

Chapter 4: Open Spatial Data Infrastructures for the Sustainable Development of the Extractives Sector: Promises and Challenges

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Abstract

Many countries will rely on the extractive sector to generate the inputs and revenues necessary to advance progress towards the sustainable development goals (SDGs). While the last decade has seen a strong push for financial transparency in the extractive sector, it is becoming equally necessary to also include the social and environmental performance of the extractive industries across the entire value chain. However, to maximize the value of this broad range of data for improved stakeholder dialogue and decision making, a geo-spatial approach is needed for effective data integration, management, analysis, and monitoring. This requires capacity building to extractive companies and to the various transparency initiatives to ensure that reporting and disclosure data is spatially enabled as well as inter-operable, open, quality controlled and published to a spatial data infrastructure (SDI) that is publically accessible.

Ideally, this SDI can then inform and benefit many stakeholder dialogues, support reforms in natural resource governance, promote more equitable benefit-sharing, and enhance the performance of monitoring of the sector at the concession level. We discuss here the benefits and challenges of SDIs in the extractive sector. This is done using the experience gained by the authors in the design and implementation of a new Open Data Platform for the Extractive Sector called MAP-X (Mapping and Assessing the Performance of eXtractive Industries) in the Democratic Republic of Congo.

Keywords: Spatial data infrastructure, interoperability, extractive industry value chain, mapping, open data, conflict prevention, environmental transparency, sustainable development goal

1. Introduction

Extractive resources such as oil, gas, minerals and timber can have a transformative impact on the development trajectory of a country. They can create jobs, generate revenue and stimulate further economic growth. Over 100 countries will rely on their extractive resources to generate the inputs and revenues necessary to advance progress towards the Sustainable Development Goals (SDGs) (UN, 2015). This is over 50% of the member states in the United Nations, representing approximately 80% of the planet's land mass and containing around 70% of the population. Moreover, as a recent international inter-agency consultation process showed (WEF, 2016), there are potential direct and indirect contributions from the mining industry toward all of the 17 SDGs.

While the potential benefits offered by the extractive sector are significant, harnessing these opportunities presents numerous challenges and pitfalls. This is especially the case in countries affected by fragility, conflict and violence (FCV). Many of these countries suffer from the "resource curse" (Sachs and Warner, 1995): a term referring to the paradox that countries with abundant non-renewable resources like minerals and hydrocarbons tend to have lower economic performance, more corruption, and worse development outcomes than countries with fewer of these resources. There are debates about the various potential causes of the resource curse (van der Ploeg, 2011), and also about whether sufficient evidence now exists for a sub-national, spatially delimited, resource curse in some countries (Cust and Viale, 2016). Inherent to this resource curse is the fact that in many countries around the world, the extractives sector is plagued by decades of opaque contracts, backroom deals and decisions taken without public consultation or dialogue with local communities. As a result, stakeholder trust breaks down and benefits are not shared equitably, which can generate social grievances and conflicts (e.g. Hilson, 2002; Rustad et al, 2012; Kooroshy et al, 2013). If the extractive sector triggers social violence, any meaningful progress towards the SDGs is undermined.

In 2012, UNEP and the World Bank collaborated as part of a wider UN process to assess key conflict risks across the extractive industry value chain. One of the key findings of this joint work (Rios et al, 2015) was that social conflict across the extractive industry value chain is often related to a lack of transparency and access to authoritative information about concession revenues, risks and benefits. There is little public access to authoritative information about the revenues the sector is generating, or the social and environmental risks it is causing. Lack of access to basic information increases suspicion and mistrust, as well as miscommunication and misunderstandings which then tend to fuel tensions and even violent conflict. The massive information asymmetries among

stakeholders in the extractives sector also lead to unfair deals and to the inequitable sharing of benefits and risks between major stakeholder groups.

To address many of these challenges, the last decade has seen a global push for transparency in the extractive sector, essentially toward disclosure of financial and contractual data (Haufler, 2010). This has included details of the call for proposals and bidding process for natural resources exploration and development contracts, the contents and terms of these contracts, payments made by companies to governments (royalties, taxes, signing bonuses, fees), prior informed consent to communities affected by proposed developments, and the distribution of resource rents. At the forefront of this endeavor is the Extractive Industry Transparency Initiative (EITI), a global initiative launched in 2002 to promote open and accountable management of natural resources. In each EITI implementing country, a coalition of government ministries, companies and civil society work together as a multi-stakeholder group to achieve compliance toward the EITI standard (EITI, 2016). Although some studies have shown EITI implementation in countries can be successful in mitigating some of the aspects of the resource curse (Corrigan, 2014), other studies challenge the short term effectiveness of EITI in improving governance and economic development outcomes (e.g. Sovacool et al, 2016) or corruption scores (e.g. Kasekende et al, 2016).

We argue in this chapter that the benefits and impact of financial transparency could be increased by expanding transparency reporting to cover social and environmental dimensions, and by managing this information in an integrated manner using a geo-spatial approach based on a spatial data infrastructure (SDI). We start by discussing the potential benefits of spatial data access, interoperability, aggregation, and visualization for a range of transparency data in the extractive sector. We continue by introducing MAP-X, a new initiative aiming at making extractive data and other geospatial data more accessible and useable in an online open platform, and we finally discuss the challenges of field testing MAP-X in the Democratic Republic of Congo.

2. Open Spatial Data Infrastructures and the Extractive Sector

The past decade has seen numerous initiatives and incentives to make data in all sectors more available, more accessible, and more integrated. Because data production, finding, access, use and dissemination are tightly linked to factors such as standards, regulations, legislation, land use, administrative boundaries, infrastructure and other human factors, this justified the development of Spatial Data Infrastructures (SDI) as an enabling platform for efficient geospatial data workflow, management and analysis. An SDI can be defined as the appropriate set of technologies, policies and institutional arrangements that facilitate the availability of, and access to, geospatial data (Rajabifard et al, 2002; Nebert, 2008). In the context of our chapter, we can further loosely define an "Open SDI" as an SDI that is making use of *open source software* to help data management and publication; *open standards* for enabling interoperable discovery and access

to data (Yaxing et al, 2009; Ramage, 2011); and that is encouraging *open data* sharing principles to make as much data and information available for re-use as possible (Arzberger et al, 2004).

Several global level initiatives are currently promoting the creation and implementation of SDIs, and most of them are driving the trend of free and open data due to the benefits it can offer in monitoring impact and development goals (Gurin and Manley, 2015). Today's best global effort to promote large scale data sharing is represented by the Group on Earth Observations (GEO), a voluntary partnership of more than a hundred countries and 95 participating organizations, that is coordinating the implementation of the Global Earth Observation System of Systems (GEOSS, GEO secretariat, 2008). The GEOSS is aiming to act as a gateway between data producers and users providing comprehensive access to environmental data and information on various thematic areas (Giuliani et al, 2011). In its recently renewed work program, GEO has launched its activity CA-06 ("EO data and mineral resources") to foster the use of Earth Observations for improving the monitoring of the mining life cycle with the objective to move towards more responsible and sustainable practices and better addressing the societal acceptability of issues related to mining activities. The United Nations initiative on Global Geospatial Information Management (UN-GGIM, <http://ggim.un.org> [accessed 14 September 2016]) is also leading the effort for promoting the use of global geospatial information to address key global challenges such as improved land governance and management.

Within geosciences and extractive industries, several initiatives aim at helping to discover and access relevant data and information. OneGeology (<http://www.onegeology.org> [accessed 14 September 2016]) is an international initiative from geological surveys to create a global dynamic geological map and increase awareness of the geosciences and their relevance (Janssen and Kuczerawy, 2012). Another global initiative is represented by OpenOil (<http://www.openoil.net>) that allows users to search and access a collection of more than one million records about oil, gas, and mining concessions. This initiative has collected information on the text of contracts, company disclosures and government reports and provides maps of concessions areas. In the same line, the Natural Resource Governance Institute (NRGI, <http://www.resourcegovernance.org> [accessed 14 September 2016]) aims at improving critical aspects of the natural resource decision chain, and provides access to different online tools to help stakeholders working in the resource governance field to perform quantitative and quality analysis and assessments. NRGI notably provides tools to facilitate access to EITI reports and related data under the form of interactive graphical visualization.

Although some of the extractive sector data are being disclosed and made available at a growing pace, there is still an urgent need to have open SDIs that would capitalize on this information by providing the ability to visualize and analyze this data together with other national, regional and global contextual data sets of interest. There is growing availability of open global data sets in standardized formats, notably through the GEOSS, but also in more thematic portals such as PREVIEW - the Global Risk Data Platform (Giuliani and Peduzzi,

2011). The latter is an interactive geoportal (supported by an SDI) to serve and share global data on natural hazards and related exposure and risk, and it has been at the forefront to enhance availability, accessibility and integration of such data. The availability of such data sets makes it timely to harness the many benefits of multi-sectorial data integration and mash-up for stakeholders in the extractive industries.

3. Potential Benefits of Spatial Data Integration and Visualization in the Extractive Sector

There are many potential benefits that can be drawn from enhanced access as well as analysis and visualization of geospatial data. It has long been known that mapping in general is an appropriate vehicle for communicating information to stakeholders on changes to land use from an extractives project given the inherent geographic context where the impacts will occur. Maps and related graphics are a corner stone for informing public debates and facilitating stakeholder consultation, especially when it is coupled with modern geospatial technology such as remote sensing (see for example Jankowski et al, 2001; Maceachren and Brewer, 2004; Bareth, 2009; McIntosh et al, 2011; Boerboom, 2012).

In the extractive sector, the large and heterogeneous set of data and information from various fields (financial, environmental, socio-economic, etc.) offers a tremendous opportunity to capture potential benefits from improving accessibility, availability and integration of this data. We highlight here six of the most significant benefits based on experience and initial stakeholder consultations.

First, spatially-explicit data combined with other statistical, legal and performance data can support the development of thematic performance maps, spatial relationships among variables, temporal trends, etc. that can inform stakeholders on the range of potential impacts, benefits and risks. This is particularly useful at the outset of a new potential extractive project when communities and governments need access to authoritative information in order to inform their engagement with companies.

Second, in terms of enabling better screening and decision-making for extractive investments, a huge potential lies in facilitating access to and integration of other contextual data such as natural disasters and other risk data (e.g. conflict risk), infrastructure data (e.g. roads, ports, energy) and water availability (hydrographic data). Many countries, and especially low income countries, usually lack the ability to publish this data in an online and accessible national SDI that would facilitate access by companies and private investors for investment screening, selection and decision making.

Third, in countries where concession boundaries information is available and accessible, special overlay of these boundaries with other types of cadaster information and land rights can be very useful to identify overlaps and the need

for reconciliation processes. Cuba et al (2014) and Slack (2014) showed how relatively simple overlap analyses between concessions boundaries (minerals, oil and gas) on the one hand, and agricultural land, protected areas and river basins on the other hand, can help cadaster reconciliation, informed discussion and decision-making among Ministries regarding land-use priorities. Showing a lack of overlaps would also help boost investor confidence and reduce potential uncertainty.

Fourth, there is also great potential in aggregating data from industrial mining sector and that from the artisanal and small-scale mining (ASM) sector. However, ASM data is generally much more difficult to get, suffers from great uncertainty, is infrequently updated, and its authoritativeness is often challenged. Nonetheless, many studies have shown the effectiveness of analyzing these various spatial data sources with geospatial tools in an effort to evaluate impacts, dynamics, and governance of natural resources in specific areas (e.g. Baynard, 2011; Hinojosa and Hennermann, 2012; Aistrup et al, 2013; Emel et al, 2014; Patel et al, 2016).

Fifth, online access to this growing information is also becoming increasingly useful as a communications tool among stakeholders and also for the media. Use of interactive maps in concert with a narrative is the core of the relatively new concept of "story maps" (ESRI, 2012), defined as storytelling using information products that allow an online linear exploration of data, information and media (pictures, video, interactive graphs, etc.). Journalists covering the various facets of the extractive industry can also help generate public awareness and pressure towards specific governance reforms using authoritative and aggregated data (Schiffrin and Rodrigues, 2014).

Finally, a concerted national process for an open SDI in the extractive sector demands strong standardization and interoperability among data custodians. One of the barriers often encountered in low income countries is the lack of proper unique identifiers for key variables such as company names or concessions. This can greatly hinder aggregation of data between, for example, national EITI database holding reporting information from companies and the official national mining concession cadaster. However, once such interoperability barriers are solved and aggregated data are available, the many benefits of opening data (CODATA, 2015) can start to unfold, and this can trigger similar initiatives in other sectors.

The six points below discussed benefits by stakeholder group, but it can also be useful to depict the relations between a simplified extractive value chain and some of the possible useful data sets and tools that could be implemented in an extractive SDI, as shown in Figure 1. The depicted simplified value chain takes into consideration the four main components that start with the typical exploration and selection of numerous sites, followed by a "development and construction phase" (i.e., contract acquisition, public consultation, environmental impact assessment, site construction) where still no marketable product come out of the site. Then follows the "operations and processing phase" when products flow out

and revenue flow in, and finally "decommissioning and closure" when the site is closed down.

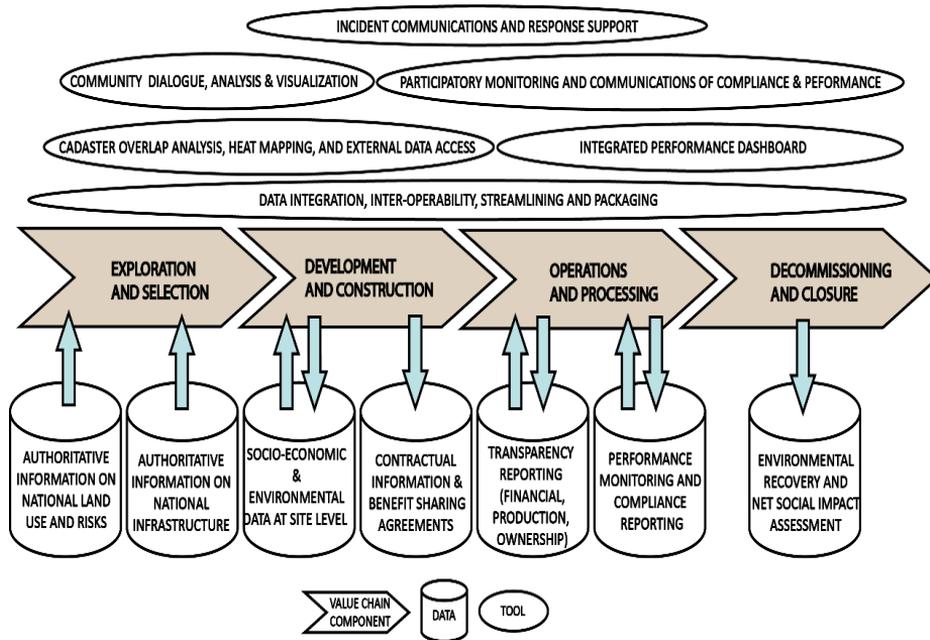


Figure 1. A simplified extractive sector value chain and the potential of providing access to geospatial data and tools in an open Spatial Data Infrastructure. Vertical arrows indicate input/output of data to/from value chain components

4. Governance and Technical Challenges

Despite the many benefits discussed above, several challenges remain for spatially enabling the extractive sector and for streamlining transparency and inter-operability of data. The recurrent challenge, particularly exacerbated in fragile states (i.e. low-income countries suffering from weak state capacity and/or state legitimacy), is the low buy-in and weak mandate from Government bodies to invest and maintain such an SDI. An open SDI in the extractive sector demands a strong level of Government commitment and stakeholder engagement, which demands continuous and considerable work to operationalize and sustain the data sharing workflows. This can further be jeopardized by frequent turnover of key individuals in Governments who can dramatically influence political will on national disclosure and data sharing priorities. The EITI has been engaged for years in pushing for financial and contract transparency and disclosure, but has not fully embraced the need to share this information in a geo-spatial or open manner. However, a major step forward was taken in the revised 2016 EITI

standard (EITI, 2016) with the adaptation of an open data policy. The revised standard notes that improving the accessibility and comparability of EITI data can be supported by publishing data in an open format. In particular, the open data policy encourages EITI-Implementing countries to orient government systems towards open data by default and to ensure that this data is fully described, so that users have sufficient information to understand the strengths, weaknesses, analytical limitations, and security requirements of the data, as well as how to process it.

The classical fear of losing data ownership or potential revenues from selling data is also pervasive in the extractive sector, and of course particularly so with data from companies that are in competition for mining concession contracts. A big challenge with companies is to provide them with the right incentives to share their own data, and to provide clarification on commercial versus non-commercial data. The fear of data misuse and especially of unintended consequences of sharing spatially-explicit information in the extractive sector adds to this. For example, we gathered from our stakeholder consultations two such possible unintended consequences: (1) disclosing boundaries of a newly agreed concession could act as an incentive for some individuals and displaced people to occupy lands within the area of the concession in order to obtain financial or other type of compensation when asked to relocate; (2) enabling easy access and display of several natural disaster and other risk maps could highlight high-risk areas where no company will invest, and therefore whose locations could be targeted by groups dealing with illegal mining activities.

Another dire need in many countries is to be able to obtain a measure of the authoritativeness and quality of available data sets. A national open SDI on the extractive industry must find ways to verify and assess the quality of the data sets made available, with clear indication of the intended use of the data (e.g. for visualization, analysis) and its associated precision and uncertainties. The verification and quality control processes must also be tailored to the data collection and reporting capacity of different stakeholder groups. For example, the data quality threshold for local communities should be vastly different from governments and companies.

Besides the governance challenges discussed above, many technical challenges are also present, especially in low income countries. Low IT technical skills, and especially those linked to Geographic Information Systems (GIS) and SDI, are common in many governmental bodies and other stakeholder groups, and could drastically hinder the speed at which geospatial enablement in the extractive sector can be achieved. Many African countries have a low level of SDI implementation (Guigoz et al, *in press*) and the propensity to use an open SDI by local stakeholders can only come after some capacity building of key individuals and leaders in the community (e.g. Giuliani et al, *in press*). This should include specific evidence on how they can benefit from accessing the system and also listening to their needs in terms of developing specific features and functions (e.g. monitoring benefit sharing agreements, showing distribution of employment between villages, or SMS notification of concession contract issuance in areas of interest). Low internet connectivity and a disruptive network can also plague the

effectiveness of adoption and use of an open SDI. In the extractive sector, this is particularly true for those potential user groups that are located around mining sites far from large urban centers.

According to the capacity building strategy of GEO (GEO secretariat, 2006), capacity building should be undertaken at three levels when dealing with SDI: human, infrastructure and institutional. This implies a range of activities ranging from education and training of individuals for installing, configuring and managing the required technology, up to enhancing the undertaking of the value of data and information to support decision-making processes (Sten Hansen et al, 2010).

5. Introducing the Map-X Initiative

As an answer to the opportunities and challenges discussed above, UNEP and the World Bank started in 2014 the initiative called 'Mapping and Assessing the Performance of Extractive Industries' or MAP-X. The mission of MAP-X is to strengthen transparency and access to authoritative information on the economic, social and environmental performance of the extractive industries. The goal of MAP-X is therefore to improve the use of authoritative information to support sustainability planning, stakeholder engagement and benefits sharing across the extractive industry value chain. There are three pillars to the MAP-X initiative: the online MAP-X platform (open SDI), the necessary capacity building activities to enable its use, and the standardization process to enable interoperability of existing data and metadata systems.

The online platform consists of three dimensions. The first one is a geospatial web platform providing authoritative spatial information for extractive sector using a combination of dynamic and static data sets, as well as open and restricted data, from different stakeholders (government, company, citizen, experts). Data layers belong to the following categories: (1) Extractive sector: e.g., financial, exportation and production figures that are provided by companies and taxing agencies and reconciled by the national EITI process; national mining cadaster; (2) Development: e.g., World Bank Indicators, socio-economic indicators produced by the National Statistics Institute; (3) Social: e.g., indigenous lands; (4) Environment: e.g., forest loss (Hansen et al, 2013), protected areas (IUCN and UNEP-WCMC, 2016), natural hazard risk (Giuliani and Peduzzi, 2011); and (5) Stresses, e.g., armed groups involved in mineral exploitation and trade. Where feasible this data is dynamically pulled or streamed into the platform in compliance with OGC standards (e.g. Web Mapping Service).

The second dimension of the MAP-X platform is a set of on-line tools to analyze and visualize the geospatial layers. Layers from various sources can be intersected, e.g. mining cadaster and protected areas to support identification of land use conflicts. Heat maps depicting volumes of payments by companies can be overlaid with socio-economic indicators (e.g. poverty rate) to highlight inequality in revenue sharing. A time slider allows visualizing changes over time of variables such as concession type, status, date of issue and owner.

The third dimension is a set of processes for monitoring and communicating benefits, land use changes, environmental risks and grievances. To monitor specific layers of information, users can define a geographic area of interest and receive a text message or email update when new concessions or other land use changes are detected in the area. MAP-X can also provide access to high-resolution satellite imagery as a background image (and in the future to monitor land use change over time). Another process is the documentation and access to the consolidated archive of information that is linked to the agreed benefits by a specific company to affected communities. This is particularly important for civil society members in order to monitor effectively the delivery of these benefits to the population. Finally, the ability to publish and spatially locate the results of environmental assessment studies (e.g. soil/water sample locations and associated information) could improve site-specific performance monitoring across the extractive industry value chain.

Altogether, these three MAP-X dimensions can be considered as the building blocks of a generic open SDI for the extractive sector. An advanced MAP-X prototype has been developed and is currently being deployed in the Democratic Republic of the Congo (DRC) (see below). This prototype is built entirely on open-source software using the following stack of software: R, SHINY-R, Leaflet, GeoServer, PGRestAPI, and GRASS. The prototype is publicly available (<http://mapx.org>), allowing non-registered users to visualize all public geospatial layers in the DRC. Figure 2 shows screenshots of the MAP-X platform.

6. Deploying Map-X in the Democratic Republic of Congo (DRC)

The DRC has been chosen for the initial pilot-testing and deployment of MAP-X for two main reasons. The first one is that the extractive landscape in DRC makes it likely to benefit from the availability of an open SDI. In line with the resource curse paradox, the mineral potential of the country is immense, with an estimated USD 24 trillion of untapped mineral resources (PNUE, 2012). Mining concessions represent 40% of the area of the country with more than 100 companies in operation in 2016, contributing up to USD 1 billion to the state budget (ITIE-RDC and Moore Stephens, 2015). At first sight, the extractive sector could be seen as an engine for development as it could create jobs, generate revenues, stimulate economic growth and support sustainable development. However, the highest revenues come from the informal sector, which accounts for 90% of mineral production and exports (Geenen, 2012). There are close to two million artisanal miners, and 12 millions of people depend on this sector. This sector operates in an opaque manner, beyond environmental and labor laws. It is estimated that USD 1.25 billion in natural resources are stolen every year by armed groups and transnational criminal networks (UNEP-MONUSCO-OSESG, 2015). More widely, the extractive sector is plagued by corruption, mismanagement and secrecy and is a historical source of conflict financing, which is particularly critical in the current context of political instability. Consequently, trust and effective dialogue between stakeholders of the extractive sector is weakened. It is then critical to facilitate

access to authoritative information in the extractive sector in order to manage public expectations, and the prevent misperceptions contributing to conflict.

The second reason for choosing DRC relates to the significant progress made over the past years towards transparency and disclosure of extractive industry data. This was driven by the work of the national EITI-DRC Multi Stakeholder Group (MSG) composed of high representatives of the government, civil society and private companies. DRC started to implement the EITI in 2007 and, as of 2016; it is one of the 29 EITI-compliant countries. DRC has notably been awarded in 2016 by the EITI international Secretariat for having led the way on disclosure of beneficial ownership. In its 2014 annual report (EITI-DRC and Moore Stephens LLP 2015) EITI-DRC discloses information about license allocations, licenses registers, contracts and state-participation. This information is available in tabular format.

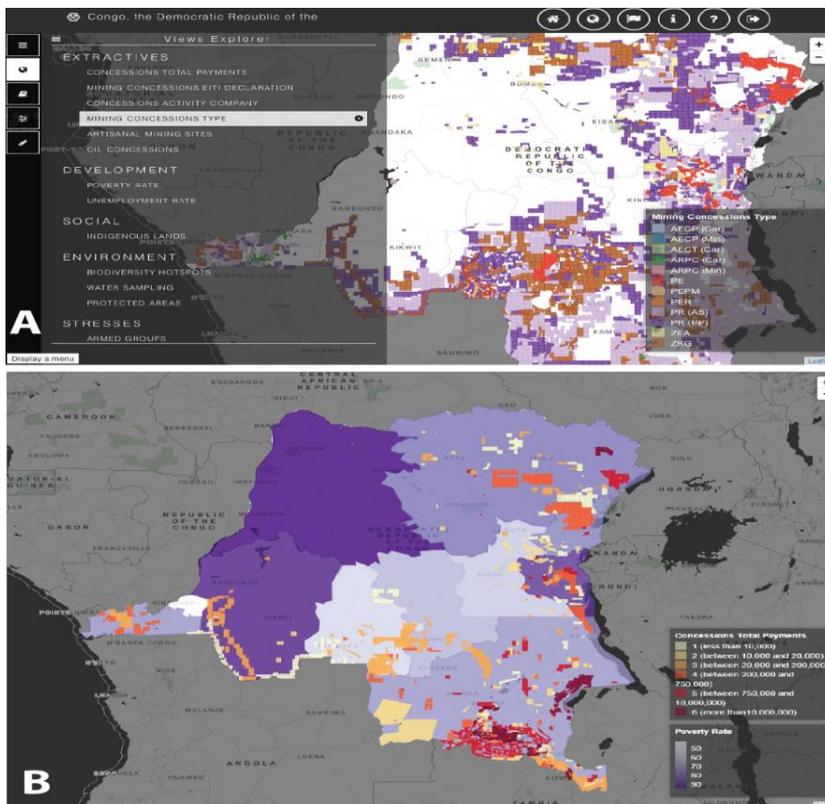


Figure 2. Screenshot of the MAP-X platform showing (A) Concession map of DRC from 2010, (B) heat map of amount of payment to Government by companies owning concessions, on top of poverty rate map per sub-region

In parallel, the DRC Mining Cadaster (CAMI) has published a public national geospatial portal to improve transparency and to promote investment in the

country. Developed on the FlexiCadastre technology the portal disseminates information on active concessions (<http://portals.flexicadastre.com/drc/en/> [accessed 14 September 2016]): exploitation permits (small mines and tailings), research authorization for quarry substances, authorizations for exploitation, exploitation and research permits along with the holder(s), application, grant and expiration dates, commodity and area. The DRC FlexiCadastre portal is however restricted to the display of a few geospatial datasets (mining concessions, protected areas, geology and satellite imagery), and it does not provide metadata about these layers, analytics (e.g., overlay functions, tools to calculate spatial statistics, download functions) or participatory processes for stakeholder dialogue and monitoring.

Our consultation process started in 2015 with various key stakeholders (MSG, Prime Minister's office, EITI-DRC, etc.). They agreed by consensus that the MAP-X initiative could be of tremendous value to DRC and supported further development and testing at the national and local level. Each stakeholder group identified different benefits they could gain from MAP-X.

For the DRC Government, there is a fundamental need for MAP-X to help establish processes that can identify and resolve boundary overlaps between different cadastral systems and designated land uses. An internal reconciliation process will be required to resolve such boundary overlaps, as they lead to uncertainty and undermine investor confidence. The second need for the Government is the support of MAP-X in resolving local conflicts linked to extractive industry projects, including through the mapping of conflicts, the provision of impartial information and performance monitoring tools. Moreover, the MAP-X initiative could help to drive the process of data standardization and data sharing at national level among governmental bodies.

Representatives of civil society expressed a strong need to access information on the standards, obligations and performance conditions that different extractive concessions and operators have agreed on. Without such information, they cannot perform a watchdog function in terms of informing the national dialogue on compliance monitoring, regulation and accountability.

Finally, representatives of extractive companies in DRC expressed interest in MAP-X for helping to identify different sources of risk to individual concessions, including disasters and conflicts, as well as environmentally sensitive sites and authoritative boundaries of protected areas. Companies would also like a simple mechanism to showcase and publically communicate some of the positive impacts they are making on local socio-economic development, for example, using story maps in the MAP-X platform.

7. Conclusions

Achieving the Sustainable Development Goals will demand a massive concerted global effort to efficiently make use of data sharing, processing and aggregation

in a highly multidisciplinary framework. The pervasive role of the extractive sector throughout these SDGs makes it particularly important to implement Spatial Data Infrastructures and associated online geoportals that can deliver many untapped benefits for various stakeholder groups. In particular SDIs are playing an important role in delivering spatially enabled governments and societies.

The technical challenges that we discussed above, notably those linked to the chosen technologies or the low ICT and SDI literacy, should not make us forget that this is only the tip of the iceberg. The bulk of the challenges are the non-technical ones, those related to human behaviors, resistance to change and sharing, buy-in and motivation, just to name a few. Capacity building activities on how the discussed benefits can unfold along the extractive value chain are critically important to carry out, especially in low income and fragile states where an increase in data transparency can make a big difference.

MAP-X is an answer to some of the data management and SDI challenges outlined in this chapter. MAP-X is a partnership between UNEP and the World Bank to strengthen transparency and access to authoritative information on the financial, social and environmental performance of the extractive industries. MAP-X integrates transparency information into an online geo-spatial platform, and offers a combination of analytical and monitoring tools to support stakeholder dialogue and decision making. By offering a dedicated on-line platform for the extractives sector, MAP-X will help to expand and modernize on-going transparency initiatives by: publishing integrated transparency data in an accessible and spatial format; extending transparency to include social and environmental dimensions; and deepening transparency to the site level for monitoring community consultation processes and compliance with legal obligations. Our hope is that the initial deployment of MAP-X in the DRC can pave the way towards the geospatial enablement of the extractive sector, with the potential for MAP-X to eventually be deployed to all 100 countries that have an active extractive sector.

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9. References

- Aistrup, J.A., Kulcsar, L.J., Mauslein, J.A., Beach, S., Steward, D.R. (2013). Hyper-extractive counties in the US: A coupled-systems approach. *Applied Geography* 37, 88-100.
- Arzberger, P., Schroeder, P., Beaulieu, A., Bowker, G., Casey, K., Laaksonen, L., Moorman, D., Uhler, P., Wouters, P. (2004). Promoting Access to Public Research Data for Scientific, Economic and Social Development. *Data Science Journal* 3, 17.
- Bareth, G. (2009). GIS- and RS-based spatial decision support: structure of a spatial environmental information system (SEIS). *International Journal of Digital Earth* 2, 134-154.
- Baynard, C.W. (2011). The landscape infrastructure footprint of oil development: Venezuela's heavy oil belt. *Ecological Indicators* 11, 789-810.
- Boerboom, L.G. (2012). Integrating Spatial Planning and Decision Support System Infrastructure and Spatial Data Infrastructure. *International Journal of Spatial Data Infrastructures Research*.
- CODATA (2015). The Value of Open Data Sharing - A White Paper for the Group on Earth Observations. Paris, France.
- Corrigan, C.C. (2014). Breaking the resource curse: Transparency in the natural resource sector and the extractive industries transparency initiative. *Resource Policy* 40, 17-30.
- Cuba, N., Bebbington, A., Rogan, J., Millones, M. (2014). Extractive industries, livelihoods and natural resource competition: Mapping overlapping claims in Peru and Ghana. *Applied Geography* 54, 250-261.
- Cust, J., Viale, C. (2016). Is There Evidence for a Subnational Resource Curse? NRG I Policy paper. NRG I, p. 22.
- EITI (2016). The EITI standard 2016. Norway, p. 64.
- Emel, J., Plisinski, J., Rogan, J. (2014). Monitoring geomorphic and hydrologic change at mine sites using satellite imagery: The Geita Gold Mine in Tanzania. *Applied Geography* 54, 243-249.
- ESRI (2012). Using Web Maps to Tell Your Story. *ArcNews*, pp. 22-25.
- Geenen, S. (2012). A dangerous bet: The challenges of formalizing artisanal mining in the Democratic Republic of Congo. *Resource Policy* 37, 322-330.
- GEO secretariat (2006). GEO Capacity building strategy. p. 13.
- GEO secretariat (2008). Building a Global Earth Observation System of Systems. p. 7.
- Giuliani, G., Lacroix, P., Guigoz, Y., Roncella, R., Bigagli, L., Santoro, M., Mazzetti, P., Nativi, S., Ray, N., Lehmann, A. (*in press*). Bringing

- GEOSS Services into Practice: A Capacity Building Resource on Spatial Data Infrastructures (SDI). *Transactions in GIS*.
- Giuliani, G., Peduzzi, P. (2011). The PREVIEW Global Risk Data Platform: a geoportal to serve and share global data on risk to natural hazards. *Natural Hazards Earth System Science*. 11, 53-66.
- Giuliani, G., Ray, N., Schwarzer, S., De Bono, A., Peduzzi, P., Dao, H., Van Woerden, J., Witt, R., Beniston, M., Lehmann, A. (2011). Sharing Environmental Data through GEOSS. *International Journal of Applied Geospatial Research* 2, 1-17.
- Guigoz, Y., Giuliani, G., Nonguierma, A., Lehmann, A., Mlisa, A., Ray, N. (*in press*). Spatial Data Infrastructure in Africa: a gap analysis. *Journal of Environmental Informatics*.
- Gurin, J., Manley, L. (2015). Open data for sustainable development. Policy Note ICT01. World Bank.
- Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342, 850-853.
- Haufler, V. (2010). Disclosure as Governance: The Extractive Industries Transparency Initiative and Resource Management in the Developing World. *Global Environmental Politics* 10, 53-73.
- Hilson, G. (2002). An overview of land use conflicts in mining communities. *Land Use Policy* 19, 65-73.
- Hinojosa, L., Hennermann, K. (2012). A GIS approach to ecosystem services and rural territorial dynamics applied to the case of the gas industry in Bolivia. *Applied Geography* 34, 487-497.
- ITIE-RDC and Moore Stephens (2015). RAPPORT ITIE RDC 2014. Kinshasa, RDC, p. 194.
- IUCN and UNEP-WCMC (2016). World Database on Protected Areas, Version 2016. WCMC, Cambridge, UK.
- Jankowski, P., Andrienko, N., Andrienko, G. (2001). Map-centred exploratory approach to multiple criteria spatial decision making. *International Journal of Geographical Information Science* 15, 101-127.
- Janssen, K., Kuczerawy, A. (2012). Increasing the Availability of Spatial Data held by Public Sector Bodies: Some Experiences and Guidelines from the OneGeology-Europe Project. *International Journal of Spatial Data Infrastructures Research* 7, 249-276.
- Kasekende, E., Abuka, C., Sarr, M. (2016). Extractive industries and corruption: Investigating the effectiveness of EITI as a scrutiny mechanism. *Resource Policy* 48, 117-128.

- Kooroshy, J., Lahn, G., Bernice Lee, B. (2013). Conflict and Coexistence in the Extractive Industries. London, p. 119.
- Maceachren, A.M., Brewer, I. (2004). Developing a conceptual framework for visually-enabled geocollaboration. *International Journal of Geographical Information Science* 18, 1-34.
- McIntosh, B.S., Ascough li, J.C., Twery, M., Chew, J., Elmahdi, A., Haase, D., Harou, J.J., Hepting, D., Cuddy, S., Jakeman, A.J., Chen, S., Kassahun, A., Lautenbach, S., Matthews, K., Merritt, W., Quinn, N.W.T., Rodriguez-Roda, I., Sieber, S., Stavenga, M., Sulis, A., Ticehurst, J., Volk, M., Wrobel, M., van Delden, H., El-Sawah, S., Rizzoli, A., Voinov, A. (2011). Environmental decision support systems (EDSS) development – Challenges and best practices. *Environmental Modelling & Software* 26, 1389-1402.
- Nebert, D.D. (2008). Developing Spatial Data Infrastructure: The SDI Cookbook; http://www.gsdidocs.org/GSDIWiki/index.php/Main_Page.
- Patel, K., Rogan, J., Cuba, N., Bebbington, A. (2016). Evaluating conflict surrounding mineral extraction in Ghana: Assessing the spatial interactions of large and small-scale mining. *Extr Ind Soc* 3, 450-463.
- PNUE (2012). Évaluation Environnementale Post-Conflic de la République Démocratique du Congo. Nairobi, Kenya, p. 355.
- Rajabifard, A., Feeney, M.-E.F., Williamson, I.P. (2002). Future directions for SDI development. *International Journal of Applied Earth Observation and Geoinformation* 4, 11-22.
- Ramage, S. (2011). Geospatial standards, data sharing and interoperability. *PoPositionIT*, pp. 36-37.
- Rios, M.O., Bruyas, F., Liss, J. (2015). Preventing conflict in resource-rich countries - the extractive industries value chain as a framework for conflict prevention. The World Bank, p. 41.
- Rustad, S., Lujala, P., Le Billon, P. (2012). Building or spoiling peace? Lessons from the management of high-value natural resources. In: Lujala, P., Rustad, S.A. (Eds.), *High-Value Natural Resources and Peacebuilding*. Earthscan, London, pp. 571-621.
- Sachs, J.D., Warner, A.M. (1995). Natural Resource Abundance and Economic Growth. National Bureau of Economic Research Working Paper Series No. 5398.
- Schiffrin, A., Rodrigues, E. (2014). Covering Oil: Big Data, New tools and Journalism. Global Investigative Journalism Conference, Rio de Janeiro.
- Slack, K. (2014). Mapping the bigger picture: Using mapping to promote better development outcomes from extractive industries. *Applied Geography* 54, 237-242.

- Sovacool, B.K., Walter, G., Van de Graaf, T., Andrews, N. (2016). Energy Governance, Transnational Rules, and the Resource Curse: Exploring the Effectiveness of the Extractive Industries Transparency Initiative (EITI). *World Development* 83, 179-192.
- Sten Hansen, H., Schroder, L., Hvingel, L., Skovdal Christiansen, J. (2011). Capacity building for SDI Implementation – A Danish Case Study. *International Journal of Spatial Data Infrastructures Research* 6.
- UN (2015). Transforming our World: The 2030 Agenda for Sustainable Development. A/RES/70/1. <https://sustainabledevelopment.un.org/post2015/> [accessed 14 September 2016]
- UNEP-MONUSCO-OSESG (2015). Experts' background report on illegal exploitation and trade in natural resources benefitting organized criminal groups and recommendations on MONUSCO's role in fostering stability and peace in eastern DR Congo. Available at www.unep.org. p. 39.
- Van der Ploeg, F. (2011). Natural Resources: Curse or Blessing? *Journal of Economic Literature* 49, 366-420.
- WEF (2016). Mapping Mining to the Sustainable Development Goals: A Preliminary Atlas. p. 76.
- Yaxing, W., Santhana-Vannan, S.K., Cook, R.B. (2009). Discover, visualize, and deliver geospatial data through OGC standards-based WebGIS system. *Geoinformatics, 2009 17th International Conference on*, p