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Designation of Potential Excavation Zones Suitable for Mining - Modelling Different Types of Land Uses; MINATURA2020 Hungarian Case Study (Tállya Region)

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Introduction

The exploitation of minerals in Europe is an indispensable activity to ensure that the present and future needs of the European society can be met. This means that sufficient access is required to explore and exploit minerals. At the same time the mineral requirements of our society must be met without compromising the ability of future generations to meet their own needs. Accordingly, potentially exploitable mineral deposits (known deposits, abandoned mines and historical mining sites) need to be assessed against other land uses, taking into account criteria such as habitats, other environmental concerns, priorities for settlements, etc. Decisions on the development or management of these diverse land uses requires adequate consideration of their significance and the exclusiveness (MINATURA2020 press release 2015). A strategic national land-use planning policy for minerals requires reliable geological information on the known or potential deposits in order to safeguard resources and their environments from unnecessary sterilisation (ADWG 2014). A new EU project entitled MINATURA 2020 (www.minatura.eu) – Developing a concept for a European minerals deposit framework, funded within the European Commission's Horizon 2020 Programme, was launched in the beginning of 2015 as a response to social needs to safeguard mineral deposits of public importance for the future. The exploitation of indigenous mineral deposits in Europe is essential if we are to ensure that the needs of European society can be satisfied in a sustainable manner.

Area description

The study area at the beginning was designated for a larger area in order to have enough data for different types of aggregates and to be able to test the method for assess potential area for excavation. Although for sand, gravel and construction stones we collected all the necessary geological and other biophysical data with legislative limiting factors. In this preliminary study we focus on construction stones that are used for crushed stones mainly for infrastructure purposes. According to the fact that the majority of the geological formations appropriate for infrastructure developments are in the middle of the originally planned study area, we made observations for the Tokaj or Zemplén Mountains. During the 20th century the Tokaj Mtns. were intensively explored for precious metals and exploited for raw materials such as clays (kaolinite, illite, bentonite), zeolites, pure silica and alunite, as well as perlite and andesite for building and road construction.

In the Tokaj Mountains and the Nyírség area thirteen major lithostratigraphic units (andesite, pyroxene andesite, dacite, dacitic tuff, trachite, potassium-metasomatized pseudo-trachyte, basalt) can be recognised related to construction (crushed) stones mainly Upper to Late Miocene in age (max. Early Pannonian (14 to 9.6 Million age) (Haas 2010).

Many types of these volcanic rocks (e.g. Baskó Andesite Formation, Mulató-hegy Andesite Subvolcanic Group) formations are excavated for crushing and using aggregates for concrete, asphalt mixes, surface dressing, ballast for roads and railway. For example at the Tállya Quarry average most important geotechnical parameters are: rock type: pyroxene-andesite, density: 2.69 g/cm3, compressive strength: 200 MPa, Micro Deval: 7 - 13 %, Los Angeles: 14 - 18 %, Polishing: P1, freezing resistance: increased (www.colas.hu).

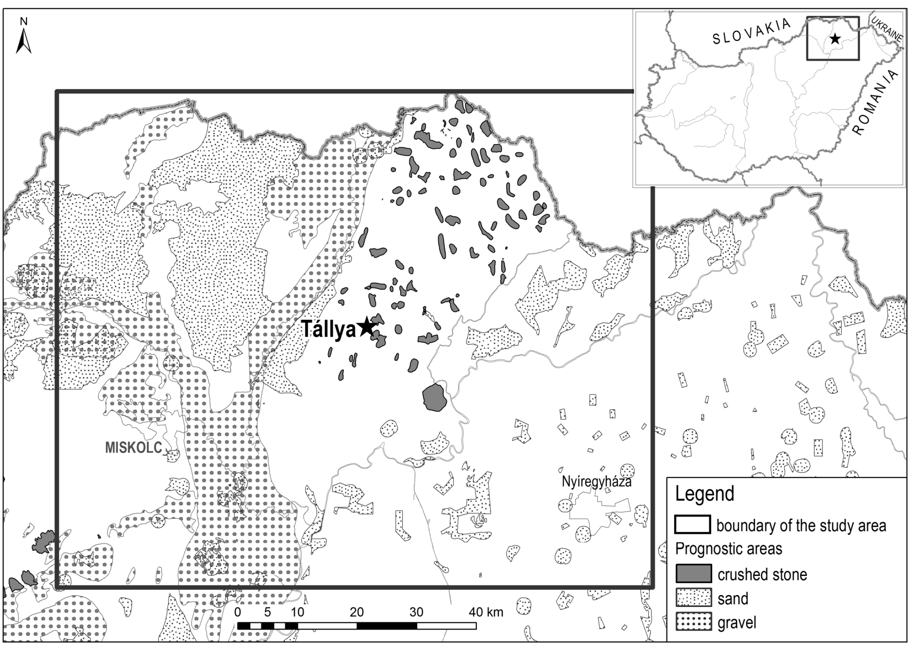

Figure 1. Map of gravel, sand and crushed stone potential areas in the study region

Goals and objectives

The purpose of this work was to map constrained and unconstrained mineral resources which may support the designation of the suitable potential extraction zones, based on the available spatial data on the potential areas for sand, gravel and crushed stones. These potential area maps do not only show the location of the minerals in the case study region, but also the estimated volumes. However, these volumes cannot be excavated completely due to legislative limitations, such as national parks, Natura 2000-sites, Ramsar sites, groundwater protection zones and important areas for preserving cultural heritage. Moreover, there are spatial constraints due to high groundwater levels, flood risks and built-up areas. The aim is to identify potential mineral extraction areas for a selection of important minerals and the extent and/or significance of competition with other land uses. While doing this, we find rules that are useful for the building of the mapping and regulatory framework of MDoPI (Mineral Deposits of Public Importance) that can be used to extrapolate the methodology to EU level.

Method

Potential suitable areas for mining activities and zones of conflict were identified using the mapping tool QUICKScan (Verweij et al, in prep., http://www.quickscan.pro/). QUICKScan is both an approach and a software tool that is applied in group processes with policy makers and experts to develop and explore potential policy options and assess likely impacts of those options through data integration. In the first step available data was collected. The following basic information was used: a spatial dataset describing the boundaries and content of the potential areas (i), spatial data with the all known factors influencing the access to mineral deposits: legislation (nature conservation, cultural heritage, protection of water resources), biophysical (infrastructure, land use, groudwater table, flood-inland water and socio-economic factors of importance. (ii), the average thickness and the related data for mineral resource (collected and estimated types were used based on CRIRSCO 2010 reporting template (for resources „D" means 60% or more uncertainty)) (iii). Concerning potential areas GIS based data for selected mineral deposits had been collected in the frame of the MFGI institutional project between 2012-2014 (Figure 1). To the identification and determination of these areas was a result of prior research (classical geological, geological maps, exploration, former potential areas) and data on recent mining at cadastral sheets (active, closed mines), exploration areas („exploration area"). All available datasets were modified and refined by using updated geological information (location of geological formations and boreholes), practically the boundaries of potential mineral occurrences were extended. The basic information was prepared in ArcGIS 10.2 (ESRI, 2014). Input data may be presented as objects which makes spatial analysis easier. However linear objects (e.g. infrastructure) can be easily converted, and even for quantitative observations it is mandatory to convert as polygons. This way legislative prescriptions can be indicated concerning polygon type areas (e.g. buffer zones around roads and railways) and finally uniform database structure can be developed. Since QUICKScan is an raster data based environment all vector type data first needed to be rasterized in order to be accepted by the tool. In the next step basic data were combined and weighted using build in QUICKScan features for easy handling of expert knowledge. Knowledge was captured in a variety of rule types: rule-matrices, if..then..else structures, map algebra, and multi-criteria analysis. Rule component for classification of importance was done.

Factors influencing the access of mineral deposits – that had earlier been systematized according to their roles by legal, biophysical and other (socio-economic) aspects – in order to achieve spatial analysis were converted to the following expert knowledge rules:

1. limiting factors: mining activity is not allowed in these areas, there is no access to mineral resources (e.g. national parks, Ramsar area, cultural heritage, protection zones of drinking water bases, road network, urban areas)
2. access with proviso: if specified conditions are met in these areas mining activity can be operated, having partial access to mineral resources (e.g. NATURA2000 areas, ECO-network, farming type land use, flood water, ground water area)

Maps and rules were merged together on the modelling canvas of QUICKScan to create a chained string of rules. An iterative modelling procedure was followed; after the basic rules and conditions were applied, the results were reviewed and existing rules were refined. Also additional conditions were added when considered crucial by the participants. All rules defining the limiting factors (I: legal, biophysical, other), together have a combined effect on the original condition of each raster cell in the map. The effect of the specified conditions set by accessibility calculations (II) was given as a weighted average of all sub factors involved. The weighted average ranges between 0 and 100 and can be valued differently in terms of protection importance (i.e. area should always be protected vs. area is not important to protect), depending on the scenario chosen. The expectation was that, especially for crushed stones, restrictions could lead to a major reduction in volume that can be excavated, compared to the potentially available volume. Two scenarios were defined, one in which a milder reduction in volume was assumed (75% after "good consultation") than for the other, "worse case"-scenario (50% after "good consultation). The use of the weighted average serves opportunity to set up multiple „scenarios". (full protection or support of mining). As a final step potential areas were compared with the map resulting from the combination of accessibility factors. The rate of change may be represented on both visual and numerical ways; the volume of the mineral resources is fully, partially or not available in a specific potential area. Due to having the estimated data of mineral resources, the changes in volume may also be presented. As a comparison for future developments two scenario were created by changing underlying priorities in the rulesets (supporting and rejecting the opening of mines).

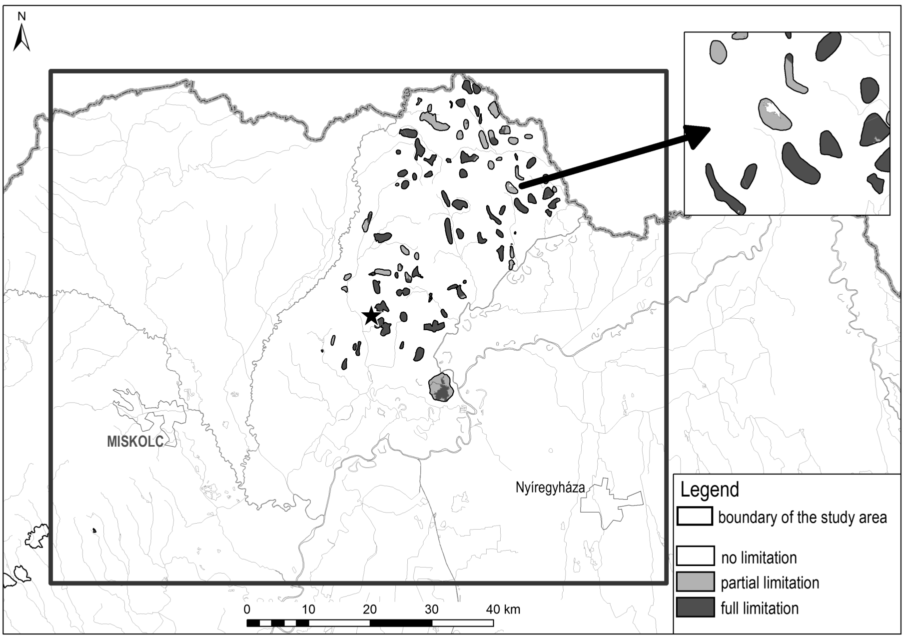

Figure 2. Map of different types of limitations (no, partial and full) for crushed stones in the study region. 52 objects are subject to full limitation, 17 objects are subject to partial limitation, 8 objects are subject to partial limitation shared with full limitation in the same potential area. Only 1 object is subject to no limitation.

Results

The potential area maps do not only show the location of the minerals in the case study region, but also the estimated volumes. However, these volumes cannot be excavated completely due to legislative limitations, such as national parks, Natura 2000-sites, Ramsar sites, groundwater protection zones and cultural heritage. Moreover, there are spatial constraints due to high groundwater levels, flood risks and build-up areas. Especially for crushed stones, these restrictions lead to a major reduction in volume that can be excavated, compared to the potentially available volume. Two scenarios were defined, one in which a milder reduction in volume was assumed (after "good consultation") than for the other, "worse case"-scenario. The map in Figure 2 shows the potential areas of crushed stone, with superimposed the legislative and biophysical limitations. The bar chart gives the reduction in volume following from the two assumed scenarios, compared to the potentially available volume based on the potential areas map. The volume of the available mineral resource in the presented crushed stone potential area has significantly decreased. Taking into consideration the accessibility factors, the majority of potential areas have become „no go areas" primarily due to legal regulation (e.g. nature conversation). If we look at the map of different types of limitations (no, partial and full limitations) for crushed stones in this region, the following ranking was detected: 52 areas are subject to full limitation, 17 areas are subject to partial limitation and eight areas are subject to partial limitation shared with full limitation in the same potential area. Only one potential area is subject to no limitation.

From Figure 8 the following numbers could be derived

- More than 2.2 x 10^9 m^3 construction stone registered in prognostic areas is known in the study area (entire volume in the Tokaj Mountains).
- Around 0.4 x 10^9 m^3 construction stone would be available if the "good case" scenario is fulfilled that means about 78 % reduction in the available volume.
- Around 0.25 x 10^9 m^3 construction stone would be available if the "worse case" scenario is fulfilled that means about 89 % reduction in the available volume.

Conclusion

This methodology is appropriate to support land use conflict management and to demonstrate the changes in the accessible volume of mineral raw materials depending on different scenarios using a participative mapping approach. Consultations between different stakeholders represented by different sectors (e.g. mining, geological, environmental, cultural heritage, land use planning, municipalities, experts, research institutes, authorities, ministries, NGO's) on national, regional and local scales are crucial for the sustainable land use planning and mineral planning. Their different perspectives compared and taken into account by the participative mapping approach can feed discussions in a much more guided and substantiated manner.Through keeping track of calculation progress and by drilling down in in calculation results by tracing into the causal chain of rules and the underlying data, the consistency of the rulesets could be checked during the workshop. By doing so, (the effect of) data imperfections could be immediately appointed during the mapping sessions, strengthening the focus on essential discussions.

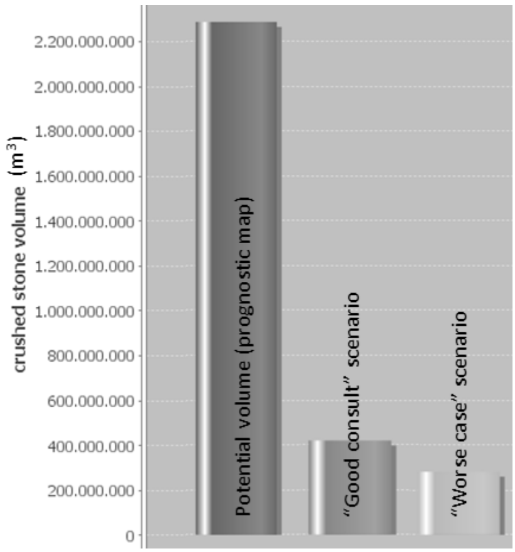

Figure 3. The volume of the potential mineral resources for crushed stones and the changes in volumes according to the different cases of consultation.

Next steps

Results of Hungarian case study and other examples (e.g. Sweden, Slovenia, UK, Poland, Italy) in the frame of the MINATURA2020 project (Work Package 1 led by ALTERRA, Wageningen University and Research Centre) will contribute to the concept and methodology of the Mineral Deposits of Public Importance). Guidance and joint vision for mineral safeguarding as a Pan-European approach will be developed. On national level this type of work and the related stakeholder consultations may contribute to the development of the "sustainable mineral resource" -, better to say "nature resource management".

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