Life cycle assessment and cadastral administration for a better environmental sustainability

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Key words: Cadastre; Land distribution; Land management; Sustainable development; land ownership, Life cycle assessment.

SUMMARY

Land Administration (defined by the UN/ECE as the process of determining, recording and disseminating information about ownership, value and use of land, when implementing land management policies) (UN, 1996) includes processes of land registration, cadastre, valuation and land inventory. Every country in the world pursues these activities in one form or another (UN, 2001) to sustain these land resources.

Resources that are linked to nature are many fold - land is the most abundant natural resource which provides all such natural minerals. Efficient and beneficial exploitation of natural mineral resources provides an important part of the economies of many countries, both in the developing and in the developed world. It is in this context, a life cycle analysis of mineral usage aided by cadastral administration can lead to identification of resource exploitation and finding of abatement costs due to each such mineral exploitation from a piece of land.

Defined by *ISO 14040.2 Draft: Life Cycle Assessment - Principles and Guidelines-"*Life cycle analysis (LCA) is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by compiling an inventory of relevant energy and material inputs and environmental releases, evaluating the potential environmental impacts associated with identified inputs and releases, interpreting the results to help you make a more informed decision." Land administration or proper land management practices dictates the rate at which a land can be exploited for the extraction of several mineral resources.

A cradle to grave analysis that gives leads to identifying the extraction of all those mineral resources to the extent of their usage can be linked to identify the pollution levels each such mineral can contribute. For example using iron ore as a resource in steel industry entails severe land mining as a start of resource exploitation and this iron ore during its usage can lead to pollution due to industrial usage of the ore for steel production.

Life cycle data as part of cadastral information leads to identification and understanding the technical and institutional elements of land resource usage. Further it can be used to analyse the impact of such resource usage on environment and measures to reduce environmental degradation. Measures of individual exploitation similar to "neo colonialism" can be

identified and minimised proportionally to the rate of environmental degradation due to such resource exploitation and this leads to better environmental management practices.

The relationship between property rights, sustainable development and environmental management has been clearly enunciated in the 1992 World Development Report titled "Development and the Environment" (World Bank, 1992). First it establishes the relationship between environmental management and development: "The protection of the environment is an essential part of development. Without adequate environmental protection, development is undermined; without development, resources will be inadequate for needed investments, and environmental protection will fail." By identifying the developing a theoretical analogy of using Life cycle analysis data for building a mining digital cadastre for a secure mineral rights system, this paper attempts to show the role of Life cycle assessment combined with cadastral administration for a better environmental sustainability

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INTRODUCTION

Efficient and beneficial exploitation of natural mineral resources provides an important part of the economies of many countries, both in the developing and in the developed world. Developing countries need to promote the utilisation of the natural resources for the benefit of their population. Population growth in several developing countries is considerably higher than resource availability. In some cases all though the resources are available, due to lack of technological know-how, the available resource may not be put to judicial use to derive potential benefits out of it.

The ability to exploit mineral resources can be an important factor in the growth and a driving force for the national economy, increasing wealth and general infrastructure. Exploitation of mineral resources can be misleading if proper measures to control the ownership rights of mineral resource is not well documented. For secure and long term sustenance of a mining industry, it is required to regulate the mining in developing countries. It is in this context a mining cadastre reinforcing a mining law becomes relevant.

MINING CADASTRE

"A cadastre is the core or basis of a land administration system and is defined as a parcel based and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and ownership or control of those interests, and often the value of the parcel and its improvements."

Unlike a well defined definition of cadastre, an uncertainity in deriving a concrete definition of a mining cadastre is still prevalent . There has been a proposition to call mining cadastre as mineral rights cadastre. From literature sources – "A mining cadastre is the principal public institution that manages mining titles in a country. Such a cadastre, when well developed and backed by capable public mining sector institutions, integrates the regulatory, institutional, and technological aspects of mineral rights administration and forms the cornerstone of good mineral resource management in a country." [1]

A Mining Cadastre is the cornerstone of a secure mineral rights system and records the geographical location, ownership and time validity of mining rights, and for compliance with the payment of fees and/or other requirements to keep a concession valid. Security of tenure is very important both to large and small scale mining operations both to ensure a return on investment over the life of a mine and to avoid legal disputes over ownership."[2]

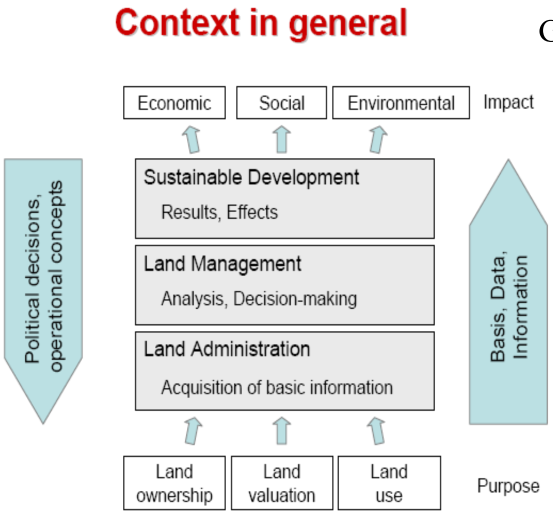
There are several ground rules that should be observed for the mining cadastre to operate properly and they are security of tenure, security of title , auctions and *“First come, first served.”* i.e exploration licenses are granted on a first-come, firstserved basis, which means that the first individual or company to apply for the rights to a certain area where mineral resources may exist will have the priority right to be granted the license or lease.

MINING LEGISLATIONS AND LAND ADMINISTRATION

During the past 25 years, many countries, particularly in Latin America, Africa, and Asia, have instituted legal and institutional reforms in their mining sectors to modernize sector management, attract investments, and optimize the contribution of mining to their economies at national and local levels. Some of these developments have led to impressive results, for example, in Argentina, Chile, Ghana, Madagascar, Peru, and Tanzania.One of the decisive factors for a thriving mining sector is the security of land tenure. Not only should the Mining Law guarantee this tenure but the administration of the Law and Regulations should be fair, transparent, decisive and efficient.

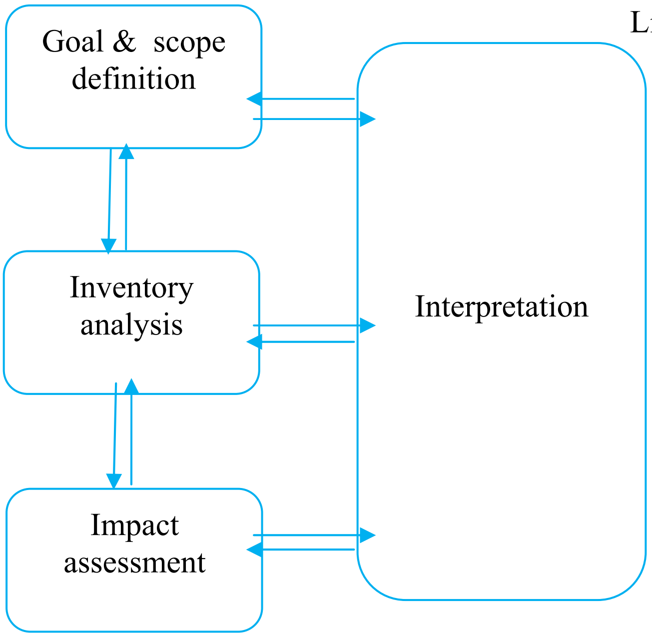
For the Investor, the Mining Cadastre System is often perceived as the substance of the Mining Law. It is therefore critical to have an efficient cadastre system that enhances investor confidence in the sector. For the Government, an efficient Mining Cadastre System guarantees that the intentions of the Mining Law are carried out in practice and provides management data that can be used to formulate policy making. In the Private Sector, Mineral Title is the very essence of any mineral resource company. Without efficient management of their land holdings, a company runs the risk of losing its life blood. Corporate mining cadastre management requires more than just knowing the date that mineral title comes up for renewal. Complete mineral life cycle management solutions manage all obligations to the State or Joint Venture Partners, monitor work and legal commitments, link to company financial and document management systems, provide management consistency across operations and reduce time required to generate statutory reports[5].

RESOURCE EXPLOITATION AND SUSTAINABILITY FOCUSSED TO ENVIRONMENTAL SUSTAINABILITY



G.H Brundtland (1987) in – "*Our common future: The world commission on environment and development*" defines sustainable development as the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs. Sustainable development (SD) today, has an expanded definition and scope. Sustainable development is the *development to reach equilibrium in between poor and rich, between current and future generations, between humankind and nature without compromising the cultural, social and biological diversity*.

ENVIRONMENTAL SUSTAINABILITY AND LIFE CYCLE ASSESSMENT



Life cycle assessment (LCA) can be described as a tool for the systematic evaluation of the environmental impacts of a product or service through all stages of its life cycle - from raw material extraction, through production, distribution, use, to waste management and final disposal. As shown in figure4 above, the LCA framework conssits of 4 different steps _ goal and scope, inventory analysis, impact assessment and interpretation.

Following the requirements established in ISO 14040 , the goals of LCA could be:

- weak point analysis in the production or optimisation of processes;
- accompanying assessment in the development of new materials;
- optimisation of materials by analysing the system performance within an application;
- decision-making assistance in marketing;
- optimisation of the production of a component or the comparison of components;
- optimisation of a product component

- in view of the product and its life cycle ;
- optimisation of a product in its life

Life cycle inventory (LCI) is the phase of the LCA involving the compilation and quantification of inputs and outputs, it comprises data collection and data calculation. Data collection consists of the identification and quantification of the relevant input and output flows for the whole life cycle of a product.

Basic flow types: Basically three types of flows can be differentiated: elementary flows (emissions, resources) that are emitted into the environment or extracted from it, product flows (goods, services), that come from or go to the technosphere, and waste flows (a sub-type of product flows). The use of resources and the use of land, raw materials, fabricated products, auxiliary materials, energy carriers and electricity are recorded as inputs. Emissions to air, water and land as well as wastes and by-products are outputs in an inventory analysis. In the later stage of the impact assessment, the quantitative information on the product system's elementary flows (and in some methods the waste flows) are used to analyse the product's impacts.

Life cycle impact assessment (LCIA) is the phase of LCA involving compilation and quantification of inputs and outputs for a given product system throughout its life cycle. The impact assessment is carried out on the basis of the inventory analysis data. The inventory flows are classified according to their potential impact on the environment, human health, or resources in so-called impact categories. These categories provide indicators

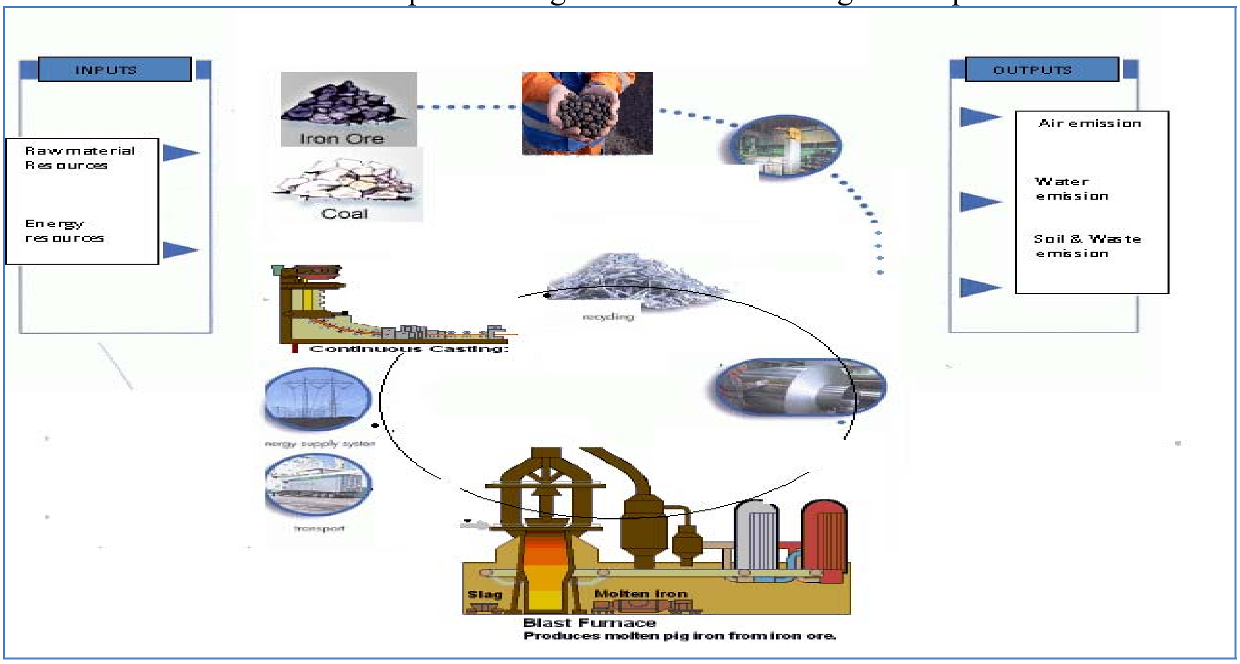


Figure 2: Life cycle assessment of iron industry

of potential environmental impacts and not necessarily contributions to the actual effects. Actual effects may be dependent, for example, on the concentrations of contaminants in the environment and the exceedance of thresholds due to multiple sources at specific times and locations. In contrast to Environmental Impact Assessment, the Life Cycle Impact Assessment is hence (typically) not site-specific and only sometimes site-dependent. An integrated use of both methods in a joint "tool-box" is under scientific development.

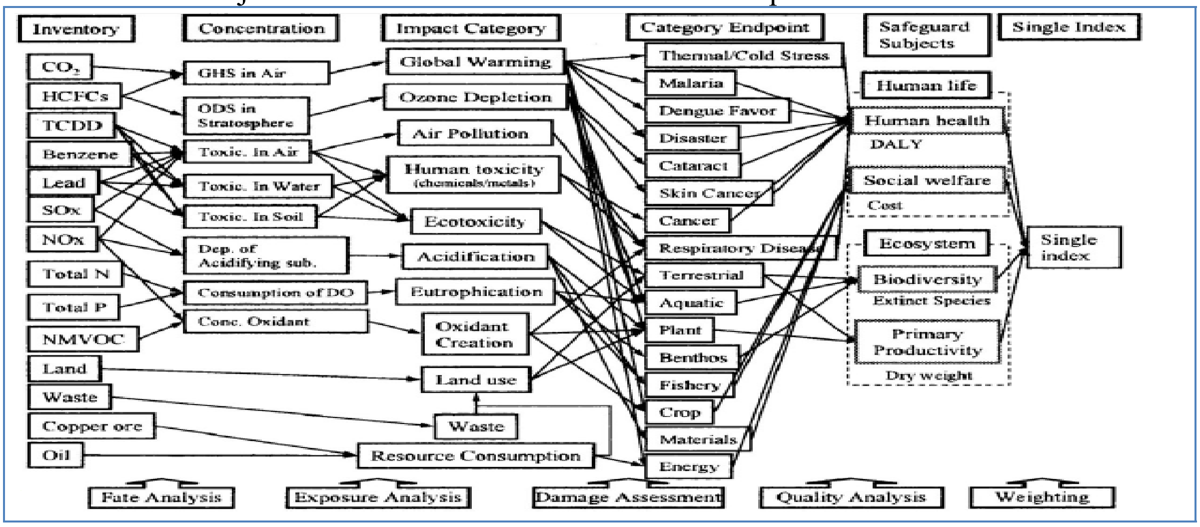


Figure 3: Air emissions and their impacts merged as single index Itsubo and Inaba, 2007[16]

A well known impact category is the Climate change (formerly "Global warming ") potential. All emissions which produce a potential contribution to the greenhouse effect are assigned to this category . The most well-known emission in this category , due to the current discussion, is Carbon dioxide . In classifying the inventory data according to their potential environmental impact categories , an aggregation in each impact category takes place. The number of the data are therefore considerably reduced and the results can be better interpreted by referring directly to the environmental impacts . Since the inventory data are related to the quantitative reference of the product or process, this relation also exists in the life cycle impact assessment . The impact assessment results and also data obtained from the inventory analysis can be used jointly for the (later) interpretation phase of the LCA study.

The interpretation phase of LCA has within its framework of an evaluation, the results from the impact assessment and the inventory analysis are analysed and conclusions and recommendations are established. A further aspect is the transparent presentation of the LCA results.

As a case study approach when the above principles are applied to an iron industry as shown in figure5, the basis raw material source in the iron industry is the iron ore. So the processes of cradle to grave when applied start from the extraction of iron ore and at the grave stage is seem to be producing air emissions that affect the nature. This air emission can be linked back to the associated amounts of iron ore mined from a particular mining site owned by a public authority or an individual. It is at this context to pin pointedly determine the source of air emission and correlate to the ownership of the mine that attributed to environmental degradation, a mining cadastre can be useful when each of the single index as shown in figure6 is computed for the associated iron ore.

LCA AND MINING CADASTRE WITH FOCUS TO ENVIRONMENT

Depending on their particular legal system, governments grant mineral exploration and mining rights to particular areas by means of concessions, leases, licenses, or agreements. Efficient and effective granting procedures tend to be based on the following principles:

- A clear legal and regulatory framework
- Well-defined institutional responsibilities
- Transparent and non discretional procedures.

Several core principles have been integrated into the legislation of most mining countries.

"These principles are as follows:

- Mineral resources belong to the state.
- The right to explore and exploit these mineral resources may be temporarily transferred to an individual or corporate entity through a written document, normally called a license or lease.
- The mineral rights granted through such a license or lease are considered real estate properties, but are independent from surface or land ownership rights.
- The granted license or lease usually does not provide for visible physical boundaries (such as fencing); instead, the area is usually delimited by geographic references or coordinates.
- The holders of the granted license or lease must fulfill pre-established conditions to maintain their rights over the area.
- When the validity of the granted license or lease ends, the rights return to the state."

All the above core principles can be incorporated in to a core data model an example of which is shown in figure7. Figure7 shows the possible linkages that can be drawn in a data model of a mining cadastre or a general cadastral system to Life cycle assessment.

"Resource management, i.e. the extraction and processing of natural resources, is viewed as crucial for LCA studies, because the impacts of this stage may well surpass those of other life

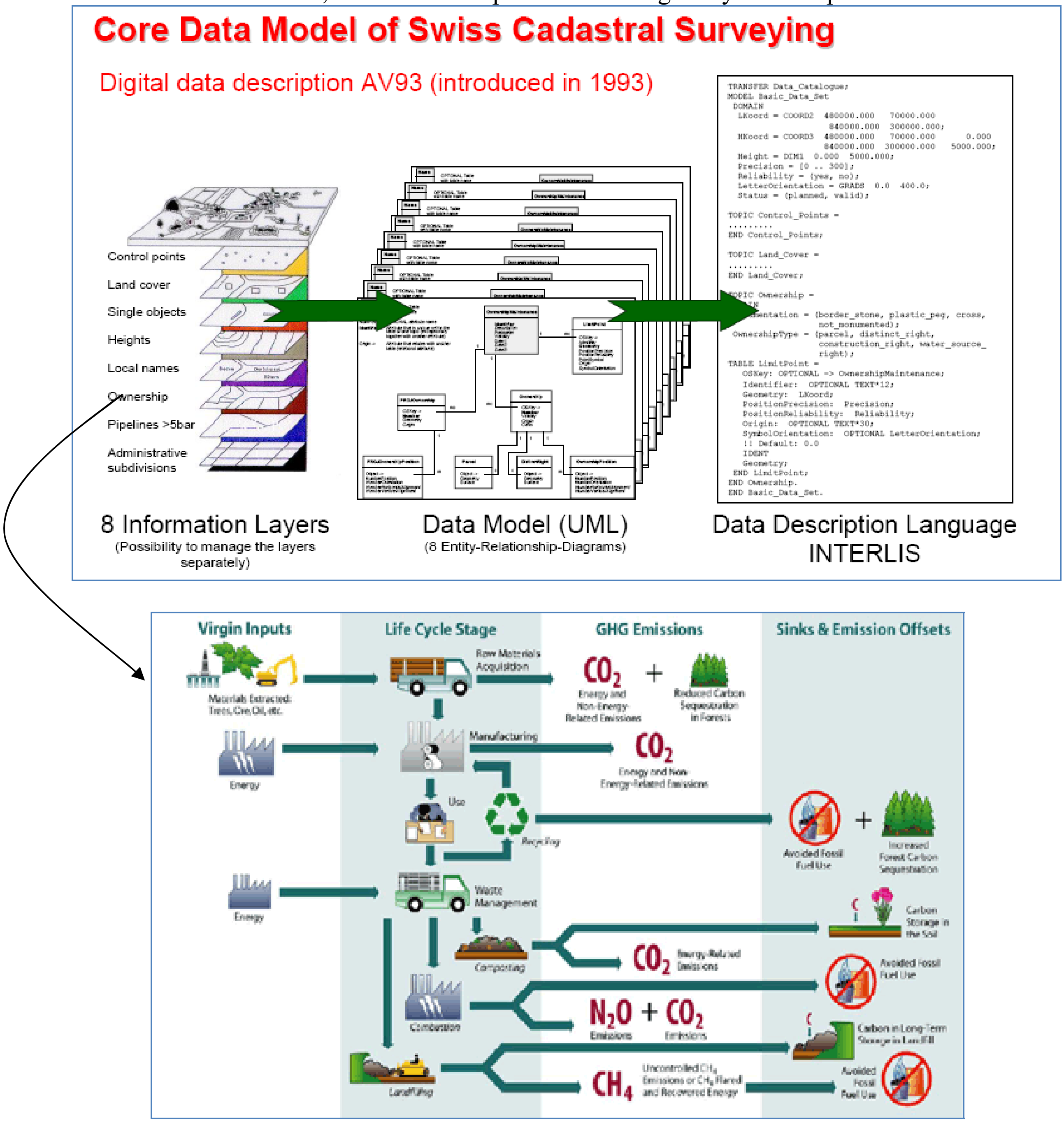


Figure 4: example of interlinkage of a cadastral system to Lifecycle analysis

cycle stages (Udo de Haes 2006). The LCIA framework of the global life cycle initiative indicates that abiotic resources form part of the natural resources area of protection, as a safeguarded subject, i.e. an operational subject of direct value to human society (Jolliet et al. 2004)." Scarcity always has a time dimension; it can be interpreted as change in availability over time. This is difficult to address, as we know little about the future and less if it is further away. With minerals, scarcity is typically used synonymously with decreasing concentrations of mineral resources at some time in the far future. It has been shown (Strauss et al. 2006) that a comparison of current use with known economical reserves provides a much different picture of scarcity than that obtained when concentration and difficulty of extraction are used. The separation of environmental and economic aspects is an important issue to consider for the actual 'impact' of resource depletion, and specifically the comparison of one mineral resource to another.

MINING DATA AND IMPACT ASSESSMENT METHODS:

The existing impact assessment methods for the mined abiotic resource categories have been defined to fall into six groups [4]: "

- No aggregation or assessment of mined abiotic resource depletion in the characterisation phase of LCIAs (but rather in later phases, e.g. during weighting) [7].
- Aggregation of natural resource extractions on a mass basis [8].
- Aggregation and assessment based either on the quantity of resource that is ultimately available, or the (perceived) part of the reserve base that can be economically extracted, and the extraction rate at the time of the assessment [9–12].
- Aggregation and assessment based on the cost associated with substituting current extraction processes by improved (presumed) sustainable processes [13].
- Aggregation and assessment based on energy or exergy content or change [7,14].
- Aggregation and assessment based on the change in the anticipated environmental impact of the resource extraction process due to lower-grade deposits that have to be mined in the future [15,16].

ECONOMIC EVALUATION OF EACH EMISSION BASED ON ENVIRONMENTAL IMPACT ASSESSMENT ECO INDICATOR : CONSTRUCTING AN ECO PROFILE

"Eco-indicator 99 method [15], only takes into account the long-term trends of lowering resource quality. The method assumes that if the quality of a mined abiotic resource is reduced over time, the effort to extract the remaining resource will increase. Market forces will further ensure that the highest quality of the resource is exploited at all times. The increased future efforts are expressed in surplus energy units, i.e. the difference between the energy that is needed to extract a resource presently and at some point in the future. The future surplus energy calculation is based on an arbitrary multiplication of the amount of a resource that has been extracted prior to 1990 "

"Another characterisation procedure that is commonly used in South Africa, the CML methodology [4], applies the ultimate reserves and rates of extraction approach, which reflect the seriousness of resource depletion [10]. The characterisation factor is referred to as the Abiotic Depletion Potential (ADP) of each resource compared to a reference resource through the following formula (for mineral resources) [4]:"

$$ADP_i = \frac{DR_i}{(R_i)^2} \times \frac{(R_{ref})^2}{DR_{ref}}$$

Where
ADP_i= Abiotic Depletion Potential of resource i (dimensionless)
R_i= Ultimate reserve of resource i (kg)
DR_i= Extraction rate of resource i (kg.yr–1)
R_{ref} = Ultimate reserve of the reference resource, *viz.* Any heavy metal (kg)
DR_{ref} = Extraction rate of the reference resource (kg.yr–1)

"The result of the average production calculation and comparison with the Demonstrated Reserve is an impact score that is directly related to the depletion of resources. The ratio of the average annual production to the economic reserve (*depletion factor*) determines the rate of depletion"[3]: $D_f = P/R$
Where
D_f = Depletion factor
P = Average annual production of virgin material (kg.yr-1)
R = Economic reserve for the mineral (kg)

"A smaller ratio indicates a slower rate of depletion. This penalises minerals with a high production to reserve ratio, i.e. minerals that are currently being depleted at a faster rate. In addition to this, the actual use of the mineral for a specific process should be weighed against what is currently available to determine its relative impact, i.e. by comparing the actual use of the mineral to its economic reserve (*Use factor*)[3]:
$U_f = m/R$
Where
U_f = The Use factor that relates the mass of virgin material used in a specific process to what is economically mineable
m = Amount of virgin material used in a specific process (kg)
The calculated impact score of a mineral χ (in a specific process) is the product of the *Depletion factor* and *Use factor*:

$$\boxed{I_x = \left(\frac{P_\chi}{R_\chi^2}\right) \times m_\chi = \left(\frac{P_\chi}{R_\chi^2}\right) \text{(per kg } \chi)}$$

Since the average annual production of virgin material directly dictates the calculated impact score of a mineral – it is desirable to identify all the ownerships of the mineral resource that has high impact score. The amount of virgin material used in the specific process can be linked to the ownership of the virgin mineral resource from the mining cadastre and the final index in the form of impact score of the mineral can be calculated for the associated ownership. It can be well attributed that this impact score for the corresponding mine can be used for the allocation of mineral rights to owners. For a given production lesser the impact score, higher is the rate of exploitation of virgin resource and this information can be used to restrict additional mineral exploitation from a particular mine. As soon as there is a violation of the norm, mining cadastre can allocate for a new ownership, thereby reducing the amount of exploitation or at least bringing in measures to decrease resource exploitation.

CONCLUSION

A good mineral resource administration system based on the data and information about mineral ownership, valuation, and mineral use forms can lead to better mineral resource management. Several declaration's concluded that sustainable development needs sound land and mining administration. In developing countries, there is the potential that mine deals can be kept secret and there is a hidden uncertainty for local populations. This scenario could be blocked and the situation made more transparent with a well-defined mining cadastral system.

Mineral Title is the very essence of any mineral resource company. Without efficient management of their land holdings, a company runs the risk of losing its life blood. With the help of impact factors the mineral resource ownership can be restricted to promote less mineral exploitation. The depletion factors and use factors of the minerals are an useful attribute to identify the mines that are over exploited, this is facilitated through LCA. So life cycle analysis data for building a mining digital cadastre is essential to build a secure mineral rights system, the role of LCA combined with cadastral administration can lead to a better environmental sustainability with some minor problems in implementation measures.

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BIOGRAPHICAL NOTES

Manohar Velpuri graduated as a civil engineer from Indian Institutes of technology, Madras in 2005 and is pursuing Masters in department of Management, Technology and Economics, Swiss Federal Institute of Technology (ETH) in Zurich (ETH) with specialisation in: Sustainability and technology. After having involved in the design of software models like Easy plan for managing large construction projects like MRTS, Chennai in 2005, he worked for International business machines (IBM) as a software engineer in 2006 and later as a Developer in healthcare industry viz, Athena health care in 2007. Since 2005 he is closely associated in sustainability projects like carbon foot print calculator for Care for cimate(CfC) in addition to his professional experience in software modelling. Recognised from his efforts to develop the sustainability projects, he was invited to attend as one of the representation from India to Youth Encounter on Sustainability (YES) – delivered under the leadership of the ETH, Center for Sustainability (ETHsustainability) in collaboration with MIT Boston (USA), Technical University of Vienna (Austria), University of Tokyo (Japan), Chalmers University (Sweden) (August-September 2008). He was one of the 25 selected students from all over the world to attend the Oikos Winter school which aimed at converting ideas on sustainable economics and management into action. In 2008 he became one of the founding memebers of organisation careforclimate in Zurich.

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