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Deliverable D4.1 Literature review of Sustainable land management (and Risk-based land management) that can be applied to the Ronde Venen case study

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Author of deliverables: Hélène Beauchamp

Project coordinator organisation name: VU – Department of Animal Ecology

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1. Introduction

This document briefly reviews elements of Sustainable land management, and its application in the form of Risk-based management of contaminated land. The role of decision-support tools (including ERA and LCA) in the management process is briefly touched upon, as a means of facilitating stakeholder involvement. A case-study is introduced that outlines this process and presents different management scenarios. These scenarios will later be evaluated according to the framework developed in the course of the project MuSA.

2. Sustainable Land Management

Sustainable land management entails evaluating land management decisions based on criteria for sustainability, which implies consideration of the impacts on current and future generations of decisions made today. This is an explicit extension of the temporal and spatial scales usually applied in land management that is not based on concerns for sustainability. Sustainable development specifically entails the involvement of stakeholders from the socio-cultural, economic, technological, and environmental sectors in the decision-making process (Pollard et al 2004).

One aspect that deserves special attention within the framework of sustainable land management is the extension of the spatial scale beyond that of the site being considered. There are many benefits to be gained from approaching the management of contaminated and non-contaminated sites based on a regional strategy. Regional monitoring campaigns provide realistic gradients of soil characteristics, contaminant concentrations, ecosystem types, and land-use categories; yet, will minimize the variations between sites due to climatological and hydrological considerations. Moreover, data generation and analysis may be more efficient and informative when approached at a regional level. Furthermore, the allocation of resources to ecological restoration, contaminated land remediation, and development of land for human use can be evaluated simultaneously; thereby taking into account factors such as nature area connectivity that will strongly influence the success of ecological restoration projects.

A similar argument can be made for the extension of the temporal scale. Sustainable development explicitly considers the effects of decisions made today on future generations; whereas classical management methods may have been more focused on technological capabilities and cost-benefit analyses, while neglecting to consider ecological impacts or social equity.

3. Risk-based Land Management

Risk-based land management is a general strategy based on integrating concerns about sustainability into the management of contaminated land (Vegter 2001). More specifically, it applies to the decision-making process regarding cases of historical pollution. This is due to the general impression that contamination occurred historically because human beings did not know, or realize that their actions would have deleterious effects on the environment; whereas cases of pollution arising these days are due to negligence or willful disregard of ecosystem and human health (Vegter 2001). The latter cases are the burden of the responsible party, but the former cases are usually subject to governmental (municipal, provincial, or federal) management (Posthuma 2008). Laws are relatively clear regarding the legal limits of concentrations of substances in water, soil, and sediments, as well as the legal requirement to remediate in cases of exceedance; however, concerns exist about the economic, social, and environmental consequences of remediation on scales large enough to clean up the legacy of pollution left by generations of industrial activity.

Economic concerns are related to the high costs of soil remediation. These costs are high because the unit cost of remediating soil is high, and there are large amounts of soil to remediate. In many industrialized countries, including the Netherlands, social concerns are related to the notion of acceptability, which can only be defined in a specific socio-cultural context (Van Leeuwen and Vermeire 2007). Environmental concerns are related to the ecological impact of remediation activities (which are often destructive of the soil ecosystem), the environmental impact associated with the disposal of the remediation by-products, and the consumption or contamination of natural resources during the remediation activities. These concerns will be addressed briefly below.

3.1 High costs of soil remediation

In industrialized countries environmental awareness has lagged behind technological advances and population growth. This has resulted in the dissemination of persistent substances into the environment, the accumulation of which damages aquatic and terrestrial ecosystems, and may also threaten human health directly. It is unfortunately much easier and less costly to contaminate the environment than it is to clean it up. The significant lag time between the creation of environmental problems and the realization that they exist, combined with modern society's demand for industrial products and procedures has resulted in the current large spatial extent of contamination. The unit cost of removing contaminants from soil or sediments is high, and the quantities of soil requiring treatment are large; this combination results in high financial costs to any individual or organization undertaking soil remediation as a management strategy for contaminated soil.

3.2 Social acceptability

Risk is an indication of the probability that an adverse event or effect will occur (*sensu* Van Leeuwen and Vermeire 2007). In the case of historical pollution, the term "damage" may better describe what needs to be evaluated, since the substance is already present in the environmental compartment and any probability is related to the nature and extent of the effect it will cause rather than its occurrence in the soil or sediment (NICOLE 2002). The two notions of probability and adversity imply a subjective evaluation that will depend on the socio-cultural context of the situation, the person or organization assessing risk, and the legal framework defining an adverse event or effect.

As stated in a discussion paper created within the framework of the European Union research network NICOLE, one of the primary goals of risk-based land management is "reducing or eliminating risks associated with contamination to the acceptable levels for humans and ecosystems," (NICOLE 2002). This implies that as society changes its definition of acceptability, management goals and strategies for contaminated land may change as well. It also implies that environmental and ecological concerns are not of utmost importance in a society that accepts a certain level of contamination or environmental degradation either as a necessary trade-off for industrialization, or as the only economically viable option.

3.3 Environmental concerns

3.3.1 Ecological impact of remediation activities

Remediation techniques are typically sub-divided into three categories based on where and how they are carried out: in-situ techniques remove or extract contaminants without moving the bulk of the soil, onsite techniques involve large disruptions of the soil but do not involve transport of the soil off the site, and offsite techniques involve removal of the soil, transport to a treatment center, and may involve replacement of the clean soil, replacement using clean soil originating in another place, or no soil replacement. All remediation techniques will have an impact on the soil ecosystem; however, the impact on soil-dwelling organisms associated with non-destructive contaminant extraction will be lesser than the impact associated with excavation and incineration, for example. The positive side of this trade-off is the maintenance of the soil ecosystem, but the negative side is the typically lower removal efficiency and longer treatment times associated with this type of technique.

3.3.2 Disposal of remediation by-products

The by-products of soil remediation vary depending on the type of contamination and the technique employed, but they generally fall into the categories of soil solids, plant biomass, ash/ incineration products, and extraction or treatment liquids. The disposal of these by-products must be conducted in such a way that the contaminants contained within them do not re-enter the environment. Otherwise, the remediation efforts will result in the transfer of contamination from one site or environmental compartment to another. This situation does not satisfy the legal requirements typically associated with the remediation of contaminated soil; however, the acceptability of this kind of situation may fluctuate depending on the nature and amount of the contaminant, as well as the socio-cultural context of the contaminated site.

3.3.3 Consumption or contamination of resources

Remediation activities consume resources. The amount and nature of the resources consumed will vary with the type of contamination and the technique employed. Typical resources associated with remediation activities include fuel for excavation and transport vehicles, chemical substances used for extractions, water, materials (cement, asphalt, plastic), and energy resources used for incineration. The production and use of these resources result in emissions of greenhouse gases to the atmosphere.

4. Fitness-for-use approach to contaminated land management

The volume of contaminated soil, whether considered globally or on a national scale, is overwhelmingly large and continuously growing. Due to the high economic costs of contaminated land remediation and social implications of vast proportions of national territory being classified as "contaminated", many decision-makers have modified initial legal requirements for remediation. It should be noted that these decisions are made on a pragmatic level, rather than an ecological level. In some ways this seems contradictory to the concept of sustainable development whereby ecological considerations parallel economic and social considerations in the decision-making process. However, the theory behind sustainability is that three poles (ecology, economy, society) are considered in every step of the decision making process.

In the current socio-economic climate it is unrealistic to expect industrialized societies to value ecology as much or more than economy, because no consensus exists as to how to express ecological entities, services, or systems in universally meaningful terms. Moreover, the democratic political process is such that unpopular measures, such as the expenditure of public funds on massive ecological restoration projects, are unlikely to succeed in the absence of a) unequivocal scientific evidence of irreversible ecological damage, b) demonstrated risk or occurrence of damage to human health, or c) massive public outcry and support in favor of such measures despite lack of a) or b). The current trend is to approach this delicate compromise by considering the social, ecological, and economic implications of management decisions based on site-specific information.

Rather than apply the same rules regarding contamination concentrations to all contaminated sites, a graduated approach is taken whereby sites with different intended land uses have different legal requirements for the "cleanliness" of the soil (Swartjes 1999, Vegter 2001). This approach is based on the reasoning that sites with high ecological value and/or sensitivity should be granted priority over sites with little or no ecological value. For example, the concentrations of trace elements in soil to be used as a paved parking lot need not be as low as those in soil used as a playground for children, or as a wildlife reserve (*sensu* NICOLE 2002). Risks of contamination of groundwater due to soil contamination are assessed separately from risks to soil ecosystems, although the current trend is towards a harmonization of these processes (Jensen et al 2006).

5. Decision-support tools in the Risk-based land management process

The use of decision-support tools can facilitate a decision-making process by making it transparent and approachable to stakeholders of various backgrounds. Use of these tools can aid in the elaboration of criteria with which to evaluate different management scenarios, the prioritization of sites for management, and the setting of environmental quality criteria (Pollard et al 2004).

Ecological Risk Assessment (ERA) of contaminated land is a descriptive application of ecological risk assessment that may be more accurately described as impact assessment (Jensen et al 2006). It entails the description or estimation of changes in populations or ecosystems at specific sites or areas already polluted (Jensen et al 2006). Ecological risk (or impact) assessment is one decision-support tool embraced by many regulatory and management agencies.

Life Cycle Analysis (LCA) is a decision support tool that evaluates the environmental and human health impact of products or services. When considering management options for contaminated land, the impacts of various strategies can be evaluated in a common framework.

6. Application to a case study: the Ronde Venen in the Netherlands

Risk-based land management encompasses management options for contaminated soil that fall outside the realm of classic remediation techniques. This is particularly applicable in cases where removal efficiencies are low for the contaminant in question, the spatial extent of the contamination is large, and effects of the contamination on human health are low or non-existent.

Recently, a large research program was conducted in the Netherlands that aimed at elucidating the ecological effects of widespread, diffuse contamination on terrestrial ecosystems. This multidisciplinary program included in-depth investigations into two floodplains and one agricultural site having received soil amendments in the form of dune sand, municipal waste, and sewage sludge for approximately 350 years (Kools 2005). This site, called Ronde Venen, is currently grassland used as pasture for low densities of cows and sheep and habitat for birds and other wild fauna (Kools 2005). The soil of this site exhibits patchy distribution of elevated metal concentrations, specifically cadmium, copper, lead, and zinc; in some areas these concentrations exceed legal soil quality standards (Kools 2005). The Ronde Venen will be retained as a case study for the development and illustration of project MuSA. Five management scenarios will be explored; these are described below.

6.1 Do nothing

Description: The fields are not subject to evaluation according to ecological or toxicological criteria. Management is according to the desires of the landowner, and does not evaluate or consider the possible risk posed by metals or other substances in the soil.

Development of the site is according to the desires and goals of the landowner, and is most likely driven by considerations of economic value. No restrictions are placed on possible land use.

Questions and concerns:
1) What are the human health implications of not restricting land-use? For example, would residences be built on the site? If so, are there health risks for a) children playing in lawns or gardens, or b) inhabitants growing and consuming vegetables and/or fruit?
2) What are the ecological implications of taking no action? If adverse ecological effects occur, will they be detected?
3) Will there be an influence on local drinking water supplies?

6.2 Monitored natural attenuation

Description: Concentrations of metals in the soil decrease with time due to the effects of leaching, weathering, and soil development. Monitoring takes place at regular intervals and includes measuring metal concentrations in soil and plants, and evaluating the ecological status of the site. The input of atmospheric deposition will be considered to assess whether or not it is negligible.

Questions and concerns:
1) Natural attenuation in this case implies leaching into surface and groundwater: is this acceptable?
2) Are the animals grazing on the grassland consumed as meat, and if so, are there concerns regarding limitations of human consumption of that meat?
3) The ditches surrounding the fields are periodically dredged and the sediments spread on the perimeters of the fields: what proportion of the metals leached into the surface water is exported, and what proportion is contained in the sediments and re-introduced onto the grassland? How does this impact the time needed to reduce metal concentrations to below their legal limits?

6.3 Existing biomass removal

Description: The current vegetation is allowed to grow tall enough to mow and easily remove once or twice a year. The metals contained in the aboveground tissues are thus removed from the system. This is similar to the current practice except that currently grazing animals recycle much of the biomass to the fields via their droppings, whereas under a scenario of existing biomass removal, grazing animals would be excluded from the site in order to allow the vegetation to grow tall enough to cut and efficiently remove.

Questions and concerns:
1) Mowing and removal interfere with grazing by sheep and cows. How important economically or socially is this grazing activity to the local inhabitants? Would they find it acceptable that their animals could no longer graze the fields?

6.4 Phytoremediation

Description: Plant species known for their ability to accumulate metals in aboveground tissues are planted at the site. Their aboveground organs are periodically harvested and removed. Three sub-scenarios are identified:

a) use *Phragmites communis* (common reed) as remediation species
b) use *Salix spp.* as remediation species
c) use *Salix spp.* as remediation species + periodically add EDDS to increase removal efficiency

Questions and concerns:
1) Does phytoremediation constitute an ecologically significant means of transfer of contaminants from the soil to a) other sites or environmental compartments, b) organisms currently inhabiting the site, or c) organisms that will be attracted to the site based on preferences for the type of vegetation used for remediation?
2) Does the use of one plant species or the other provide more favorable habitat, or promote greater biodiversity?

6.5 Excavation

Description: The contaminated soil layer (average depth 50 cm) is excavated and removed. Soil is treated in a thermal plant (incinerated), or washed and brought back to the site. This scenario could proceed according to two options: a) refill the site with clean soil (indigenous or allochthonous) or b) do not refill the site.

Questions and concerns:
1) What would be the ecological impacts of not refilling after excavation, in terms of habitat for wildlife species or soil-dwelling organisms, for example?
2) If the site is not refilled, would it become a wetland ecosystem? If so, can the impact of changing from one ecosystem type (grassland pasture) to another (swamp, pond, or wetland) be quantified/assessed?

7. Conclusions and next steps

Incorporating concepts of sustainability into the management of contaminated land is important, especially when considering sites characterized by large surface areas and persistent contaminants. The use of decision-support tools within a framework of risk-based land management will promote transparent decision-making processes and may prevent counterproductive remediation efforts. The combined use of two existing decision-support tools (ERA and LCA) will provide useful insight into the environmental and ecological impacts of management strategies. This combined use will be illustrated via a case study based on the evaluation of management strategies for a grassland ecosystem in the Netherlands characterized by historical pollution and high levels of certain trace elements.

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