SNOWMAN NETWORK

Knowledge for sustainable soils

Rejuvenate

Crop Based Systems for Sustainable Risk Based Management for Economically Marginal Land

Final report

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- REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Land, Phase 2, Midterm Report, 2011, Andersson-Sköld, Y, Crutu, G., Enell, A., Georgescu, P-D, Hoppenbrouwers, M., Vanheusden, B., Wagelmans, M, Witters, N., Bardos, P., Track, T. www.snowmannetwork.com/upload/documents/call2vienna/Rejuvenate%20Midterm%20Report.pdf

- Andersson-Sköld, Y., Chalot, M., Bert, V., Deplanque, M., Crutu, G., Track, T., Bardos P., The Rejuvenate DST for biomass selection on marginal land – results from case study applications, Manuscript in prep. 2013

- Enell, A., Vestin, J., Wagelmans, M., Lithner, D., and Andersson-Sköld, Y. Cultivation of bioenergy crops on contaminated land – Risks and potentials based on field experiments in Sweden. Manuscript in prep. 2013

- REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Land – Micasasa, Copsa Mica, Romania, 2012, Crutu, G., Lithner, D., Wagelmans, M., Andersson-Sköld, Y. http://projects.swedgeo.se/r2/index.php/downloads

- REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Land, DST Short User Guide, 2013, Andersson-Sköld, Y, Bardos, P., Track, T.

- REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Land - Ecological and environmental assessment of the crop based systems for sustainable risk based land management (RBLM), 2012, Wagelmans, M. Bioclear report

- Legal and economic aspects of crops selection for phytoremediation purposes and the production of biofuel. Vanheusden, B., Hoppenbrouwers, M., Witters, N., Vangrosveld, J., Thewys, T., Van Passel, S., 2012,. Report, Hasselt University.

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1 SUMMARY

The Rejuvenate project was initiated by a desk study carried out by four organisations from the United Kingdom (UK), Sweden the Netherlands and Germany. Its goal was to assess the potential opportunity for using marginal land, in particular brownfields and other previously developed or contaminated land, for producing biomass. This biomass could be used for energy, fuel production or as a feedstock. The aims of the first phase were (i) to explore the feasibility of a range of possible approaches to combine risk based land management (RBLM) with non-food crop land-uses and organic matter re-use as appropriate, (ii) to identify a range of potential opportunities worthy of further development in the UK, Germany and Sweden and in a wider European context, (iii) to assess how verification of their performance might be carried out and (iv) to identify what requirements remain for future research, development and demonstration.

One practical result from the first phase of the Rejuvenate project was a decision-making framework (or *decision support tool, DST*) serviceable in Germany, Sweden and the UK. These countries have substantive differences in their land, and biomass re-use, contexts and the tool was aimed to be applicable across Europe.

A central task of the project during its second phase (Rejuvenate 2) has been to evaluate the decision support tool against different case studies. In addition the project consortium was broadened to include partners from Romania and Belgium and also co-operation with other research projects. The specific objectives of Rejuvenate 2 (R2) were designed to address the research and development gaps identified in the first phase of Rejuvenate by:

1. Establishing three full scale case studies in the participating countries

2. Validating the decision support approach based on Strength, Weakness, Opportunity and Threat (SWOT) analysis, with regard to i) crop and site management and ii) biomass use and delivery of value to stakeholders.

3. Performing ecological, environmental, legal and economical assessment of the crop based systems for sustainable RBLM, including the full chain from choice of fields to biomass use.

4. Identifying ongoing research, developments and experience of implementation agendas for the re-use of contaminated land for biofuels.

5. Providing a mechanism for other countries and third party funders to add further case studies to the project over its three year life span.

This report provides a summary of findings against these objectives applying the Rejuvenate Decision Support Tool (DST) at demonstrations sites. This includes a SWOT-analysis and an example of applying the DST on radioactive land.

The DST was applied to select demonstration sites and for selecting crops to be cultivated at the sites. In Sweden the sites Vivsta varv, in Vivsta, Utansjöverken in Utansjö and the Häggatorp landfill in Kallinge were selected. In Romania Micasasa, Copsa Mica was selected.

At the Swedish sites Willow was selected after going through the DST stages. The main reasons were that (i) it is suitable for the climate, (ii) is a commonly used species for bioenergy which easily could be used in the available facilities and infrastructure and (iii) there are commercially available clones that were expected not to extract the contaminants from the soil. The final choice was *Salix Klara* for Vivsta and *Salix Inger* for the Häggatorp landfill. In Romania the main criteria was that the land owner, or nearby farmers, would be willing to manage the crop cultivation and harvest. The aim was further to investigate the uptake in the plants. The selected species, corn, sun flower, *Miscanthus*, alfalfa and potato accordingly were species currently in use in the area.

The contamination levels at the sites vary and accordingly the project has provided examples from Sweden and Romania on energy crop cultivation on low to highly metal contaminated land.

These results indicate that the risks are low at the sites with low and moderate soil concentrations (Swedish sites). The results and experiences including an extensive ecological and environmental risk assessment at one of the Swedish sites have been summarised elsewhere (Enell et al. 2013, manuscript in prep.).

The risk, based on the calculated risk for model grazing animals and the toxic pressure calculated from the soil concentrations, risk at the more contaminated site in Romania is higher than found for the Swedish sites. The results and experiences of the Romanian site has been summarised in Crutu et al. (2012).

Currently the usual use of crop grown in the area is to feed domestic cattle. This poses a higher risk than use for energy or other non-food purposes as is the intention in Rejuvenate. Accordingly, using the crop for energy instead of feeding cattle can be a more favourable alternative. To identify the best land use alternative, a discussion based on the results from this project among the different stakeholders in the area is suggested.

The results from the various demonstration sites have been used to test the DST by a Strength, Weakness, Opportunity and Threat (SWOT) analysis.

The DST has been shown to be systematic, transparent and applicable. It is useful for assessing the risks, costs and benefits on internalities, environmental risks and externalities. The experience is also that the tool is best used as a checklist in an iterative procedure. Based on the activities in Rejuvenate we even recommend the tool be used in an initial step to identify non-working alternatives and to find out which and what type of information is needed before more robust decisions and planning can be undertaken.

One of the major concerns raised about the DST was the lack of a short guide so this project has provided a short guide. This is based on the more extensive description in Bardos et al. (2010). It can be downloaded from http://projects.swedgeo.se/r2/.

2 GENERAL DESCRIPTION OF THE PROJECT

The increasing importance of biomass for energy production and feedstocks for manufacturing processes such as for biofuels and plastics has become a worldwide phenomenon. Establishment of non-food crops for biomass can contribute to policy goals related to renewable energy and carbon management (Bardos et al., 2011). However, the use of land to produce any type of biomass for feedstocks, fuels and energy has become increasingly contentious, with a number of environmental, economic and social sustainability concerns raised (Bardos et al., 2011). The use of marginal land is an emerging opportunity in this biomass debate. Marginal land includes previously developed land, under-utilised land and land affected by diffuse contamination. All across Europe there are areas of land that have been degraded by past use, which are not possible to restore easily or sustainably using conventional methods. This land includes areas affected by mining; fallout from industrial processes such as smelting; activities related to forestry and the pulp and paper industry; areas elevated with contaminated dredged sediments; former landfill sites; and many other areas where the decline of industrial activity has left a legacy of marginal land and economically disadvantaged communities. The extent of contamination may not be sufficient to trigger remediation under current regulatory conditions, and there may be little economic incentive to regenerate the areas affected. While the scale of this land bank can be seen as small compared to published estimates of likely areas needed for biomass crops, for example to meet the European Union (EU) Transport Fuel Directive, it can nonetheless be very significant in some regions and localities. Connecting the re-use of such land to biomass, biofuel and biofeedstock opportunities may be an important step in bringing this marginal land back into beneficial and sustainable use and removing its environmental, social and economic impacts on affected communities (Bardos et al., 2011, Suer and Andersson-Sköld, 2011).

The use of this marginal land for biomass may offer sustainability advantages in regions where it is present in significant amounts and cannot be readily used for built development. In addition, composts and other recycled organic matter may play an important role in the soil improvement and management necessary for the cultivation of these non-food crops. Hence the combination of biomass cultivation and soil rehabilitation could be an integral part of land rehabilitation and risk management in the long term. There may also be further benefits from this approach to land use, for example, providing: a self-funding land management regime; economic activity to deprived areas; long term improvement in land values; and environmental benefits such as carbon sequestration.

The Rejuvenate project was initiated by a desk study carried out by four organisations from the United Kingdom (UK), Sweden the Netherlands and Germany. Its goal was to assess the potential opportunity for using marginal land, in particular brownfields and other previously developed or contaminated land, for producing biomass. This biomass could be used for energy, fuel production or as a feedstock. The aims of the first phase were to explore the feasibility of a range of possible approaches to combining risk based land management (RBLM) with non-food crop land-uses and organic matter re-use as appropriate; identify a range of potential opportunities worthy of further development in the UK, Germany and Sweden and in a wider European context; and assess how verification of their performance might be carried out - identifying what requirements remain for future research, development and demonstration (Bardos et al., 2010).

One practical result from the first phase of the Rejuvenate project was a decision-making framework (or *decision support tool*) serviceable in Germany, Sweden and the UK. These countries have substantive differences in their land, and biomass re-use, contexts and the tool was aimed for to be applied across Europe.

A central task of the project during its second phase (Rejuvenate 2) has been to evaluate the decision support tool against different case studies. In addition the project consortium was broadened to include partners from also Romania and Belgium and co-operation with other research projects.

2.1 Aim of Rejuvenate 2

The specific objectives of Rejuvenate 2 (R2) were designed to address the research and development gaps identified in the first phase of Rejuvenate. These fell into five categories as described below.

Rejuvenate 2 set out to:

1. Establish three full scale case studies in the participating countries

2. Validate the decision support approach based on Strength, Weakness, Opportunity and Threat (SWOT) analysis, with regard to i) crop and site management and ii) biomass use and delivery of value to stakeholders.

3. Perform ecological, environmental, legal and economical assessment of the crop based systems for sustainable RBLM, including the full chain from choice of fields to biomass use.

4. Identify ongoing research, developments and experience of implementation agendas for the re-use of contaminated land for biofuels.

5. Provide a mechanism for other countries and third party funders to add further case studies to the project over its three year life span.

2.2 Structure of report

In this report a summary of applying the Rejuvenate Decision Support Tool (DST) at demonstrations sites including a SWOT-analysis and an example of applying the DST on radioactive land is provided. Details about the demonstration sites and their performances can be found in Andersson-Sköld et al., 2011, Crutu et al., 2012, Wagelmans (2012) and Enell et al (manuscript in prep.).

The results of applying the DST, has resulted in a short Guide for the Rejuvenate Decision Support Tool which can be downloaded from projects.swedgeo.se/r2/index.php/downloads.

The structure of the report outline is as follows: a summary of the results from the demonstration case studies; summaries of the risk assessments on ecological and environmental aspects, and legal and economic aspects assessments; a summary of applications of the DST at demonstration sites; the SWOT analysis; and a final discussion.

3 RESULTS FROM REJUVENATE DEMONSTRATION SITES

In order to enable more consistent and accurate assessments of contaminated sites in Sweden, the Swedish Environmental Protection Agency (Swedish EPA) has developed a methodology of surveying contaminated sites; MIFO (*Metodik för Inventering av Förorenade Områden, Methodology for Inventory of Contaminated Areas)* and a database where information on investigated sites are compiled. This database proved to be useful when searching for suitable sites to include in R2's full scale case studies. There were, however, several reasons for disqualification of sites, in general the most prominent ineligibility factors can be summarised as:

- Site had a small area
- No available data on contaminants
- A generally low exploitation value → Few/no soil investigations
- The area was not suited for biomass plantation (e.g. mining waste, hard surfaces)
- The land owner or municipal authorities were negative about hosting a case study, e.g. because its exploitation value was seen as to high, or that there was already an agreed remedial actions, and/or the sites were regarded too toxic.
- The site was geographically remote

In practice, after final agreements with regulators, the area available at the three most appropriate sites turned out to be rather limited: 2.5 ha at Vivsta varv, 0.5 ha at Utansjöverken and 0.075 ha at the Häggatorp landfill in Kallinge. At the Häggatorp landfill and Utansjöverken there were restrictions of land use and at Vivsta varv there already was planned remediation on the main parts of the areas. At these three sites Willow, i.e. *Salix Klara* (Vivsta varv and Utansjöverken) and *Salix Inger (*the Häggatorp landfill), was cultivated. Salix was chosen at the sites as a result of applying the DST as previously described in the Mid-term report. Of the three demonstration sites initially concerned, the Häggatorp landfill in Kallinge and Vivsta varv in Vivsta supported the trials aimed for in the project. At the third, Utansjöverken, the plantings failed but pot trials with soil from the site are still running.

The DST was applied also to crop selection at the Romanian site. The main criteria for the establishment of a full scale site in Romania was, in addition to being located in an area with known contamination, that it would be possible to find a landowner who was willing to produce biomass on the land. This implied that the land was already cultivated.

The pilots are briefly described below and the risk assessments performed for the sites is briefly described in section 4.

3.1 The Häggatorp landfill, Kallinge, Sweden

The Häggatorp landfill is located in Kallinge, Blekinge County, at an old landfill, situated at an industrial site called Kallinge Bruk. Since the mid-1800s, *Kallinge Bruk* has been the site of several industrial activities related to metalworking (such as copper rolling mills, sheet metal-, steel- and ironworks etc.). The full industrial site is approx. 240,000m^2 and previous environmental studies have shown that the soil has elevated levels of several metals. The landfill, which is called *The Häggatorp landfill,* is an old industrial waste dump area, where slag from a local metal industry and spoil from excavation works at an adjacent industrial site have been deposited. In general, the site contains of a mixture of metal slag lumps and sandy soil. The site contains several spots where slag lumps have been deposited without any further mixing with soil. The area used for cultivation is limited to approximately 0.075 ha in size.

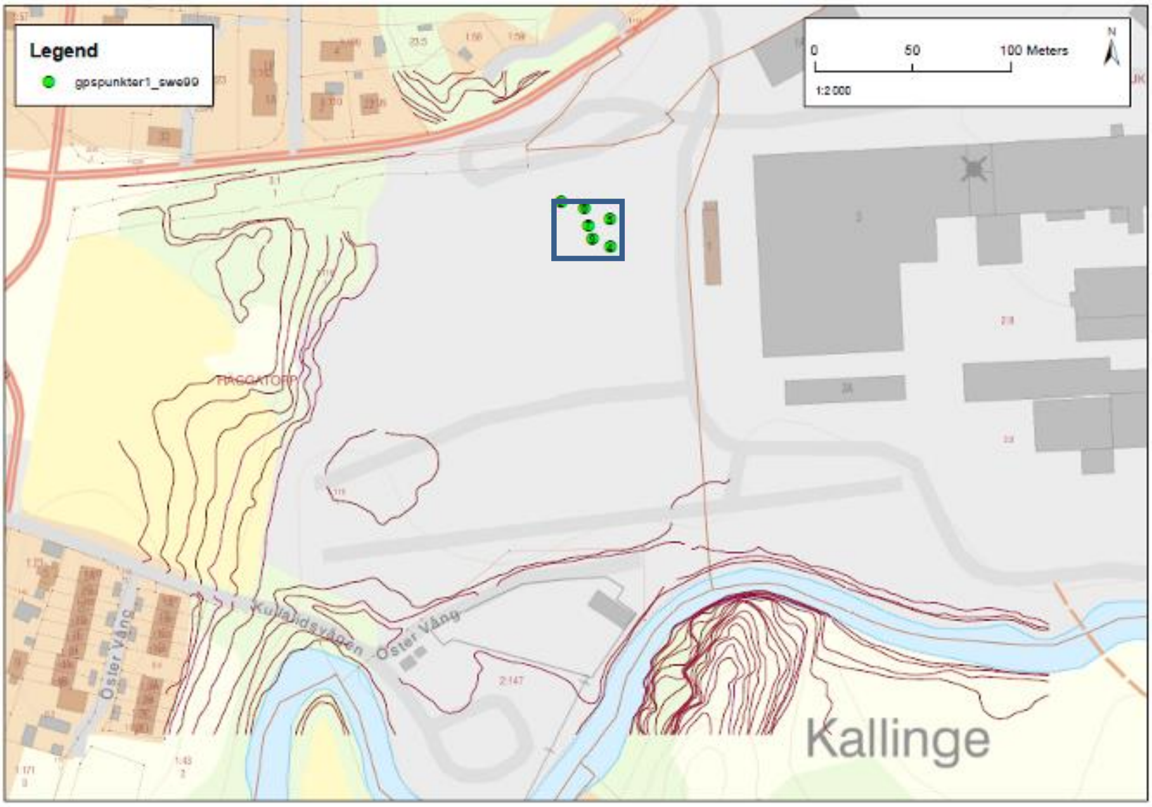

Figure 1. Map showing the designated area provided for the cultivation of willow at the Häggatorp Landfill, which is located in Kallinge, Blekinge County, Sweden.

Several environmental investigations were conducted at Kallinge Bruk during 1997-2002. However, at the specific location of Rejuvenate's pilot, at the landfill area, fewer investigations seem to have been performed. To our knowledge the only data available were on ground water (concentrations of metals and other inorganic compounds, pH, conductivity, etc.). These data collected from pipes installed at two spots adjacent to the area of the pilot. Accompanying results on metal analyses of soil samples only stated whether or not metals were found in levels above or below the Swedish guideline values for contaminated soil, i.e. no information on specific concentrations was given. Furthermore, none of the sampled spots were located directly within the actual area intended for cultivation, but only in adjacent areas. Accordingly, a pre-study prior cultivation and further sampling was carried out using energy-dispersive X-ray fluorescence spectrometry (XRF). These analyses showed elevated concentrations of metals such as copper, zinc, and lead (see Annex 1 in Mid-term report for further details). Subsequently the pilot was assessed by Triad analysis prior cultivation.

In July 2010 1,200 willow rods (*Salix Inger*) were planted at the pilot location (750 m^2). During the summer of 2010 weeds were removed manually and the site was occasionally irrigated. Nevertheless, the weeds were strongly competing with the willow plants for soil, light and nutrients and hence a geo-textile was applied to supress the weeds. In October 2011 a replanting of *Salix Inger* was carried out to replace dead plants.

Soil and biota (leaves) samples for chemical analyses were taken through the course of the project and after two years of cultivation a second Triad analysis was performed on the site. One of the main objectives of this pilot was to perform a detailed ecological risk assessment applying the Triad approach. Triad is well established to assess the ecological risks in polluted sediment, water and soils (Chapman et al., 1987; Jensen and Mesman, 2006).

The growth of willows was estimated in the autumn of 2012 using a non-destructive method.

3.2 Micasasa, Copsa Mica, Romania

Copsa Mica is a town located in Sibiu County in the centre of Romania (Transylvania). It is located in the basin of Tarnava Mare River. The river basin is surrounded by hills and includes several farming villages. The Rejuvenate demonstration site is located in Micasasa village in the west of this region (Figure 2).

The land is favourable for agriculture, but the soil is severely contaminated by deposition of heavy metals from previous metallurgical activities. The metallurgical factory for processing and mining non-ferrous minerals (today SC SOMETRA S.A.) began in 1939. The concentrations in the soil found at the start of the project were high and in the same range as previously measured in the area by Tudoreanu et al (2011).). Despite elevated heavy metal concentrations in the soil in the area, the current activities near the site are agricultural production activities and the surrounding hills are used for grazing. The total demonstration site area is 0.98 ha.

This site has been used to investigate heavy metal uptake in a selection of non-woody crops, i.e. wheat, barley, maize, sunflower, alfalfa and potatoes and *Miscanthus*.

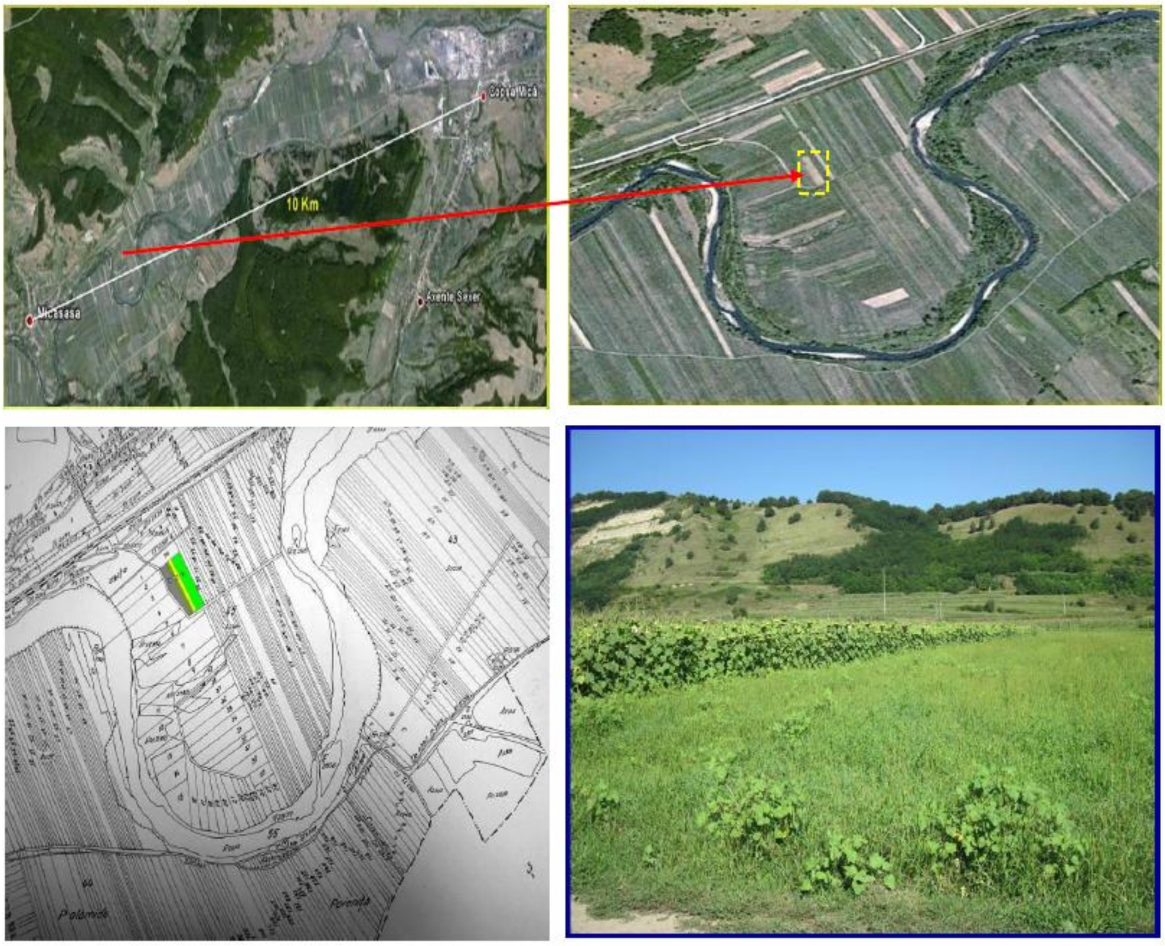

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Figure 2. The demonstration site at Micasasa, Copsa Mica, Romania.

3.3 Utansjöverken, Utansjö, Sweden

Utansjöverken is located in the middle of Sweden. Utansjöverken has been in use for industrial purposes since the 18th century. Since 1898 the major activity was pulp and paper production. Industrial use ended in 2007. A risk investigation was carried out at Utansjöverken (Sweco, 2008). The demonstration site for the Rejuvenate project (0.5 ha) is located in the northern part of the Landfill area. The Landfill area of Utansjöverken (8 ha) was previously used for waste of sludge, ash etc. from the pulp and paper industry (Sweco, 2008). In the landfill area pH is alkaline, but most of the analysed heavy metals are in concentrations below the Swedish MKM guideline value (Sweco, 2008). MKM refers to Mindre Känslig Markanvändning which is the Swedish guideline values for less sensitive use of the land such as land for industrial purposes (Swedish EPA, 1999). The aim of the demonstration site was to investigate if the willow would grow under the alkaline conditions.

In July, 2010 the demonstration site was harrowed and willow (*Salix Klara)* was planted manually. At the time for planting, composite soil samples were taken. In August 2010, further soil sampling was carried out. Samples were analysed by ALS Scandinavia for metals, sulphur, phosphorus pH, organic carbon and conductivity. No samples showed any concentrations above MKM guideline values.

Despite weeding, which was performed once in august 2010, the weeds were still dominating at the site and at some spots there was nothing growing at all. After the winter 2010-2011 most of the plants were dead. It was concluded that Salix Klara could not grow under the conditions prevailing at Utansjöverken. The study at the demonstration site was thus closed. As a complement to the field study, pot cultivations with soil from the demonstration site were investigated.

The aim of the pot cultivation with soil from the demonstration site was to study if additives like municipal sewage sludge, commercial plant soil and sand in different proportions could improve the growth conditions for the Salix Klara. Salix Klara was planted in May 2012 into five pots with different proportions of soil, sludge and sand. The five mixes all contained soil from Utansjöverken mixed with: sewage sludge (5 %); commercial plant soil (50 %); commercial plant soil (20%) and sand (30%); commercial plant soil (15 %), sewage sludge (5 %) and sand (30%); no amendments. In September 2012, the lengths of the sprouts were measured. The best growth was found in the pot with 50% commercial plant soil together with the soil from Utansjöverken. Full details about the pot trials are given in Annex 3. Commercial plant soil has an optimized nutrient composition and this large addition in the pot trial improves the nutrient conditions for the sprouts which probably resulted in the better growth.

At the conditions prevailing at Utansjö, with stones and already established weeds, *Salix Klara* did not survive while all sprouts survived in the pot trials with soil from the same demonstration site. This indicates that the site conditions with stones and weeds were the main reasons to the low survival of sprouts in the field trials and not the low contaminated soil or the highly alkaline conditions.

3.4 Vivsta varv, Vivsta, Sweden

Vivsta is located in the middle of Sweden. The area was in industrial use for approximately 200 years. The activities have included a wharf, a saw mill, wood preservation facility, a sulphate factory, a board factory and an enterprise for the production of fine paper. Industrial use ended in 2007. A risk assessment was performed on the site (Swepro, 2010). The Rejuvenate demonstration site at Vivsta (2.5 ha) is located on the former timber storage area. All measured concentrations of metals and dioxins within the demonstration site are below the general guideline values MKM. The concentrations were also below the site specific guideline values indicating that the risk is limited (Swepro, 2010). The main aims of the demonstration site at Vivsta were to investigate the biomass production (growth) and to see if there is any uptake of contaminants into the biota. The investigation includes the impact of sewage sludge as soil improver.

The demonstration site at Vivsta was already divided into smaller areas by roads. Consequently the site was suitable for testing the impact of sewage sludge compared to no amendments on the growth and contaminant uptake. In July 2010, the site was harrowed, sludge was spread on half the site and the willow (*Salix Klara*) was planted manually. Composite soil samples were taken at the time of cultivation. These samples were analysed by ALS Scandinavia for metals, sulphur, phosphorus pH, organic carbon and conductivity. Soil samples for chemical analysis were collected twice after cultivation once in September 2011 and once in 2012. Soil samples were taken at the surface and at 30 cm depth at both areas with and without sludge. The growth of willow was found to be uneven across the demonstration site. Hence composite soil samples were taken in 2012 from areas with different growth. The aim was to see if the different growth was related to soil nutrient status. Composite samples of leaves were collected from areas with and without sludge for analyses of metals, and nitrogen. A composite sample of leaves from all areas was collected for analyses of dioxins. Growth of willows was estimated with a non-destructive method. Biota samples were taken at the same occasions as the soil samples.

Metal concentrations in the soil were found to be below guideline values. The metal concentrations in areas with high growth were in the same range as (even higher than) the metal concentrations in the areas with low growth. Thus it seems that the deviations in growth depended on the soil texture rather than the contaminant concentrations in the soil.

In the previous risk assessment made by Swepro (Swepro 2010) the risks were estimated to be low. Since the concentrations found in soil and leaves during the cultivation period were lower, the risks are still estimated to be low. The demonstration area is not a recreation area for humans and the area is not exposed to grazing animals neither domestic nor wild animals. The low concentrations found in leaves and soil at Vivsta in combination with minimal exposure for animals and humans strongly indicate that there is no risk related to the cultivation for non-food use at the demonstration site.

4 ECOLOGICAL RISK ASSESSMENT AT REJUVENATE DEMONSTRATION SITES

4.1 Ecological risk assessment based on Triad analysis

Risk assessment based on only total chemical analyses has several disadvantages and does for example not take into account:

- Bioavailability of pollutants
- Mixture toxicity
- Indirect effects of pollutants and
- Specific properties of the ecosystem at a certain site

Biological measurements can be used to, at least partly, overcome the disadvantages of risk assessment based on chemical analyses. One method in which a chemical assessment is combined with biological parameters is called the Triad (described in detail in e.g. report by Jensen and Mesman (2006) and references therein). The Triad is a fully validated method to assess ecological risks at a polluted site and reduces the uncertainties of risk assessment based on chemical analyses.

Triad consists of three lines of evidence (as depicted in figure 3):
1. Environmental chemistry: analyses of pollutants and the bioavailable pollutant fraction in soil, sediment and/or water, sometimes additional analyses of bioaccumulation in organisms.
2. Toxicity: bioassays and biomarkers for toxicity testing using model organisms in the laboratory.
3. Ecology: field observations of vegetation, macro, meio and/or micro fauna.

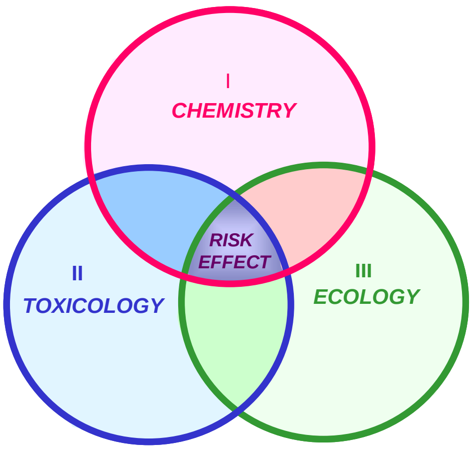

Figure 3 The Triad model; integration of three fields of research for ecological risk assessment.

For the assessment of ecological effects of a pollutant the results of the Triad analyses need to be compared to a reference sample. Preferably the reference sample shall be taken for unpolluted but otherwise similar characteristics. Finding such a reference sample can be difficult. One way of solving this is to use the sample with the lowest concentration of pollution. Furthermore, in order to determine a dose-effect relation, several sample areas with a gradient of pollution, graded from low (reference) to high (above guideline values), is needed.

Of the here investigated sites, the Häggatorp landfill site was selected as demonstration site for the Triad analyses and a number of 6 sample areas at the site, considering the area of the Häggatorp landfill site, was selected for detailed investigation to make a scientifically sound risk assessment. A first Triad analysis was performed before planting the bio-crop (*Salix Inger*) and was followed up by a second two years after cultivation. A short introduction of the analyses and the main conclusions draw from this integrated risk assessment is given here below (for more details the reader is referred to Appendix 1).

4.1.1 Environmental chemistry

Chemical analyses: total concentrations

As a basis for further soil analyses at the Häggatorp landfill site XRF analyses were performed by SGI. Based on the results of the XRF analyses six samples were taken for further Triad analyses before cultivation at the site.

In this segment of the Triad approach chemical analyses performed are total heavy metals concentration determined with digestions of soil samples in Aqua Regia (EN 13346) followed by analysis with ICP-AES (EN ISO 11885-1). Soil samples were taken from the first 30 cm bgl. The total concentration of pollutants was compared to the Swedish guidelines for contaminated soil and elevated levels of Cd, Cu, Pb and Zn was found at the site.

Chemical analyses: pollutant availability

The distribution, mobility and biological availability of chemical elements depend not only on their total concentrations but also on the forms (speciation/fractions) in which they occur at a site. At the Häggatorp landfill metal concentrations and not the specific forms of the different metals were measured. Soil organisms are able to uptake pollution which is dissolved in the aqueous phase. Especially soil dwelling organisms that are in direct contact with the soil are at risk. Therefore the Triad approach is directed at these organisms (nematodes, bacteria).

Metal fractions that are fixed in the soil have little effect on soil dwelling organisms. However, metals can be dissolved in water by processes such as oxidation and leaching. Soil properties such as pH, organic matter and clay content play an important role in modifying the soil oxidation and leaching processes.

Hence, bioavailable concentrations of heavy metals were determined on the basis of $CaCl_2$ extraction (NEN 5704). This method gives an indication of the fraction of metals

that is released to soil water and can be potentially up taken by organisms that are exposed to the pollution through soil fluids.
The parameters (pH_{H2O}), organic matter content, clay content and chalk content ($CaCO_3$) were also analysed.

4.1.2 Toxicology

The results from the chemical analysis (total concentrations of metals) were used to calculate the toxic pressure (TP) by use of the Dutch model Sanscrit (www.risicotoolboxbodem.nl). The certificates of analyses can be found in Bioclear's reports (Wagelmans, 2010; 2012). The TP varied from 2.4 to 43 % (based on total concentrations of heavy metals). According to the method standards, a toxic pressure above 25 % ecological risks is considered as a potential. Apart from analyses of total metal concentrations analyses were conducted on the available metal fraction. In only two of the six samples one of the heavy metals was measurably available, zinc in one sample and lead in another. These samples had the highest total concentration of zinc and lead, respectively. The toxicity at the Häggatorp landfill was further assessed by biological toxicity test as part of the Triad.

In the toxicity part of the Triad approach at The Häggatorp landfill in Kallinge bioassays were conducted. These are laboratory tests in which test organisms (organisms that are cultivated under standardized conditions) are exposed to polluted soil of the site. Microtox tests were carried out on site. This is an acute test in which bacteria are exposed to (an aqueous extract of) the soil from the Häggatorp landfill. This test is sensitive to heavy metals. The bioassay and Microtox test results indicated no bio-toxicity.

4.1.3 Ecology

In the ecological part of the Triad approach information about the ecosystem was collected by ecological field observation at the Häggatorp landfill site in Kallinge. Soil samples were collected for nematode analyses. Nematodes are tiny soil worms (up to 1 mm) that are present in soil in large numbers, up to 10 to 100 worms per gram of soil. Nematodes play an important role in the soil ecosystem, partly because they are present at all trophic levels (at different stages in the food chain). Thus nematodes are a measure for soil health and ecosystem disturbance. Analyses of the nematode population in soil give an indication of the degree of ecosystem disturbance.

Nematode analyses consist of determining the total number of nematodes per 100 grams of soil, as well as the number of different species, number of nematodes per species, number per feeding group (e.g. plant feeding, fungal feeding, bacterial feeding etc.), number per life strategy group (colonizer-persister (cp) scale) and the Maturity Index (MI). Colonizers are species with a short regeneration cycle and are able to colonize new sites more quickly. Persisters on the other hand prefer stable environments and have a long regeneration cycle (e.g. Wagelmans, 2012 and references therein). MI is the ratio between the number of colonizers and the number of persisters and is a measure for soil health. The use of nematodes and the MI is based on the evidence that colonizers dominate nematode communities in disturbed ecosystems. For instance, in a disturbed ecosystem, the number of persisters will decrease, which leads to a decrease in MI. The results from the ecological analyses at the Häggatorp landfill indicated that no negative effects were measured in the nematode analyses.

4.1.4 Integration of the three lines of evidence

For the assessment of ecological risks at the Häggatorp landfill the RIVM method (Mesman et al., 2007) was used for the integration of all lines of evidence

With regard to the toxicological and ecological analyses no negative effects were measured in the Microtox tests nor in the nematode analyses. After integration of all the results from the three lines of evidence no ecological risk was apparent. In all samples the lines of evidence point in the same direction. The results in 2012 (two years after planting) were comparable to the results in 2010. Based on the Triad results, it is hence concluded that the willow growth and the management measures taken, have not affected the ecological risks at this site. Overall it can be concluded that there is after two years of cultivation no unacceptable ecological risk at the Häggatorp landfill pilot site.

The Triad analysis is a rather comprehensive investigation and was only applied to one of our demonstration sites. However, since the pollutant concentrations in the soil and leaves measured in samples from Vivsta varv are lower than those measured at the Häggatorp landfill this indicates that the risk is negligible at this site as well.

At the Rumanien site Micasasa, in Copsa Mica, much higher metal concnetrations were found and the calculated toxic pressure was above 65 %. This means that at this site, severe ecological risks can be expected. Furthermore, the site is part of a bigger valley and this valley is supposed to be similarly polluted, and hence, ecological risks can be expected in the entire valley. However, if at the site the organic matter or clay content is higher, the TP decreases. The model used for the TP calculations is a rather conservative model regarding the ecological risks (Wagelmans, 2010; 2012). In an evaluation of site specific ecological risk assessment in the Netherlands, at 40 % of the sites that had ecological risks based on the computer model, no ecological risks were measured on site. That means that the risks are probably lower, but still present at Micasasa.

4.2 Risks for grazers

Above the low or no ecological risk at the Swedish sites was indicated. There may still, however, exist risks related to the intake of the crop by grazing animals. Accordingly, based on the concentrations of heavy metals in plants, risks for grazers were calculated. For this calculation cows and sheep were used as model organisms, even they do not graze directly on the plants used in this project. The assumptions used for the calculations are presented in Table 1. The risks were calculated based on dry weight of the plants.

The following calculations were used to calculate the risk quotient (R) for grazers:

R(Cow) = (Cplant * XC) / (Body weight * NOEC)
R(Sheep) = Cplant * XS / ADI

in which
Cplant = Concentration of metal in plant
XC = daily food intake for cow (dry weight)
XS = daily food intake for sheep (dry weight)
NOEC = No Observed Effect Concentration (mg/kg body weight/day)
ADI = Acceptable daily intake (mg/day).

Table 1 Assumptions made on daily intake and body weights for model organisms together with NOEC- and ADI- values for cows and sensitive sheep species.

	Cow	Sheep	Metal	NOEC[1] (mg/kg bw/d)	ADI[2] (mg/d)
Daily food intake (X)	10 kg	1.35 kg	Cd	0.09	14
Body weight	600 kg		Cu	0.67	20
			Pb	0.6	
			V	2.1	135
			Zn	37	406
			Cr		135

[1]No Observed Effect Concentration (mg/kg body weight/day) (Bosweld and van den Brink, 2001).
[2] Acceptable daily intake (mg/day), (National Research Council, 2005)

There is a risk for grazers if the risk quotient R is above 1. That means that an animal that grazes on food with that quality for its entire life would probably be at a certain risk. A high R means a high risk. Below 1 no risks are to be expected.

Based on the modelled worst case scenarios for the Häggatorp land fill and Vivsta varv it is concluded that it is safe for bigger grazing animals (risk quotients for cows) to graze on Salix leaves; R-values for all studied metals are below 1. For smaller animals (risk quotients for sheep as the model animal) indicate that there may be a risk of too high zinc-concentrations in the leaves for sheep like grazers. It should, however, be noted that all risk quotients are calculated from concentrations reported as dry weight and the concentrations in fresh leaves and stems are hence lower.

In Table 2 the calculated risk for (model) grazing animals at Micasasa, Copsa Mica, is shown. The calculations are done based on the average measured concentrations for the different vegetation parts. The cells where there is a potential risk (R > 1) are coloured by red.

Table 2 Calculated risk for model grazing animals (cow and sheep) at Micasasa.

Vegetation sample	Risk quotient, R							
	Cow				Sheep			
	Cd	Cu	Pb	Zn	Cd	Cu	Zn	Cr
Corn stem leaves	0.72	1.84	4.42	0.35	0.38	4.99	2.61	0.36
Corn cob leaves	-	-	5.62	0.82	-	-	6.02	0.52
Corn cob	0.06	0.22	0.06	0.04	0.03	0.60	0.30	0.27
Corn stem	0.78	2.45	2.13	0.59	0.41	6.64	4.33	0.78
Corn seeds	0.05	0.18	0.52	0.23	0.03	0.49	1.67	0.61
Sun flower seeds	2.81	0.31	1.13	0.51	1.46	0.84	3.79	1.04
Sun flower stem	0.40	2.60	2.96	0.37	0.21	7.07	2.75	0.16
Wheat seeds	-	-	2.19	0.73	-	-	5.39	0.41
Cereal straws	0.13	0.79	0.99	0.14	0.07	2.13	1.01	0.43
Miscantus	0.62	1.27	2.58	0.49	0.32	3.46	3.60	0.18
Alfalfa	0.49	2.14	0.75	0.17	0.25	5.79	1.26	0.51
Potatoes	0.37	-	2.29	0.23	0.19	-	1.66	0.14

Cells with R > 1 are highlighted with red colour.

As can be seen in Table 2 there is a risk for grazing animals at the Micasasa, Copsa mica, site with the exception of corn cob. The average is overestimated since the samples under detection limit are not included. However, there are many samples above the average level, and therefore we think this is a good indication of the risk in the area.

At Micasa, as at the two Swedish sites, there is no domestic grazing at the field. The harvested crops at Micasasa are however, in general used as to feed domestic cattle in the area. The general use of crop grown in the area, thereby poses a higher risk than when applied for energy or other non-food purposes.

4.2.1 Bio-concentration and translocations of metals

The bio-concentration of each metal in the plants or plant parts can be described by the bio-concentration factor (BCF), which is the ratio of the chemical concentration in biota to the chemical concentration in soil:

$BCF = concentration_{biota} / concentration_{soil}$

The calculated BCF of each metal in the Salix leaves and stems are presented elsewhere (Enell et al, manuscript in prep.)
At the Häggatorp landfill the BCF of arsenic, barium, cobalt, chromium, copper, nickel, lead and vanadium is well below 1 both in leaves and stems. Only zinc and cadmium have BCF above 1. Also at Vivsta varv the BCF is below 1 for the majority of the metals

(As, Co, Cr, Cu, Ni, Pb and V) in the salix leaves with exception for Cd, Hg and Zn (BCF > 1). In a previous study by Antoniadis and Alloway (2002) they showed that DOC can increase the mobility of especially cadmium and zinc. This could not be seen in this study as the BCF for Cd are similar both in the plots with and without sewage sludge amendment. For Hg, however, the accumulation was larger at the areas with sludge than for the non-fertilized plots.

At Micasasa the BCF varies with plant and part of plant. It also varies for the different metals. There are no plants for which none of the metals are accumulated in the plant in relation to the soil. The BCF for Pb, Mn and Cd are below 1 for all crops and parts of crops. The BCF for copper is above 1 for all crops, but in some crop parts, i.e. corn seeds and sun flower seeds, BCF for copper is below 1. The BCF for Zn is above 1 for all crops and crop parts, apart from alfalfa, corn cob and wheat straws. The average value for BCF for Ni varies among the different crop parts. The behaviour for As is to a high extent similar to the behaviour of Pb, Mn and Cd, but the BCF for corn-cob leaves and the corn stem are above 1. Among the studied cultivated plants, wheat (straws and seeds) have BCF above 1 once, i.e. Zn in wheat seeds and Cu in wheat straws. Also for potato there is only one metal (Zn) with BCF above 1.

4.3 Summary and general conclusions

In general it can be concluded that there are no ecological risks from biomass production at the Swedish sites (based on total concentrations of heavy metals and the ecological risk assessment by means of the Triad approach). At the Romanian site severe ecological risks seem likely based on total concentrations of heavy metals.

Levels of metals in plants have been used to assess the risk for grazers at all sites. At the Swedish sites it is safe for bigger grazing animals (risk quotients for cows) to graze on Salix leaves. For smaller animals (for sheep as the model animal) there is an indication that there may be a risk of too high zinc-concentrations in the leaves. All risk quotients are, however, calculated from concentrations reported as dry weight and the concentrations in fresh leaves are hence lower. Further the site at Vivsta varv site is surrounded by the Baltic sea, industry and a heavily trafficked road. Also the Häggatorps landfill site is located in an industrial area surrounded by a heavily trafficked road, limiting the risk related to grazing. The calculated risk for grazing animals is based on a daily intake from the same location. Since grazers and wild animals cannot easily access these sites, these calculations should be regarded as conservative.

At the Romanian site the risk for grazers is far higher than for either of the Swedish sites. There is no domestic grazing at the field. The field can be reached by wild animals from the surroundings but the risk is still low compared to keeping grazing animals on the field. The vegetation products, i.e. the harvested crops, in general are currently used as feedstock to feed domestic cattle in the area. The general use of crop grown in the area, thereby poses a higher risk than when applied for energy or other non-food purposes as the intention in Rejuvenate.

5 PRELIMINARY COST AND BENEFITS ASSESSMENT

The financial value and feasibility depend on the costs and revenues. The costs for the demonstration sites in Sweden and Romania are related to land management, sowing/planting, weed control, irrigation and it would also include harvesting and product transportation. As this is a research project there have also been costs related to soil and vegetation (biota) sampling and analyses. Those costs are excluded in the economic feasibility study described below.

The revenues are incomes from selling the product for biofuel or heat production. It can also be savings of heat, fuel or energy from external producers. It can also be savings by the risk control (e.g. phyto-stabilization, phyto-degradation).

The adapted gross income (AGI[1]) is the resulting net of costs and revenues related to the field managements and crop disposal This has been based on estimated costs for cultivation and income from the energy crops and exclude the change of the value of land. The direct costs were based on the real costs for the demonstration site, including the activities from sowing/planting to harvesting. The income has been based on general market prices, combined with interviews for the Swedish demonstrations sites.

In sections 5.1 and 5.2 below the adapted gross estimates related to the demonstration sites are presented for Sweden and the Copsa Mica area in Romania. Following is a summary of the Campine region study (previously reported in Vanheusden et al. (2011) and summarized in Andersson-Sköld et al (2011).

As pointed out by for example Witters et al (2009) and in the Rejuvenate report (Bardos et al., 2010) to make economically efficient decisions on crop choice, the internalities, e.g. investment costs, costs for cultivation and harvest, and revenues, should be complemented with public costs and benefits such as the renewable energy production potential. A brief discussion on the value of environmental costs and benefits such as carbon footprint impacts and other externalities is given after the field based adopted gross income estimates.

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5.1 Adapted gross income estimates

5.1.1 Sweden, the Häggatorp landfill and Vivsta varv

A template for calculations of potential costs and revenues of Willow for energy purpose and traditional agricultural crops in Sweden (Rosenqvist, 2010) was used to evaluate the economic feasibilities with this kind of cultivation. Findings were complemented by telephone interviews with heat producers and energy product producers have been made.

The revenue for energy product is based on the general flat value for the product being sold directly to a thermal plant for 704 SEK per ton ds based on the average prize for forest chips (ca 160 SEK per KWh, 2008) and the energy yield of 4.4 KWh per ton ds (Rosenqvist, 2010). The costs are based on flat rates for fertilizers, transports and working machineries

[1] AGI = revenue - cost

(Rosenqvist, 2010). The income depends on the amount of energy product produced. For a general case for a contaminated marginal land in Sweden, the production was assumed to be 5.4 ton ds ha^{-1} y^{-1} (over 20 years) which is the lowest prediction for energy crop on agricultural that is applied in the templates (Rosenqvist, 2010).

Predicted production at Vivsta varv is 0.5 ton ds ha^{-1} y^{-} over 20 years based on the measurements after 2 years cultivation (2010-2012). At the Häggatorp landfill the predicted yield is 4.15 ton ha-1 y-1 based on the measurements after 1 year cultivation (2011-2012).

The net gross income depends not only on the amount of biomass produced but also on how the crop is allowed to be treated. The final product may be regarded as produced for energy purposes, thereby supported by subsidies for energy crops as, providing a net gross income of € 50-160 ha^{-1} y^{-1}, i.e. 561-1561 SEK ha^{-1} y^{-} under the conditions at Vivsta varv and € 270-370 ha^{-1} y^{-1} (2700-3700 SEK ha^{-1} y^{-1}) at the Häggatorp landfill (Appendixes 11 and 13 in Andersson-Sköld et al., 2013a;b) The opposite, may also be the case, i.e. the product is legally regarded as waste thereby instead causing a net cost of € 165 SEK ha^{-1} y^{-1} (-1650 SEK) for Vivsta varv and even higher for the Häggatorp landfill (Appendixes 11 and 13 in Andersson-Sköld et al., 2013a;b). There also is a third alternative leaving the crop at the site. This will reduce the risk at the site by phyto-stabilisation, it will create a small carbon sequestration, and contribute to biodiversity compared to leaving the site without any action. The third alternative also results in a net economic cost, but limited compared to the waste case, and the area is improved and the risk managed.

In order to investigate which is the most realistic alternative interviews were done. Two producers of heat for municipally district (long distance) heating were interviewed. They are located in the middle (Sundsvall) and north (Umeå) of Sweden where the supply of residues from the forest industry is high. Both producers have boilers for burning of municipally wastes and boilers for burning biofuels like bark, pellets, sawdust, wood residues and tops and twigs. These producers of heat do not currently use willow as fuel owing to low supply in the north of Sweden. The producers assume that the supply from the forest industry will still be high in the future and they see no obvious need for willow. One of the producers argues that they will not deal with crops that have been growing on contaminated soil even although the concentrations in soil and crop are low or non-existent. The arguments are that these types of crops are too risky and controversial. Their view is that even if random samples are taken to estimate the levels of contaminants it is almost impossible to estimate the levels in large parties. The other heat producer assumes that their distributers of biofuels make a relevant estimation of their products and the levels of contaminants.

In addition, two producers of pellets have been interviewed. One is located in the middle of Sweden (Härnösand) and uses sawdust from the nearby sawmills as raw material. At present, this producer has a large supply of raw material and do not see a future demand for other materials like willow. The other producer of pellets is located in the south of Sweden (Jönköping). They use other biocrops than willow for their production. They have dealt with willow previously but these activities have been sold to another company and hence they are at present not interested in receiving willow.

A producer of biogas located in the middle of Sweden (Gävle) was interviewed. They convert gas from the municipal sewage plant to biogas. In other plants they produce biogas from residues of hey, grain or maize. Their opinion is that it is hard to degrade willow using anaerobic digestion and that this process should be more established before they are interested. Another company is planning to use residues from forest industry to produce biogas. They are building a plant and the first stage is planned to be operational in 2013 and the second stage is scheduled to 2016 (www.goteborgenergi.se). Since their activities have not yet started, this company has not been interviewed in this study but there is a potential for using willow as their raw material.

One organisation that deals with contaminated soil and waste has been interviewed. They deliver wood residues and tops and twigs to nearby producers of heat for municipally long distance heating. They have an established organisation for collection and delivery but no own boilers. In their opinion, willow has to be dried before burning to get a better energy output. One way is to leave the willow in field after harvest to dry for about three months. They do not see any potential implications with crops that have been growing on contaminated soil. If the content of for example metals is high in the crop, the crop should be burnt in boilers designated for waste. Otherwise the crop should be burnt in boilers designated for biofuels.

Finally, an organization that arranges planting and harvesting of willow and also manages the sales and delivery of the wood chips to the power plant was interviewed. This organization is located in the south of Sweden. They see a large market for cultivation of willow as a crop for energy production and the restrictions are the distances to the power plants. If the distance is more than 50 km to the power plant the cultivation is not feasible from an economical point of view. If it is known that the willow has been growing on contaminated soil, the organization will take random samples to assess the levels of contaminants in the crop. If the levels of contaminants in the willow are low the organization sees no limitations in using the crop as a biofuel.

In 2003 the total energy production for Blekinge county, where the Häggatorp landfill is located, was 10.4 TWh, of which biofuel constituted 45%. According to a recent investigation on bioenergy potentials in the region, an increased production of biofuel to replace fossil fuel, would not only have good/positive impacts on the climate and the environment, but also on the employment in the rural parts of the county. “Local production and use of biofuel stimulates the regions (rural) enterprises simultaneously as increasing the local energy maintenance”. The ability to commercially distribute the biomass to one of several existing biofuel producers in the area seems highly feasible.

In summary there are currently no incitements for converting the current production. On the other hand there are no strong limitations in using willow that has been growing on contaminated soil as a biofuel. From the calculated AGI the potential financial benefits depend on the amount of crop. The more managed site, the Häggatorp landfill, resulted in ha higher crop production than the Vivsta varv. The results from the Häggatorp landfill, where some areas were not managed as thoroughly as others, indicate that the management plays an important role for the growth. In addition to the amount of crop per hectare the financial supports for energy production are crucial for the net AGI. In general it is beneficial for the landowner, despite the growth, if there is energy crop support provided. An alternative benefit is that the cultivation increases the wider value and that is a relative cheap management method for marginal contaminated land.

5.1.2 Micasasa, Copsa Mica, Romania

The adapted gross income (AGI) is based on real costs at the demonstration site. The costs included the activities from sowing to harvesting and the income was based on the expected yield per ha and the normal prise for different crops in the area. Within the area the energy crops grown at the demonstration fields are generally used in the owner's household as food or feedstock for domestic cattle and the surplus is sold on the market. There is at present a potential interest in cultivating industrial energy plants such as rape and *Miscanthus*. These findings are based on interviews with a farmer and a potential investor in Micasasa (Crutu et al., 2012). The AGI is positive and was estimated to approx. 200, 700, 1000, 5000 € per ha and harvest for wheat, sunflower, corn and potato, respectively.

The use of the site after the research project is not yet decided. The landowner is most likely going to use the land with priority for crops for animal feedstock or grazing. There is also the possibility to cultivate plants for energy crop such as *Miscanthus*. As shown from the risk assessment for grazing (model) animals there is a risk related to grazing at the site and in the area. The risk can be lowered by utilising the crop for energy instead of daily intake for humans or cattle.

Currently natural gas is the major energy source for heating in the locality. If its price increases other sources will become more attractive. For a significant change to sustainable energy, however, national policy will need to be changed to encourage and stimulate energy crop production, or the prices need to be significantly increased for natural gas compared to heat and energy from energy crop.

5.1.3 Campine region experimental study, Belgium

In addition to the demonstration sites in Sweden and Romania an addition economical assessment study was provided based on a parallel project site in the Campine region in Belgium. The context differs from the two others as there is a higher land use pressure in the Campine region area. Also the energy supplies differ from both the Romanian and the Swedish sites.

The method applied for the economical assessment study was a cost benefit analysis (CBA) methodology including both internalities and externalities (Andersson-Sköld et al., 2011; Vanheusden et al., 2011). The study included rape, maize and willow.

The assessment of private costs and revenues, was based on estimated costs for cultivation and income from the energy crops and not the change of the value of land. For the calculations on the income of the energy crops the AGI was used. The AGI for rapeseed grown in rotation with energy maize result in a AGI between € 1023 and 1354 ha^{-1} y^{-1}, which is in the same range as for Romania. The estimated average AGI for SRC (short rotation coppice) of willow is 111 per ha and year. Based on the internalities, and for this specific context, energy maize combined with rapeseed are the most favourable energy crops on contaminated land (Vanheusden et al., 2011).

5.2 Wider environmental impacts

As pointed out by the beginning of section 4 the cost benefit analyses should be complemented with public costs and benefits to describe the wider value of the project.

Analysis on the wider environmental impacts was done by a life cycle assessment (LCA) (Suer et al., 2009; Suer and Andersson-Sköld, 2010) for two Swedish case studies. The case studies were done for larger sites than the demonstration sites. One site was contaminated by heavy metals, while the other was a previous oil depot (oil contamination).

A life cycle assessment aims to cover all physical changes of a product with its surroundings, ranging from inputs of auxiliary materials and energy consumption through outputs of emissions, waste and useable energy (e.g. Hanegraaf et al., 1998). The Swedish life cycle assessment was made as a comparison of alternative management strategies for contaminated land (Suer and Andersson-Sköld, 2010). One of the sites in the assessment was a previous oil depot contaminated by oil products. At the site Willow (*Salix Winimalis*) was cultivated. The management alternative considered at this site was remediation by excavation and landfill. The other case study, a previous industrial site with heavy metals and also various organic contaminants, was in reality made into a park by adding a top layer of soil and planting of trees. Cultivation of Willow (*Salix Winimalis*) was here analysed as an alternative management strategy. In both studies the use of the harvested Willow was not taken into account in the assessment. Despite not taking into account potential benefits (economical and environmental) of the consequent use of the Willow the cultivation of Willow was the most favourable alternative at both sites from a life cycle perspective. In the case the harvested willow would be used as raw material for biofuel (pellets, bio gas etc.) instead of fossil fuel the benefits may have been even larger (Suer and Andersson-Sköld, 2010).

A carbon foot print analysis was also done based on the same sites as the life cycle assessment (Suer et al., 2009). Carbon footprint considers the total set of greenhouse gas emissions, such as carbon dioxide and methane emissions, caused by for example a product or activity considering all relevant sources, sinks and storage within the boundary of the system or activity of interest (Wright et al., 20011).

Also here the final use and benefits were not included in the assessment. The study differed from the more complete LCA in that only Willow cultivation, and not the remediation alternatives, was included in the study. In addition the carbon foot print analysis only regarded the impact on the carbon footprint and no other environmental impacts that were included in the LCA. The results from this investigation indicated that the impact on the carbon footprint from cultivation of Willow depends to a large extent on the final treatment and whether the roots are left in the ground (most favourable) or if they are taken up (negative impact). The total carbon footprint, of course, depends on the further use of the Willow after harvested (Suer et al., 2009 and references therein).

Based on the carbon foot print and life cycle assessment the public costs and benefits were calculated applying the methodology by Vanheusden et al. (2011) previously applied for the Campine region sttudy described under 5.1.3.

The method applied by Vanheusden for the Campine region included a valuation of the environmental impact for maize, rapeseed and willow and their subsequent uses i.e.:

- Energy maize for heat, electricity and digestate from anaerobic digestion;
- Rapeseed for pure plant oil (PPO) and cake from cold pressing, or biodiesel, cake and glycerine from pressing and esterification;
- Willow for heat, electricity (Vanheusden et al., 2011).

Based on the caloric value from Van de Walle et al. (2007) the largest contributor to the energy cost is the indirect machinery cost, followed by planning material preparation and final removal. Despite the contribution to CO_2 the results showed that cultivation, and consequent use of biomass for biofuel use instead of fossil fuel, results in renewable energy potentials with CO_2 abatement. The result is positive by contributing to increased sustainability with regard to all investigated aspects including the impact on greenhouse gas emissions, hydrological, and geological parameters, the contamination and the potential fuels included in the assessment (Vanheusden et al., 2011).

For the Swedish demonstration sites the financial assessment shows low, no, or negative net gross income as shown in section 5.1. The major value of cultivating bioenergy crops (Willow) at these sites may be only the wider value. This wider value may also be related to relatively low cost for risk management at the sites. Cultivation of Willow may reduce the risk at the site by phyto-stabilisation. It will also create a small carbon sequestration. According to the LCA analyses for Swedish sites it will also contribute to biodiversity compared to leaving the site without any action (Suer et al., 2009; Suer and Andersson-Sköld, 2010) also contributing to a wider value. By cultivation of no-extraction crops the risk will be managed, the biodiversity will be increased and the area may be utilized by people at the nearby industrial area for activities or recreation by people from nearby urban areas.

In the Copsa Mica region utilising the crop for energy production instead of food or animal feed stock would be preferable from a health and environmental risk perspective related to the high contaminant levels in the soil and the measured uptake in plants in general grown in the area (Crutu et al., 2012). The utilisation of marginal contaminated land for energy crop is also in line with current Directives promoting alternative fuels simultaneously as restricting the use of agricultural land for energy crop production. If managed in a way that reduces the concentration of contaminants in the soil, such application may also provide land for agricultural purposes within some decades.

6 LEGAL ASPECTS AT A EUROPEAN LEVEL

There are several legal aspects to consider when cultivating bio energy crops on marginal, and especially, contaminated land. Below are some general and major aspects to consider when selecting crops, based on the review carried out by Vanheusden et al (2011). Key issues of concern at a European level have been assessed as follows.

- Invasive species. In 1993 the parties to the Convention on Biological Diversity (CBD) committed themselves to protect their ecosystems, habitats or species against the threats posed by alien species (Article 8: CBD). Belgium, NL, Sweden and Romania also are bound by the Directive on Protective Measures against Introduction of organisms harmful to plants or plant products and against their spread within the Community (Council Directive 2000/29/EC of 8 May 2002), consolidated version 14 April 2006).

- Genetically modified organisms (GMO). Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 relates to the deliberate release into the environment of GMO and repealing Council Directive 90/220/EEC, O.J. 17 April 2001, L 106. The basic principle of this Directive is that GMO:s can only be put on the market if they are safe and the precautionary principle should be a decision criterion (Article 4 Directive 2001/18/EC). General frequently used commercial crops have already taken the aspects of invasive plants and GMO into consideration.

- Soil management and crop growth (including amendments and fertilisation). There are several relevant items of legislation including European Directives relating to: Sustainable use of pesticides (Directive 2009/128/EC); Protection of groundwater against pollution (Directive 2006/116/EC); Proposal for a Directive establishing a framework for the protection of soil and amending (Directive 2004/35/EG); Water Framework Directive (2000/60/EC); Protection of the environment, and in particular soil, when sewage sludge is used in agriculture (Council Directive 86/278/EEC); Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH, Regulation (EC) 1907/2006) among several others. Two soil amendments need particular attention: sewage sludge and compost as both offer several positive sustainable benefits, but may also have some negative aspects (e.g Vanheusden et al. (2011). For those there are in addition to the soil management directives also international criteria (e.g. End of waste criteria, JRC, 2008). There are also national regulations, such as for the sewage sludge used at the demonstration site Vivsta varv.

- Harvesting. Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH); The Waste Framework Directive (2008/98/EC).

A crucial aspect when growing crops on contaminated soil is whether or not the harvested crop will be classified waste, or as biomass since this has an impact on the further utilisation and valorisation of the crop. Elevated metal concentrations in soil may also result in elevated concentrations in the crop and energy conversion of these plants may result in metal enriched end products (Vanheusden et al., 2011).

7 APPLYING THE DST AT DEMONSTRATION SITES

7.1 Description of the DST

One of the aims with this second phase of the project was to apply the decision support tool (DST) developed in the first phase of the project (Bardos et al., 2010, Bardos et al., 2011). This includes a process checklist where the starting point is an explicit statement by the project team of their objectives for the contaminated land in question, including any constraints, for example that off-site biomass re-use only is to be considered. It then proceeds through four stages considering the (1) biomass crop, (2) the site, (3) the project value and (4) the project risks to identify viable project opportunities. The project process acts as an iterative funnelling mechanism with the aim of finding the most sustainable solution for non-food crop cultivation or to elucidate if such a solution not is the most sustainable management of the actual site (Bardos et al., 2010). This funnelling process is shown in Figure 4.

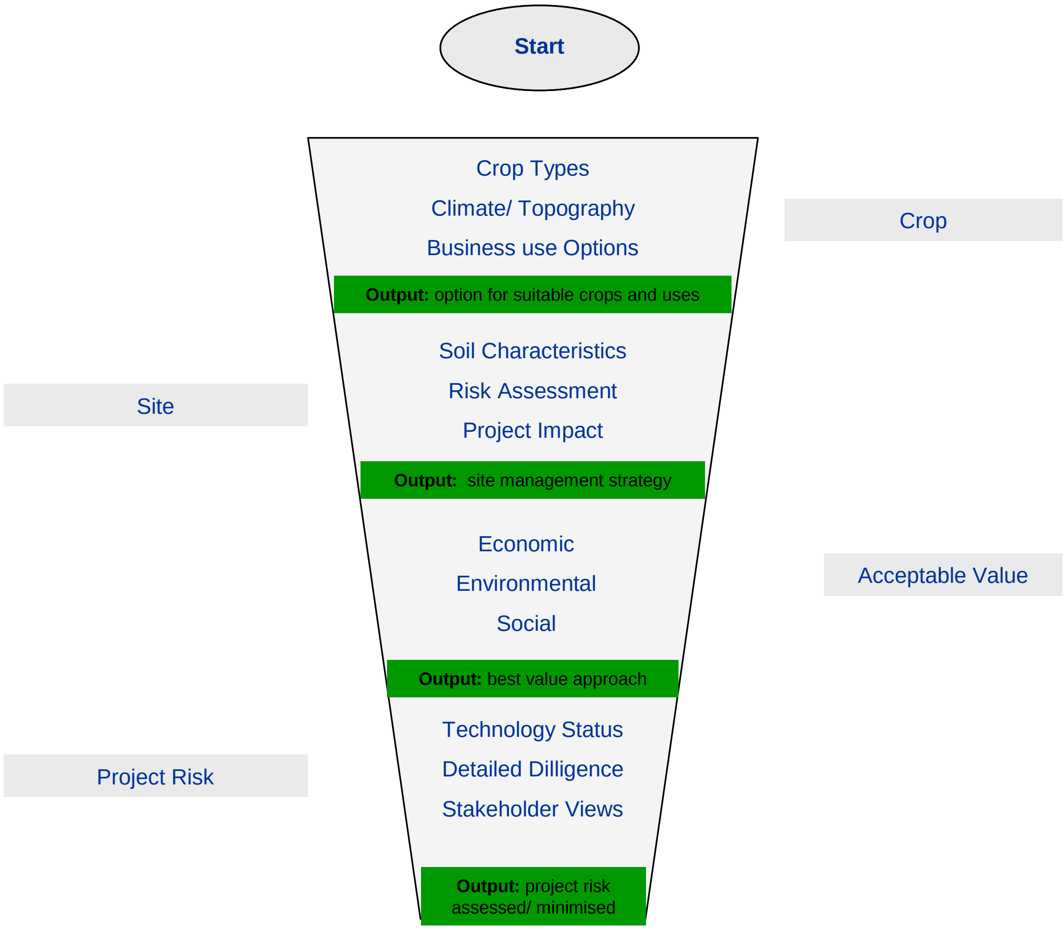
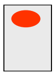
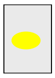
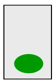


Figure 4. Project development for biofuel crop cultivation on contaminated land (from Bardos et al., 2010).


No suitable biomass option exists for the marginal land under consideration


A suitable biomass option may exist but would require starting objectives are revisited


A viable project approach is identified

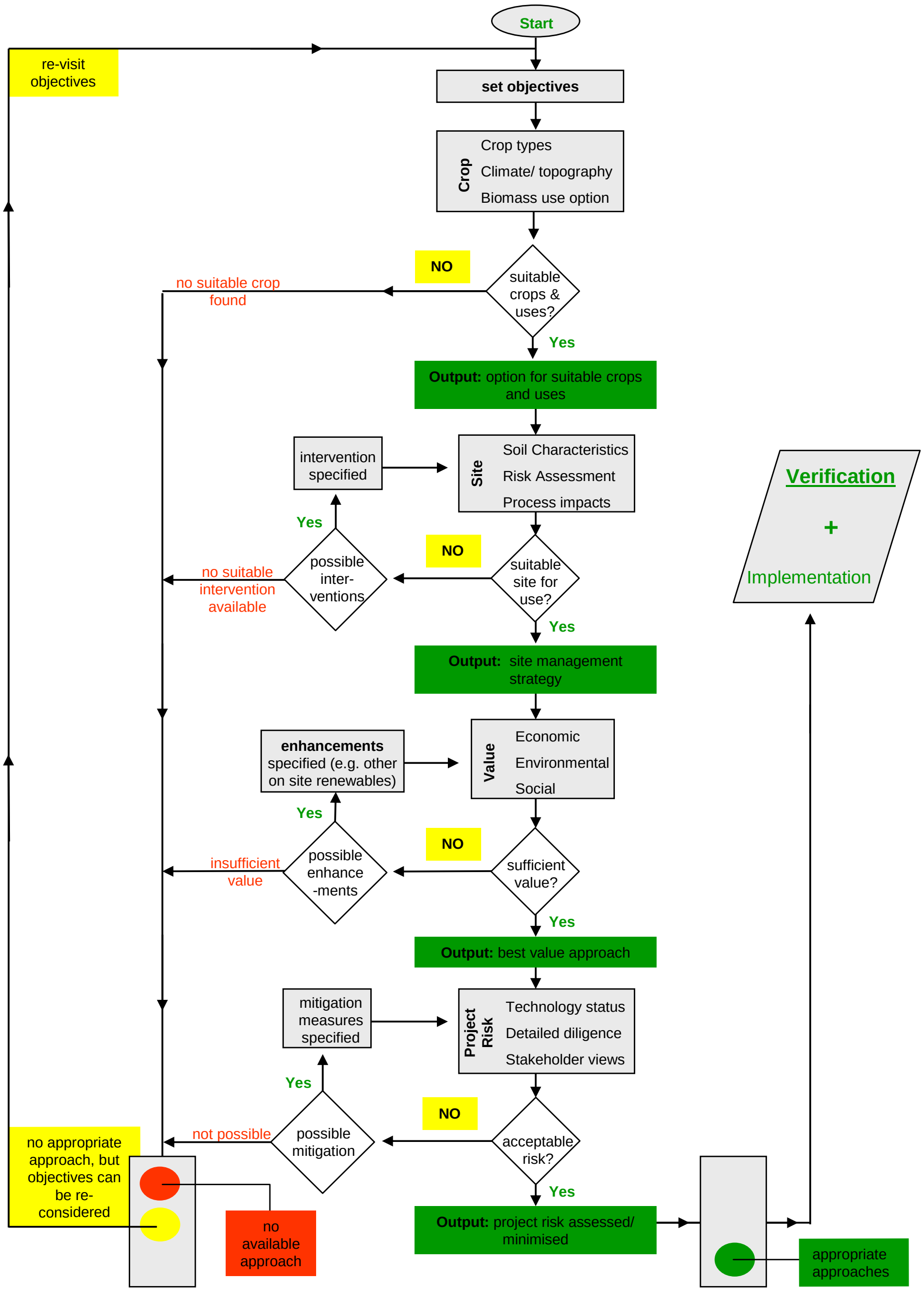


Figure 5. Overall Rejuvenate decision support flowchart

The process is a systematic procedure which uses a simple traffic light concept to describe the outcomes for project options at each stage (see Figure5). Each stage of the DST produces an interim finding or output. The goal of the decision support is to ensure a comprehensive consideration and reporting of the key decision making factors by the project team. With the aid of checklists, the scheme identifies both the considerations needed at each stage and the possible site management and other interventions that might need to be considered. It uses checklists to suggest the broad types of information needed at each stage and the outputs that might be expected from each stage and how those outputs should be reported.

7.2 Application of the DST

Most of the information needed by the DST is site and circumstance specific. Within Rejuvenate-2., the DST was applied to all of our demonstration sites. During the course of the project the DST has also begun to be tested in the HOMBRE, the Greenland, the Phytopop and the Phytosed EC1 projects.

The experience of applying the DST across this range of circumstances has resulted in a short guide (the DST user guide (Andersson-Sköld et al., 2013a). The guide is based on the more detailed description in Bardos et al. (2010) and the related worked example (2010). Experiences have also been to develop a SWOT-analysis. The result of the SWOT-analysis is presented in section 8 below.

7.2.1 Workshop on radioactive sites

In addotopm to applying the DST at demonstration sites it was also applied in a workshop on radio active sites in Romania. The exercise on the radio active sites was done as a workshop held at Reading 21-22 May, 2012, attended by Linda Marring, Deltares, the Netherlands, Pierre Menger, Tecnalia, Spain, Markus Puschenreiter, University of Natural Resources and Applied Life Sciences (BOKU) , Austria, Michel Chalot, Université de Franche-Comté, France , Marlea Wagelmans, Bioclear, the Netherlands, Paul Bardos, r^3 environmental Ltd, UK, Gheorghe Crutu, ICPMRR, Romania, Tomas Track, DECHEMA, Germany, and Yvonne Andersson-Sköld, SGI, Sweden, thereby involving representatives from the EU projects HOMBRE, Greenland, the French/Canadian projects Phytotop and Biofiltree in addition to the Rejuvenate partners.

The workshop exercise was based on information provided in advance by Gheorghe Crutu (ICPMRR) which was also complemented by additional information the second day of the exercise. Appendix 14 of the DST guide provides maps and basic information about the sites. The aims for the sites were at the start of the work shop exercise set to:

- Protect human health, surface and ground water receptors (dust blow not seen as a problem)
- Revenue from sites to support their management
- Access for local community to cross the sites

- Aesthetic improvement

At the site the following constraints and opportunities were identified:

- Currently sites are fenced and guarded, land use is prevented
- Unclear if biomass production would be permitted – this needs to be clarified
- Potentially local funding is available, but problematic to get

Potential options for the sites

1) Natural rehabilitation (no biomass removal)
2) Enhanced natural rehabilitation and risk mitigation (no biomass removal)
3) Woody biomass production (domestic vs. industrial use)
4) Oil crop for biodiesel

The result from stage 1 was that all four options are possible in flat areas, but there was a question mark on industrial wood conversion and on cultivation of oil crops. Only options 1 and 2 are possible for managing slopes. The idea of a Vegetative buffer at foot of slopes also was suggested.

The results from stage 2 of the DST process concluded that there is (in general) no soil present on site, but some spontaneously regenerated vegetation. Soil formation is needed for productive land uses. For enhanced natural regeneration, a key question is what vegetation types can survive with minimal inputs. In the Southern areas livestock manure and separately collected urban waste composts are available. The availability of sewage sludge is not known. There are no organic inputs readily available in the Northern Area. (Hence in the Northern Area only options 1 and 2 are possible). Flat and slope areas require different types of soil management. Regarding the risk management approach domestic use of biomass, such as pellets, from these sites is not appropriate as it will release radionuclides to the environment (air). Oil seed rape has been used in Belarus to make biodiesel and ^{137}CS where it was found not go into the fuel, but a more thorough review of radionuclides fate in oil seed crops is needed. Preferable management would be the remediation approach with in situ stabilisation, leaving radionuclides on site. Prevention of water ingress and runoff is a priority (e.g. improving water holding capacity of plant / soil system, downstream wetland filtration etc). There were concerns about transmission to ecological receptors, but transmission to water receptors would be reduced. Before a second iteration of applying the DST a review of Chernobyl data would be useful. Impacts of added organic matter on metal mobility (including U, Th, Zn, Cu, Ra, Cr) must be assessed. Among the participants it is also unknown how much release of metals is currently occurring on unamended sites. Test work would be needed to determine the best combination of measures to stabilise materials in situ (and in the presence of added organic matter for Southern area only). In situ stabilisation agents might include zeolites, modified charcoals, zero valent iron & iron oxides. This needs to be tested. Release from no intervention (option 1) needs to be understood. Access to sites needs to be restricted as vegetation may accumulate radionuclides.

There may impacts of adding organic matter on a slope (N and P release to water) and there are potential impacts of adding in situ stabilisation agents (e.g. on pH and redox of water runoff). The groundwater and surface water resources are in use. This is in agreement, i.e. may link to the concept of having a vegetative buffer at the foot of the slopes. Timing of materials applications and design of buffer is very important as it has to coincide with plant production to prevent excess release of nutrients etc. off site. In summary burning of vegetation on site must be prevented and organic matter return from onsite vegetation should be maximised.

The results from stage 3 of the DST process were:

- A sustainability benefit strongly depends on risk mitigation for the site
- Positive outcomes for access and aesthetics expected more rapidly for options 2-4.
- Potential wider benefits for the local economy from an improved landscape might include increase in land values / tourism. This should be further considered, e.g. in context of EU funding
- Policy changes may require the company to better manage its sites, but revenue will be helpful
- The Water Framework Directive could be a driver for rehabilitation of these sites for surface water protection
- Where funding drivers for environmental improvement are limited, revenue becomes very important. Currently the site owner is paying costs only for guards and fencing.

The landowner (Uranium company of Romania) input was found to be critical to the next iteration of this decision making Additional key stakeholders are local communities, regulators / local authorities / planners, clients for any biomass and solution providers. After this first iterative round of applying the DST the workshop participants found insufficient information to be completely confident in any of the options. Some information may already be published and available, or held by the landowner. However, it is likely that on site pilot and lab scale feasibility testing is needed.

In general the DST procedure at this work shop exercise was found useful and already at this first iterative round some alternatives could be ruled. Knowledge gaps were identified and the need to involve key stake holders in next iterative procedure was found crucial.

7.2.2 Open Workshop

An open workshop was held at the Conference on Sustainable Remediation in Vienna 14-16 November, 2012. At this workshop the DST was applied for the Swedish site Vivsta varv and the radioactive sites in Romania. In total 17 attendants participated in the activities. The workshop was finalised by obtaining participant opinions about the DST strengths and weaknesses.

Among the strengths were mentioned that it is a quick and easy screening method (1), a phased and systematic straight forward method (3) that is clear to follow (1) which works as a good guide through the processing steps (1) thereby preventing omission to consider substantial aspects and questions (2) for organised thinking (19 in an iterative system (1) that also is transparent (1) and good as discussion basis and as communication tool with stakeholders (2). The numbers in the brackets indicate the number of keynote words provided. In addition it was mentioned as easily applied (2) and as a good tool for contributing to good sources of renewable energy (1) and RBLM (1). The weaknesses were that the order of the steps may not always be optimal, e.g. starting with choice of crop in a more broad and generic perspective than from the site conditions (2). Otherwise the weaknesses were more related to the results of the application on the pilots, such as the complexity of regulations, perceptions, land use pressure/interests of land owners and lack of examples, hindering the application of phytoremediation for energy (and other non-food) purposes (5). Many weaknesses are, however, addressed by an iterative approach of the DST application and by involving key stake holders at an early stage of the process.

8 SWOT ANALYSES BASED ON APPLYING THE DST AT DEMONSTRATION SITES

The major result from applying the DST for all case study applications is that the tool is useful. The experience is also that the tool shall be used as a checklist in an iterative procedure.

The tool is useful already in the first iterative step were its application is based on limited information. In such an early stage of the process it is useful to identify non-working alternatives and to find out which, and what type of information, is further needed before sustainable decisions and planning can be further undertaken.

The work shop exercise on the radio active contaminated was done as a test of the idea of potential vegetation application's such sites in Romania. At this early stage of the procedure one of the major results was the identification of knowledge gaps and information needs before any management alternatives could be suggested. The process, however, also ruled out some of the alternatives initially on the list as potential management alternatives. The subsequent work, accordingly, could be focussed on the most relevant alternatives. The activity showed the strength of the DST process as an interactive and iterative process tool.

Below a summary of the strength, weakness, opportunities and threats found when applying the DST in the different activities is provided (Table 3).

A general finding is that it is important to define the group of stakeholders to be involved in the process. We recommend a small group to do the scoping in a first stage of the iterative process and once the scope and relevant management alternatives have been selected a broader stakeholder group shall be involved. Relevant participants for the forthcoming process are, in addition to one or two experts in the field, regulators and stakeholders (or stakeholder representatives) that will be affected by the decision.

Table 3 Summary of identified strength, weakness, opportunities and threats (SWOT) of the DST.

Strength	**Weakness**	**Opportunities**	**Threats**
Systematic and holistic assessment (site specific to global impacts, including environmental, social and economic aspects)		Helps by disciplining the process to find synergies with other management and product uses	
Transparent		Contributes to more efficient decision making	
Works also for portfolio of sites			
Critically depending on good objective settings (well defined objectives)			If the objectives are not appropriate (but

Strength	Weakness	Opportunities	Threats
			the process set up to delaminates this)
Basic information on each step summarised in final report and worked example (Bardos et al, 2010)	No short guide on basic information available	A short guide is provided in Rejuvenate phase 2	Lack of examples and short guide may lead to wrong assumptions and estimates
The method can be used to early in the decision process describe the potentials relative to risks of non food crop alternatives.	The environmental risks, but also other impacts are site specific but more generic information could be developed	More detailed, user friendly, generic benefits and risks to be used for assessing crop in relation to other management strategies as well as different crops under different types of conditions could be developed based on further examples	
Used iteratively the tool reveals at an early stage key information gaps.	The tool would gain from being updated by more information about potential crops.	The demonstration pilots provide examples on how to assess the risk (see appendixes 1-3).	
The method is adaptive and sensitive to different national and regional contexts, caused by varying policy, regulatory and market drivers	Examples from one country can not be used directly for assessing a site in another country	Examples for Germany were worked on in phase 1, examples from Sweden and Romania are tested in phase 2	
	Does not include legal and financial risks/opportunities in the first step	Can be linked to other tools and methods such as the more generic HOMBRE methodology. The iterative process reduces the risk that this is not regarded in an early stage of a decision process.	
Considers non-food crop as a management strategy and shows opportunities on crops for non food uses	Does not include other than vegetative management alternatives	Can be linked to other tools and methods such as the more generic HOMBRE methodology	Non food crop will not be assessed systematically in relation to other management alternatives.
		The process is widely applicable also for	

Strength	Weakness	Opportunities	Threats
		other potential uses and the same type of process can be applied for other marginal land management approaches	
Critically depending on good objective settings (well defined objectives)	The method does not include constrains and opportunities already explicitly mentioned under setting the objectives		
It has been possible to apply it to all the contexts (demonstration sites, worked example, all the Romanian radioactive sites on which the tool was applied in the workshop exercise.	Only demo cases being tested Not tested at real large scale sites	The sites for which it has been tested indicates that it is applicable also at real sites	
The quality of information is the key. The process provides information of gaps and increases the assessment of potential relevant alternatives only within 2 hours by a relatively small team		The application of the tool at demonstrations sites have provided examples on how the risk assessment can be done (see annexes 11 – 15) to the DST guide.	
The systematic process reveals differences in perspectives (knowledge, and culture, etc) and hopefully creates an opportunity for a generic perspective among the stakeholders			
Allows all stakeholders to express their opinion			
Not defined sustainability approach. The perception and definition of sustainability is context dependent and there can not be any provided rules. The DST is compatible with sustainability assessment approaches being developed by different jurisdictions.		Examples are provided in the worked example (2010) and in annexes 11 – 15 to the DST guide.	
Includes both bankable and sustainable in a wider perspective	Difficult to model financial viability in advance, but this is the reason why this is done in the stage 4 of the DST procedure.		
Small team identified stakeholders, who to talk and what information is before stakeholder involvement			

The major strengths can be summarised as the tool provides a framework for a systematic and holistic assessment including environmental, social and economic aspects that encourages transparency. The method is also generic as it has been found to work well for case studies in Sweden, Germany, Belgium, Romania and is currently applied for different case studies in France.

The weaknesses and threats that have been mentioned are in general due to lack of guidance. This is addressed by the short guide resulting from this second phase of the Rejuvenate project. The short guide is also complemented by examples (annexes 1 – 15 to the DST guide). The weaknesses mentioned are also due to uncertainties always found early in a process, which is addressed by the iterative procedure.

There are several opportunities as the DST can be linked to other tools and frameworks such as those developed within HOMBRE. Another opportunity is that the DST can be continuously upgraded by linkages to new information and results from current and forthcoming field studies on phyto-remediation and new results from bioenergy developments.

As with all decision support tools there is a risk that non experts apply the tool and thereby provides non scientifically based results for the different stages of the process. We therefore recommend scientific (risk assessment) experts to take part of the process.

9 DISCUSSION AND CONCLUSIONS

The DST developed in Rejuvenate has been applied in the second phase (Rejuvenate2) at several demonstration sites. The tests included the application of the DST starting from the selection of site and the subsequent selection of crops to be cultivated at the demonstration sites. For the crop selection the tool, and the related use of information across the different DST stages was found applicable. Through the course of Rejuvenate 2 the DST was also applied based on the results from the demonstration sites to assess the environmental and economic risks.

The combined results from the different demonstration sites show that the risk depends on several factors including contaminant concentrations in soil. The results indicate that the risks related to health and ecotoxicity and ecology caused by the energy crops grown on low to moderately contaminated land, such as at the Swedish sites Vivsta varv and the Häggatorp landfill, are low. The risks at the lowest contaminated site, Vivsta varv, are even very low.

At Vivsta varv the risk for grazing animals is also very low taking into account all contaminants apart from zinc. At both the Swedish sites the uptake of zinc and cadmium is accumulated in the leaves in relation to the soil concentrations. This is in agreement with previous findings of willow species, e.g. Laidlaw et al., 2012. The Willow clones (Salix Klara and Salix Inger) cultivated at the Swedish sites were, however, selected as they were expected to be no or low metal extractors, which is true for the other metals measured in the soil and the leaves. Despite the extraction, the calculated risk for grazing model animal cow at Vivsta varv is acceptable, while the risk for grazing model animal sheep is just above accepted level for zinc. At the the Häggatorp landfill the risk quotients for grazing animals show that there is no increased risk when the whole field is considered (risk assessment based on mean values and not the maximum values for the analysed metals). The calculated risk is based on the daily intake. The real risk is much lower as the accessibility for grazing, including by wild animals, is very low. Both sites are located next to, or in the middle of an, industrial area and are surrounded by the sea or highly frequented roads. The results from this study consequently indicate that cultivating willow at moderately and low contaminated land results in acceptable risks with regard to health, ecotoxicity and ecology and also for larger animals if there is low probability for the site being the major feedstock. It should also be noted that all risk quotients are calculated from concentrations reported as dry weight and the concentrations in fresh leaves and stems are lower.

At the more contaminated site in Romania both the ecotoxicity and the risks for grazing animals were found to be higher. At this site, different types of crops were grown. For individual elements the calculated risk for grazing animals varies across the different crops and parts of the crop, but none of the plants or parts (with exception for corn cob) of the plants investigated shows results where there is no calculated risk for grazing animals. There is currently, however, no domestic grazing at the field. The field can be reached by wild animals from the surroundings but the risk is still low compared to keeping grazing animals on the field. More importantly, currently within the area the harvested crops are used to feed domestic cattle. The current use of crops grown in the area thereby poses a higher risk than crop production for energy or other non-food purposes as the intention in Rejuvenate.

Accordingly, to utilise the crops for energy instead of feeding cattle can be a more favourable alternative. To identify the best land use alternative, a discussion among the different stakeholders in the area is suggested as there are several interests to be reconciled. These interests include socioeconomic aspects such as salaries, food and energy demands, and the value of the land and products.

As part of the valuation of the crops grown at the demonstration sites the internalities (direct cost and revenues) were assessed. The results from the sites show that the costs and benefits depend on how the product can be used. For the Swedish demonstration sites there is a need of financial support, such as EU bioenergy support, or that there is a significantly increased demand of energy from non-agricultural land thereby increasing the revenue of the product. Otherwise there will be low, or no, net direct financial benefits for Swedish sites such as Vivsta varv or the Häggatorp landfill, and the projects will not be bankable per see. This cost case is however improved by avoided costs, such as costly alternative remediation methods.

The results have shown that cultivation, and consequent use of biomass for biofuel use instead of fossil fuel, results in renewable energy potentials with CO2 abatement (Vanheusden et al, 2011). The wider environmental benefits of phytoremediation compared to excavation are significant, while utilising the land as a park depends on the amount of soil importation needed for such utilisation (Suer and Andersson-Sköld, 2010). The biological diversity is increased in both cases (energy crop cultivation and park establishment) while the social values depend on the context. A park may create opportunities for recreation and leisure, while willow for energy purposes may contribute to jobs or other values.

The DST has been shown to be systematic, transparent and transferrable. It is useful for assessing the risks, costs and benefits on internalities, environmental risks and externalities. The experience is also that the tool shall be used as a checklist in an iterative procedure. Based on the activities in Rejvunate we even recommend the tool to be used already in the first iterative step to identify non-working alternatives and to find out which, and what type of information, is further needed before sustainable decisions and planning can be further undertaken.

The experience from applying the DST is that it is important to define the group of stakeholders to be involved in the process. We recommend a small group to carry out the scoping in a first stage of the iterative process and once the scope and relevant management alternatives have been selected a broader stakeholder group can be engaged. Through the course of the decision process, for a relevant process and robust decision making, we argue that there is a need for trained risk assessment professionals to take part from the initial start of the process. Relevant participants for the forthcoming process are, in addition to one or two experts in the field, regulators and stakeholders (or stakeholder representatives) that will be affected by the decision.

Under the condition that relevant stakeholders and experts participate in the procedure the DST framework is useful as a checklist and guide to facilitate transparency and assessments already at an early stage of the process.

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11 LIST OF ABBREVIATIONS

AGI	Adapted gross income
ADI	Acceptable daily intake
BCF	bio-concentration factor
Bgl	Below ground level
CBA	Cost and benefit analysis
CBD	Convention on Biological Diversity
CP-scale	colonizer-persister scale (a scale used to define the groups of nematodes with different life strategy)
DST	Decision support tool
EPA	Environmental protecting agency
KM	Känslig markanvändning, Swedish Guidelines for sensitive use of the land
GMO	Genetically modified organisms
LCA	Life cycle assessment
NOEC	No Observed Effect Concentration
MIFO	Metodik för Inventering av Förorenade Områden, Methodology for Inventory of Contaminated Areas
MI	Maturity index (index used in the TRIAD analysis). MI is the ratio between the number of colonizers and the number of persisters and is a measure for soil health.
MKM	Mindre Känslig Markanvändning, Swedish Guidelines for less sensitive use of the land, e.g. industrial activities
PPO	Pure plant oil
R2	Rejuvenate 2
RBLM	Risk Based Land Management
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SGI	Swedish Geotechnical Institute
SRC	Short rotation coppice
SWOT	Strength Weakness Opportunity Threat

TP	Toxic pressure
XRF	X-ray fluorescence spectrometry