

greater in plots amended with fertilizer and compost than in plots receiving no fertilizer or amendment. Moreover, TPH concentrations were lower in the vegetated plots than in the unplanted plots. As well, a site-specific plant mix generally out-performed a standard seed mix. Specific associations between hydrocarbon degrading bacteria and some plant species were detected, and activities of these bacterial communities were correlated with hydrocarbon degradation. The lessons learned from this field study, and the opportunity to utilize plant-microbe associations for field-scale phytoremediation of contaminants will be discussed.

Economic opportunities of phytoremediation

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Many large (medium) polluted areas involve agricultural activities. Because it is accepted only to grow high-value crops for human consumption on clean soils, the clean soil yields a higher income after remediation than before. This higher income should not be ignored when calculating the net present value of the labor income originating from the use of the soil. This is why a sufficiently long period of time has to be taken into consideration. The social acceptance of phytoremediation then suffers from a dilemma. A choice has to be made between: (i) a faster remediation using hyper accumulator crops, with no (or only a very small) income during this period because the harvested biomass is very low, but on the other hand realizing an earlier re-establishing of the clean soil with corresponding higher revenue opportunities; and (ii) a slower remediation using crops with higher biomass which can be valorised e.g. as a base for renewable energy, but reaching the clean soil situation with much more delay. An economic optimum will involve a mixture of (i) and (ii).

The case study considered applies to a large area in the eastern part of Belgium in which diffuse heavy metal pollution is a heritage from the historical zinc smelters in the region. As a reference to evaluate the income effects of phytoremediation we use the net present value (NPV) of the actual labour income of the average farm (36 ha) earned by cultivating roughage (grassland and fodder maize for dairy cattle rearing). We assume that roughage, previously own produced, but now partially substituted with other crops, will be bought externally.

To find the economic optimal land use we develop a 'blueprint' model involving the most important strategic variables which take numerical values according to probability ranges. We investigate the influence of the initial distribution of the land coverage between (i) the accumulating crop, willow (*salix* spp.) in 'short rotation forestry' (SRF)

versus (ii) the renewable energy 'cash' crops: rapeseed (*brassica nappus*) and energy maize, and (iii) roughage, to continue - but in a decreasing degree - the traditional dairy cattle rearing. A parameter in the model takes into account the decrease in income (base value 30%) every 5 years from the current activity because the government is urging to cut back the production of milk in this polluted area. Other parameters represent the metal uptaking capacities of the different crops, the price for biodiesel (actual and projected) produced with rapeseed oil, the price of energy maize and the future income on the reclaimed land (with the conservative assumption to be 50% higher).

An initial cultivation scheme (on the 36 ha) then looks as follows: 10 ha of SRF willow (with harvest every 4th year), 6 ha of rape (in 4 year rotation); 10 ha of energy maize; and 10 ha of roughage. The reclamation activity aims at removing on average (we distinguish the area according to 3 pollution intensities) 2,5 kg Cd/ha. The NPV over this period of the gross labour income resulting from the mentioned phytoremediation cultivation scheme is 11% higher than the NPV of continuing the actual land occupation (the reference). If we take into account a possible decrease in income from the current activity of 30% every five years, because of the increasing awareness of the influence of the contamination on the safety of the milk from the traditional dairy cattle rearing, the same phytoremediation scheme results in a 65% higher NPV than the adjusted reference. Increasing the surface of SRF willow to 15 ha shortens the calculated remediation period from 40 to 32 years; the NPV is now 76% higher than the reference.

Comparing the NPV results from changing (from 0% to 30%), the size of the expected decrease in income from the current activity (ΔI) in combination with 3 different intensities of SRC (the 'phytoremediation crop') at the start, leads to the following conclusions. The larger ΔI - reflecting the government's awareness about the health risks emanating from the pollution:

The larger the relative financial advantage of phytoremediation compared to the continuation (be it in a digressive way) of the current dairy cattle rearing.

The more important it is to start with land coverage characterized by a large share for the strongest accumulating crop (SRC) so that the area reaches the 'clean' status sooner, giving opportunity to cultivate higher value added crops which actually is not possible just because of the contamination.

Using realistic values for strategic variables, Monte Carlo simulations calculate the probability of the labour income results. The variation in the NPV of the labour income is mostly accounted for (% based on the 10 ha SRC scenario): (i) the decrease in income (ΔI) from continuing rearing dairy cattle fed with the own grown fodder maize on the polluted soil (46%); (ii) the uptaking capacity of the SRC willow (17%); (iii) the labour income from energy maize (11%) and maize (10%); (iv) the future increase in income from the land after reclamation (9%).
