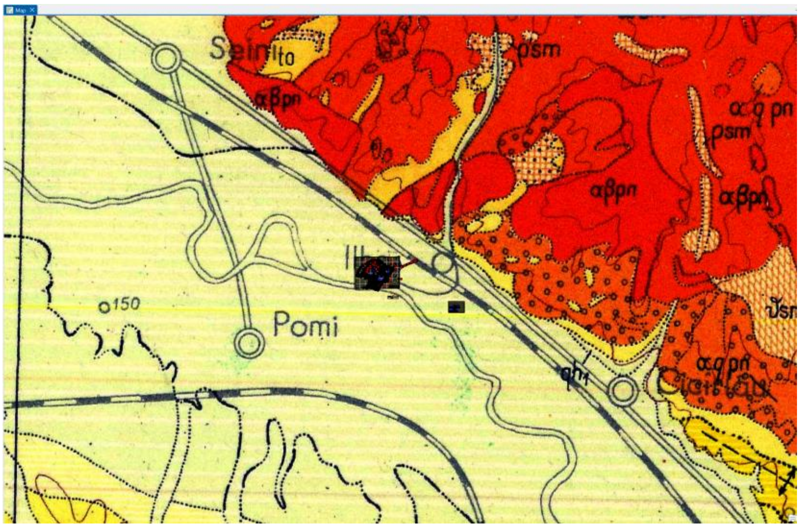

Fig.1. Geological map for the monitored area in ARCGIS Pro [4] - *Gravel, sand, argilous sand, mud (silt), alluvium, resedimented loess*

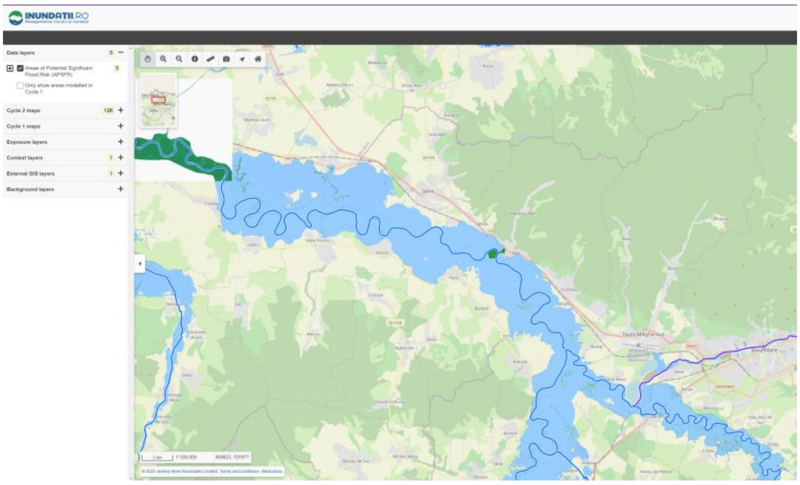

Fig.2. Public map on the portal related to Areas of Potential Significant Flood Risk (APSFR) [2]

- Remote Sensing & Satellite Imagery: By integrating satellite and drone imagery, the software allows ArcGIS Pro a crucial role in ensuring environmentally sustainable gravel extraction by leveraging geospatial databases for site assessment, impact analysis, regulatory compliance, and environmental monitoring. High-resolution imagery and spectral analysis help assess land cover changes and detect environmentally sensitive areas.

The proposed monitored area is placed between two orbits (Table 1):

Table 1. Relative orbits for the Sentinel 2A

RELATIVE ORBIT 114		**RELATIVE ORBIT 136**	
Satellite	SENTINEL2A	Satellite	SENTINEL2A
Relative Orbit	114	Relative Orbit	136
ANX Longitude	36.244755 deg	ANX Longitude	-157.601399 deg

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Copernicus Sentinel-2 is a satellite mission that provides high-resolution multispectral imagery for Earth observation. It features **two satellites (Sentinel-2A and Sentinel-2B)**, each carrying a **MultiSpectral Instrument (MSI)** that captures data across **13 spectral bands** in the **visible (VIS), near-infrared (NIR), and shortwave infrared (SWIR)** regions.

Table 2. Sentinel-2 Multispectral Bands [2]

Band	Resolution (m)	Wavelength (nm)	Primary Use
B1	60	443	Coastal/aerosol monitoring
B2	10	490	Blue - Water, vegetation, bathymetry
B3	10	560	Green - Plant health, water bodies
B4	10	665	Red - Vegetation, land classification
B5	20	705	Red Edge 1 - Chlorophyll absorption
B6	20	740	Red Edge 2 - Plant stress, biomass monitoring
B7	20	783	Red Edge 3 - Forest monitoring, agriculture
B8	10	842	Near-Infrared (NIR) - Vegetation health
B8A	20	865	NIR Narrow - Plant structure analysis
B9	60	945	Water vapor absorption
B10	60	1375	Cirrus detection (atmospheric correction)
B11	20	1610	Shortwave Infrared (SWIR 1) - Moisture, burned areas
B12	20	2190	Shortwave Infrared (SWIR 2) - Snow, ice, soil moisture

Some Key Applications of Sentinel-2 Bands:

- **Vegetation Monitoring:** Uses **B4, B5, B6, B7, B8, B8A** for NDVI, LAI, and other vegetation indices.
- **Water Bodies & Coastal Analysis:** B1, B2, B3 for detecting water quality, depth, and pollution.
- **Urban & Land Use Mapping:** B4, B11, B12 help distinguish built-up areas from vegetation.
- **Wildfire Detection:** B11, B12 highlight burned areas and active fires.
- **Snow & Ice Monitoring:** B10, B11, B12 detect snow cover, glaciers, and ice melting trends.
- **Atmospheric Correction:** B9 and B10 help correct for water vapor and cirrus clouds.

3. Applying methods and data interrogation

Using the lates data available in the system (for example 2025-02-01-00_00_2025-02-01-23_59_Sentinel-2_L2A_False_color_(urban).tiff) the user can ingest the tiff data with a high quality of resolution (2500px by 1506px).

False Color Urban Composite (fig. 3) - This composite enhances the visibility of urban areas. Vegetation appears in shades of green, while urban regions are depicted in white, gray, or purple. Soils, sand, and minerals are displayed in a range of colors. Snow and ice show up as dark blue, and water appears as black or blue. Flooded regions are represented by very dark blue, almost black. This composite is particularly useful for identifying wildfires and volcanic calderas, which show up in shades of red and yellow (fig. 3).

Fig.3. False Color Urban Composite [4] - *Based on bands B12, B11, B4*

False Colour Composite (fig. 4): A false color composite utilizes at least one non-visible wavelength to capture Earth's imagery. A widely used version employs near-infrared, red, and green bands (a band represents a specific region of the electromagnetic spectrum, which satellite sensors use to image Earth). This technique is primarily used to evaluate plant health and density, as vegetation reflects near-infrared and green light while absorbing red. Urban areas and exposed soil appear in shades of gray or tan, while water is depicted in blue or black.

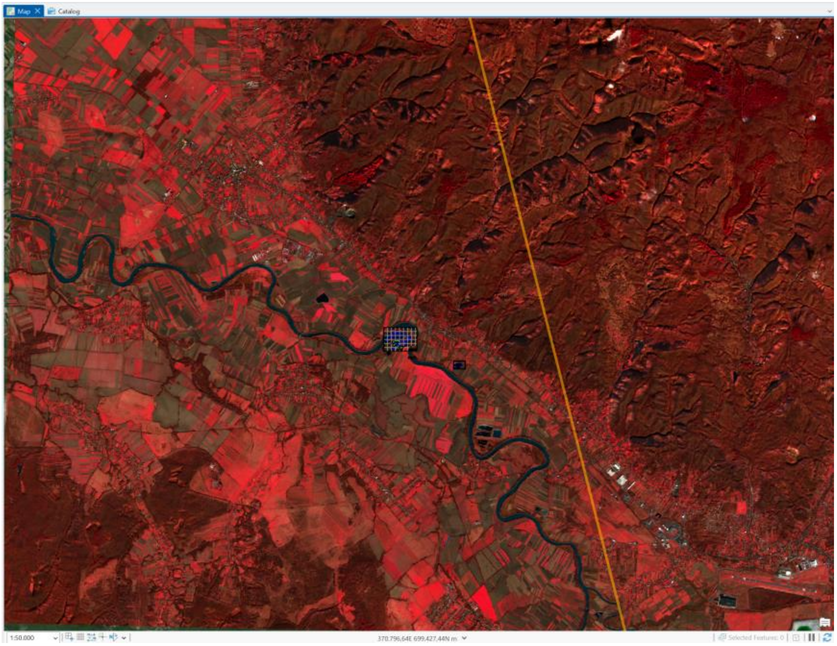

Fig.4. False_color [4] - *Based on bands B8, B4, B3*

True color optimized (fig. 5): This optimized true color composite utilizes the visible light bands—red, green, and blue—mapped to their respective color channels, producing a natural-looking image of Earth as it appears to the human eye. The visualization applies highlight compression and enhances contrast and color vibrancy through subtle adjustments to contrast and saturation.

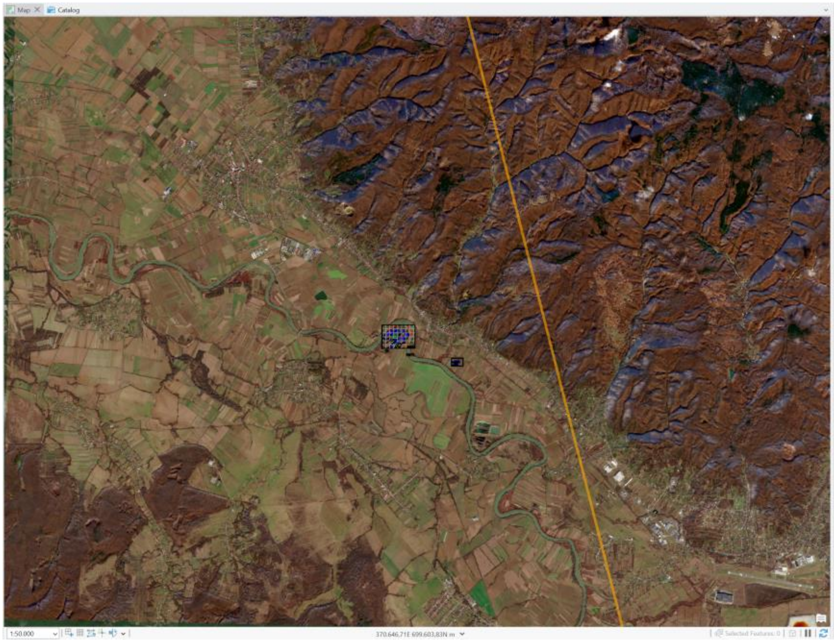

Fig.5. True color optimized [4] - *Based on bands B4, B3, B2*

Short wave infrared composite (SWIR) (fig.6): SWIR measurements help scientists assess water content in plants and soil, as water strongly absorbs SWIR wavelengths. These bands, which represent specific regions of the electromagnetic spectrum captured by satellite sensors, are also useful for differentiating cloud types (water clouds vs. ice clouds) and distinguishing snow and ice, which appear white

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in visible light. In this composite, vegetation appears in shades of green, while soils and built-up areas take on various shades of brown. Water appears black. Recently burned land reflects strongly in SWIR bands, making them essential for mapping fire damage. Additionally, different rock types reflect SWIR light uniquely, allowing for geological mapping by analyzing their reflected signatures.

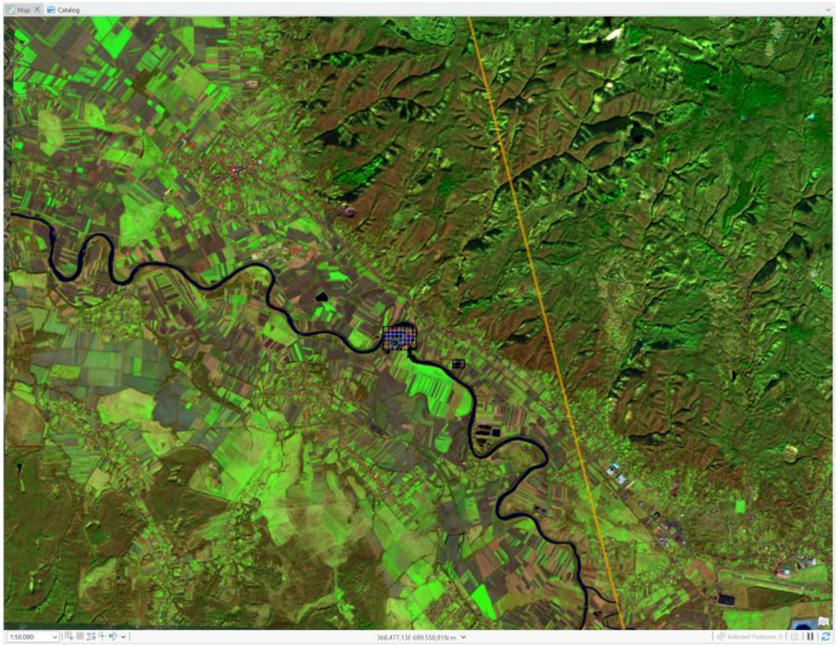

Fig.6. Short wave infrared composite (SWIR) [4] - *Based on bands B12, B8A, B4*

Normalized Difference Vegetation Index (NDVI) - Based on a combination of bands (B8 - B4) / (B8 + B4): Is a widely used indicator for monitoring plant health and vegetation cover. It measures how plants reflect light at specific wavelengths to assess their condition and density. NDVI values range from -1 to 1, with higher values indicating healthier, denser vegetation. Low positive values (0.2 to 0.4) correspond to sparse vegetation like shrubs and grasslands, while high values (approaching 1) signify lush, healthy forests. Near-zero values (-0.1 to 0.1) typically represent barren land, and negative values indicate water. NDVI is essential for tracking plant growth, detecting drought stress, and assessing agricultural productivity *in case of perimeter closure and rehabilitation effectiveness*.

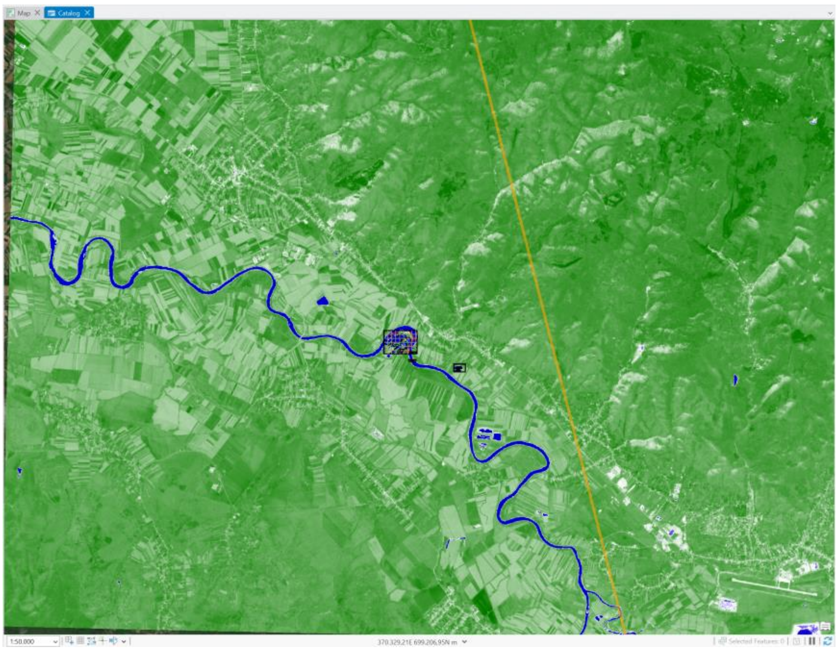

Fig.7. Normalized Difference Water Index (NDWI) [4] –
Based on a combination of bands (B3 - B8)/(B3 + B8)

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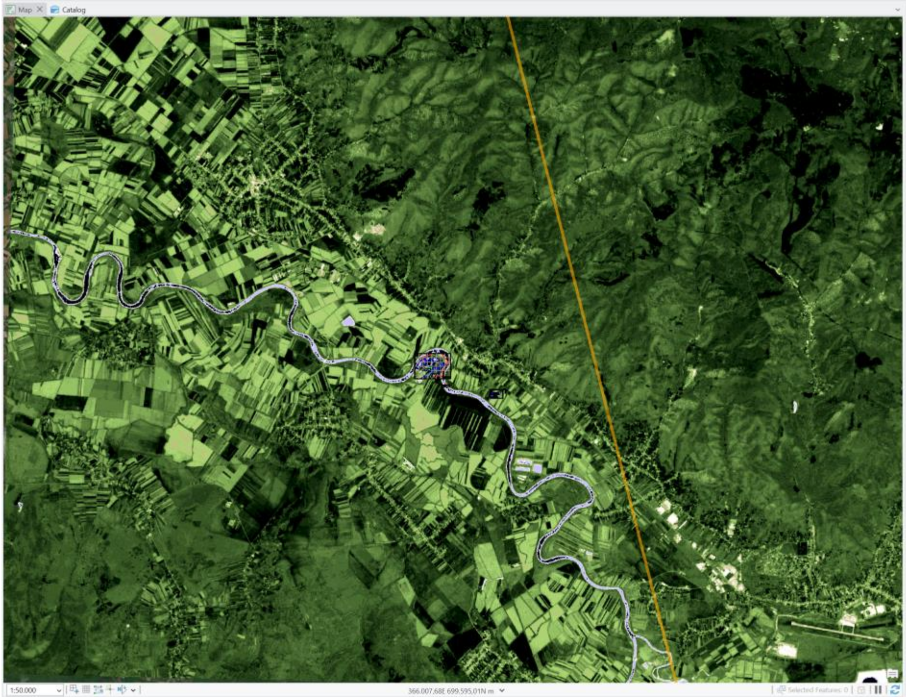

Fig.8. Normalized Difference Vegetation Index (NDVI) [4]
- Based on a combination of bands (B8 - B4) / (B8 + B4)

Moisture index or **Normalized Difference Moisture Index (NDMI)** (fig.9) - is primarily used to monitor water stress in vegetation and assess its water content (needed in case of rehabilitations surfaces). NDMI values range from -1 to 1. Negative values (close to -1) typically represent barren soil, while values around zero (-0.2 to 0.4) are indicative of water stress in plants. High positive values (ranging from 0.4 to 1) suggest healthy vegetation with adequate moisture, showing no signs of water stress. NDMI is a valuable tool for tracking drought conditions and the impact of water scarcity on plant health.

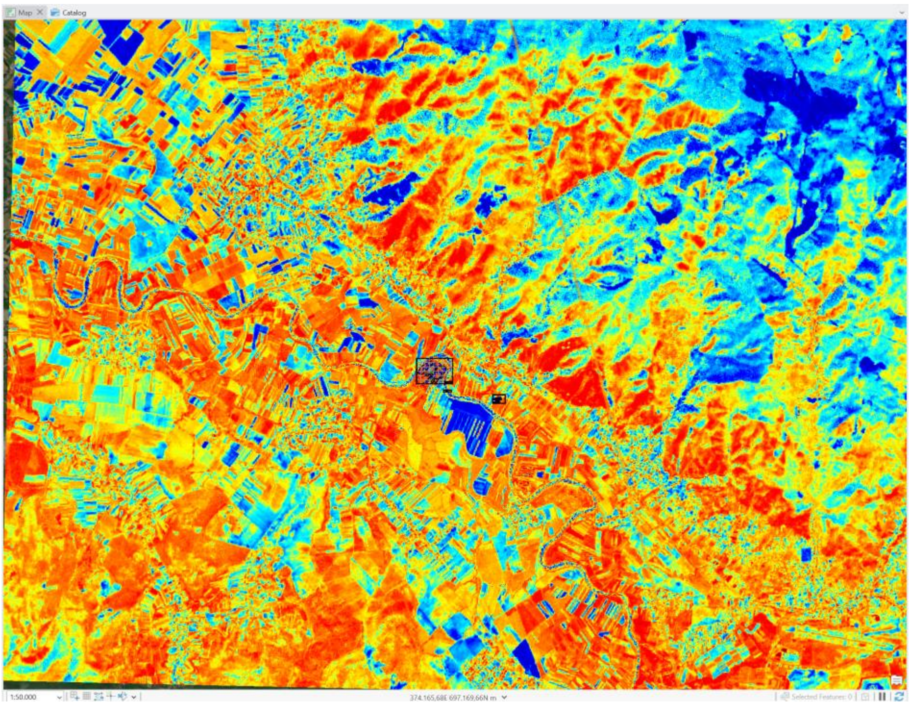

Fig.9. Moisture index (NDMI) - Based on a combination of bands (B8A - B11) / (B8A + B11)

- 3D Terrain & Watershed Modeling: Digital Elevation Models (DEMs) and watershed analysis assist in evaluating surface water flow and potential impacts on nearby ecosystems.

Using the European DEM created

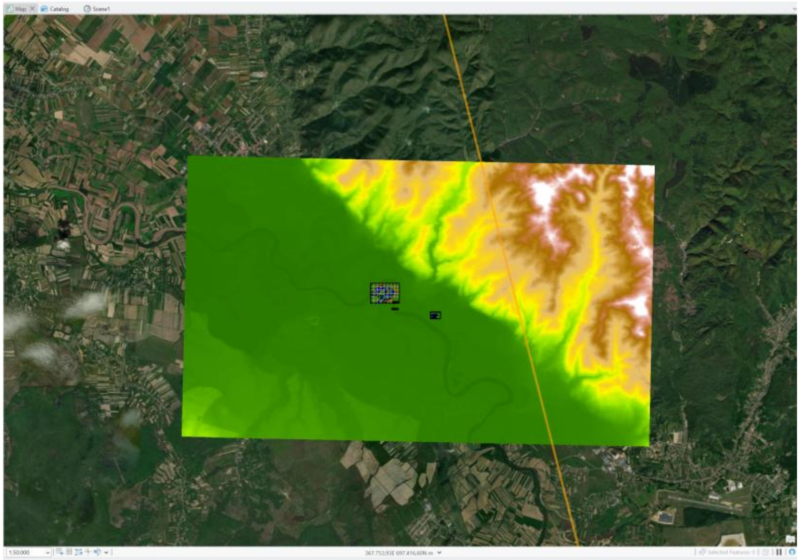

Fig.10. DEM - Based on a Copernicus .tiff file [2]

2. Environmental Impact Monitoring & Analysis

- Biodiversity & Habitat Protection: GIS databases store and analyze biodiversity data to ensure that extraction does not encroach upon protected habitats.

Hydrological Impact Assessment: GIS tools model groundwater levels, surface runoff, and sediment transport to prevent water contamination and erosion.

Using the rain module of heavy rain (fig.11) we can observe, and counter fight the negative effects of the heavy precipitations in the monitored area.

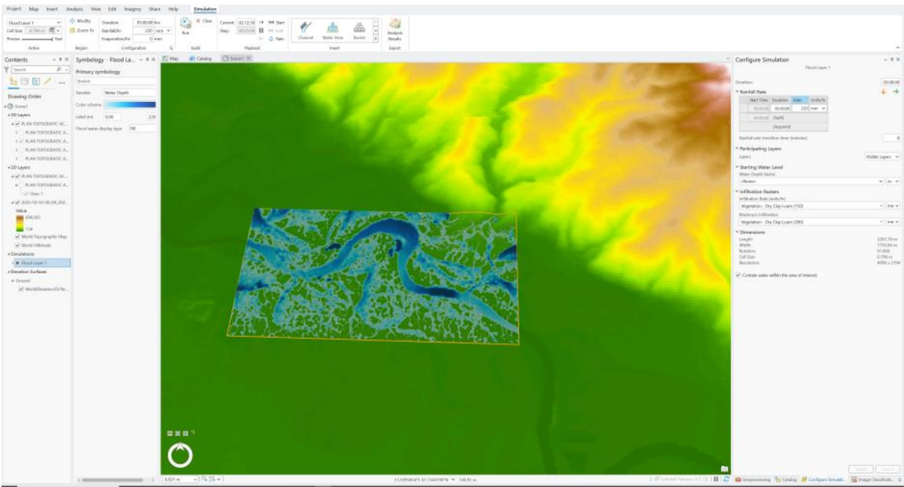

Fig.11. Using the module of heavy rain situation (220mm in 5 hours)
– here presented an intermediate result by time of 2 hours and 15 minutes

- Air & Noise Pollution Mapping: ArcGIS Pro processes real-time environmental sensor data to track air quality and noise levels, ensuring compliance with environmental standards.

3. Regulatory Compliance & Environmental Data Management

- Zoning & Legal Restrictions Mapping: GIS databases integrate zoning laws and protected area boundaries to ensure extraction activities meet environmental regulations.
- Permit Management & Compliance Reporting: ArcGIS Pro centralizes permit documents, regulatory frameworks, and compliance reports, streamlining environmental approval processes.
- Historical Data & Change Detection: Time-series analysis compares past and present land conditions, detecting unauthorized land disturbances and ensuring site reclamation.

4. Sustainable Operations Planning & Restoration
- Optimized Resource Extraction with Minimal Ecological Footprint: GIS-based planning helps reduce unnecessary land disturbance and optimize material transport routes.
- Drones & IoT for Real-Time Environmental Monitoring: ArcGIS Pro integrates drone imagery and IoT sensor data to track air, soil, and water quality throughout extraction.
- Rehabilitation & Reclamation Planning: Post-extraction site recovery is guided by GIS-based vegetation and soil restoration models, ensuring compliance with land rehabilitation policies.

5. Stakeholder Engagement & Environmental Transparency
- Interactive Dashboards for Decision-Makers & Regulators: Real-time GIS dashboards provide stakeholders with visual insights into environmental impacts and regulatory compliance.
- Public Participation & Environmental Risk Communication: Web maps and GIS applications enhance transparency by informing communities about potential environmental risks and mitigation strategies.

By leveraging ArcGIS Pro's geospatial databases, gravel extraction operations can minimize environmental impact, enhance compliance, and ensure sustainable resource management while maintaining ecological integrity.

Also, using the data base of EUSO [7], where the Technical University of Cluj-Napoca, Faculty of Engineering got the data license in order to create new maps and to develop the assessment of the impact of historical mining, we can help the development not only of the small perimeters but also of big extraction license effects on the environment.

3. Conclusions

The various indices and composite methods discussed provide valuable tools for monitoring and analyzing Earth's surface, particularly in relation to vegetation, water bodies, land cover and reserves. Key indices include the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Moisture Index (NDMI), and several other spectral bands like Shortwave Infrared (SWIR) and the Normalized Difference Water Index (NDWI).

NDVI is widely used to assess plant health and density by analyzing how plants reflect light at different wavelengths. Positive values indicate healthy vegetation, while lower values suggest barren or stressed areas.

NDMI helps monitor vegetation water content and is particularly useful for tracking water stress in plants. Low values signal water stress, while higher values suggest healthy vegetation with adequate moisture.

SWIR bands provide essential data for identifying water content in vegetation and soil, distinguishing cloud types, mapping fire damage, and analyzing geological features based on how different materials reflect shortwave infrared light.

NDWI is an effective index for mapping water bodies, with values above 0.5 corresponding to water. It helps in differentiating between vegetation and water, with each reflecting distinct wavelengths.

Vegetation Monitoring: NDVI is a crucial tool for assessing plant health, density, and vitality, helping to detect droughts, monitor agricultural lands, and manage forest ecosystems.

Water Stress Detection: NDMI plays a vital role in identifying areas experiencing water stress, making it invaluable for drought monitoring and agricultural water management.

Water Body Mapping and Other Applications: NDWI and SWIR bands are essential for mapping water bodies, detecting floods, and assessing fire damage. SWIR bands also provide key insights into soil moisture and can be used for geological mapping.

These indices, when used in combination, offer a comprehensive approach for understanding and managing Earth's ecosystems, aiding in environmental monitoring, disaster response, and natural resource management.

Using the ARCGIS Pro license and the cloud computing systems like CLOUDUT [5] we can speed up the data interrogation of various sources and produce very accurate maps for several stakeholders (companies and authorities).

Using the already created data bases, we will upgrade them and improve also using the results of other mining perimeters like in [8, 9, 10].

Acknowledgements

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