MULTISCALE – MULTISENSOR – MULTITEMPORAL APPROACH FOR A REGIONAL TO GLOBAL INVENTORY OF POTENTIAL MINERAL RESOURCES AND THEIR EXPLOITATION IMPACTS: A PROSPECTIVE VIEW

Stéphane CHEVREL
Point of Contact for the GEO CA-06 Community Activity

MinPol GmbH, Agency for International Minerals Policy, 2753 Dreistetten, No 120/1 – Austria

Robert Hewson

University of Twente

This paper reviews several major possible applications of multisensor - multiscale - multidate Earth Observation data to a global to local inventory of mineral resources and the impacts of their exploitation. It relies on the experience of the author and of many international projects ran by scientists, many of whose are actively involved in the Group on Earth Observations (GEO) Community Activity on the “EO for Managing Mineral and Non-Renewable Energy Resources”.

1. INTRODUCTION

Nowadays, and thanks to national and international space agencies, as well as the private sector, a bunch of various remote sensing data are made available and at disposal of scientists involved in studies of the raw materials cycle.

These data include optical multispectral and hyperspectral imagery, LiDAR imagery, DEMs and DSMs, radar imagery, being acquired from space, from aircrafts and UAVs or in situ.

Ground resolution varies in a range from point in situ data to sub-metric pixels and decametre ground cells. Sensors with high revisit capabilities enable observations on a nearly daily basis.

Numerous research and/or operational projects have proven the usefulness of these data in the exploration of raw materials and the monitoring and assessment of the environmental and societal footprint of their exploitation.

Thanks to the GEO open data policy and Data Sharing Principle (DSP) and the EU contribution through the Copernicus program, several raw or processed data are freely accessible (or at marginal cost), e.g. Landsat TM and Sentinel data, SPOT Heritage...

This idealistic picture presented above however still suffers severe lacks: ASTER sensor has not yet been replaced despite its invaluable contribution to raw material studies thanks to its global coverage, its 14 spectral bands and its free data access policy. The 16 VNIR-SWIR spectral bands at high ground resolution of WorldView-3 are accessible freely only for researchers and students. A global operational systematic coverage by high-spectral resolution (hyperspectral) spaceborne sensors in particular is not available yet. On the other hand, high revisit capability sensors and very high ground resolution sensors are limited to the private sector and at high purchase costs. These limitations severely hamper systematic applications. It is not forbidden however to hope the situation will favourably evolve in the medium to long term...

From this picture, one can imagine an upscaling - downscaling approach for a global mapping of Earth's surface minerals or mineral associations, and its derivation in multiple products (e.g. maps of mining wastes, early warning systems for illegal mining and pollution, deposits of public importance...).

2. GLOBAL GEOSCIENCE MAPS

With its public web-accessible “ASTER Geoscience Map of Australia” [1] released in 2012, CSIRO (Commonwealth Scientific and Industrial Research Organisation) has paved the way for the production of a “Global Geoscience Map from ASTER data” [2]. The proposal made for the production of such maps has unfortunately not been selected for funding by NASA.

The recently released "Sentinel-2 cloudless mosaic" offers “*the first global (almost) cloud-free view of the planet*” [3] opens similar perspectives provided all spectral bands would be processed as surface reflectance.

3. MAPPING MINING-RELATED TOXIC WASTES

Some of the methodological developments carried out during several research and operational projects to identify exploration targets or exploitation footprints are not site specific and could hence be applied regionally or even globally, provided adapted to "local" conditions.

Such an upscaling approach has been used in the late 1990s by the EU Joint Research Centre (JRC) during the PECOMINES project [4] and [5] where it has been possible to map toxic wastes (FeOx and OH^- bearing minerals) in EU pre-acceding countries using Landsat TM imagery and ancillary data.

Deploying a similar but improved methodology using Sentinel 2 data would make possible mapping such toxic wastes at regional to global scale on a regular timely basis.

Inversely, identifying local anomalies (e.g. spectral anomalies, elevation anomalies...) from global processed mosaics could help in defining anomaly identification criteria and parameters that could be applied to processed imagery in detecting similar anomalies. Such a downscaling approach could be used at national to regional and local level to detect formerly unknown e.g. waste dumps and ancient mining activities and contribute to the enforcement of regulation on mine wastes [6].

4. MONITORING ILLEGAL MINING

Many developing countries are severely affected by illegal mining, in particular gold mining, that not only induce drastic environmental consequences (acid mine drainage, mercury pollution, deforestation, etc.) but also strong societal costs, e.g. insecurity, armed conflicts, land use conflicts, settlement sprawling and related health issues, etc.

Developing methodologies for an early warning system on illegal mining, using spectral identification, pattern recognition, land cover changes and other approaches e.g. InSAR, may lead in national to regional regular mapping of these illegal activities and help these countries in enforcing their mining regulation.

5. MAPPING ASBESTOS CONTAMINATION

Asbestos is a major environmental and health concern in many countries, due to its carcinogenic potential on the long term to population exposed. Spectral identification of asbestos minerals requires very high resolution spectrometry and their spectral identification has been successfully carried out by several organisations in the lab or on the field [7], [8].

Upscaling from reflectance point measurements to reflectance at image pixel level for different ground resolution however remains a challenge that has to be addressed before being able to map these minerals regionally or globally.

6. MAPPING POTENTIAL MINERALISATIONS AT COUNTRY SCALE

The United States Geological Survey (USGS) has demonstrated the potential contribution of high spectral resolution in mapping potential mineralisation over the whole Afghan territory, combining regional geophysical data, ASTER data and high-altitude HyMap hyperspectral airborne survey [9].

The study led to the identification of previously unrecognised targets of potential mineralisation.

7. SAFEGUARDING MINERAL DEPOSITS OF PUBLIC IMPORTANCE

Very high spatial resolution on the other hand brings invaluable contribution to accurate land-cover land-use mapping at local to regional scale.

The concept of "mineral deposits of public importance" (MDoPI) has been developed in the European Union for the safeguarding of EU's strategic mineral resources. "*A mineral deposit is of public importance where information demonstrates that sustainable exploitation could provide economic, social or other benefit to the EU (or the member states or a specific region/municipality).*"

The SAFEMIN H2020 project aims at fostering the safeguarding of such deposits (and the surrounding surface areas holding them) by their inclusion in land use planning instruments and national mineral policies [10]. A key message is that areas known to host (or with potential for) MDoPIs are as valuable as other land uses, so they must be taken into account in parity with them.

The combination of high spectral and high spatial resolution, along with other EO data and ancillary data, may strongly contribute to the selection and mapping of MDoPIs at country level, taking into account all constraints to their exploitation, including Social Licence to Operate (SLO) issues.

8. CONCLUSION: LINKING EO-BASED METHODS AND INTERNATIONAL POLICIES FOR MINERALS

The Strategic Implementation Plan (SIP) of the European Innovation Partnership on Raw Materials (EIP-RM) clearly states that "*Mining has a bad public perception in certain parts of Europe, due to a long history of negative impacts on the environment and high risk. Advanced technologies can be used to monitor environmental impacts arising from mining, processing or metallurgical operations, including their waste facilities. The technology can be used to help determine what mineral types are on the ground, the economic feasibility of potential* *mining operations (including mining of waste), and expected future environmental hazards. Essential components include satellite and airborne earth-observation technologies combined with in situ data collection infrastructure, data transmission capabilities and data management centres, which can alert the relevant authorities be it necessary. These could facilitate decision-making in order to conduct mining operations in an environmentally friendly, safe, manner. It can provide a cost-effective way of ensuring monitoring to meet high environmental standards and contribute to improving public acceptance. Within this context, international cooperation in the field of remote sensing methods should be strengthened, in particular cooperation on hyperspectral remote sensing techniques."*[11]

All the potential approaches above reviewed, being either realistic in the short term or needing both relevant sensors and/or methodological developments in the longer term, can play a significant role in such a policy frame.

It is worth to note that they fit within the GEO vision for a "future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth Observations and information".

They only reflect however the personal views of the main author, backed by more than twenty years of experience in remote sensing and Earth Observation applied to the whole mineral cycle.

9. REFERENCES

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