EGU23-3221
https://doi.org/10.5194/egusphere-egu23-3221
EGU General Assembly 2023

Growing perennial grasses on contaminated soils for phytoremediation and renewable energy: a nature-based solution to maximise energy and eco-system service provision?

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Available data indicates 2.8 million potentially contaminated sites, just across the EU-28. While 650,000 sites have been registered, only 1 in 10 have so far been remediated[1]. The management cost of European contaminated sites is estimated at €6 billion annually[2]. The main types of contaminants are potentially toxic elements (including heavy metals). Similarly, a 2014 Government study in China found 16.1% of all soil and 19.4% of arable land showed contamination, with Cd, Ni and As being the main pollutants[3]. Meanwhile, the global challenge of feeding growing populations while still reducing greenhouse gas emissions leaves less agricultural for dedicated bioenergy crops[4]. Therefore, there is a pressing need to successfully combine nature-based decontamination through phytoremediation with bioenergy production.

Given the wide variety of non-agricultural marginal lands[5], species selection must combine significant biomass production with acceptable levels of contamination for subsequent use or energy conversion. Whereas specialist hyperaccumulator plants may achieve higher levels of contaminants and greater bioconcentration and translocation factors, their inherently lower productivity means that biomass, energy yield and mass of contaminants removed per unit area will be relatively small. In contrast, high yielding, low contaminant uptake characteristics, such as for conventional energy crop species, could result in greater energy production, economic viability and biomass utilisation potential.

Here we report on field scale trials to implement this strategy, part of the CERESiS (ContaminatEd land Remediation through Energy crops for Soil improvement to liquid biofuels Strategies) H2020 Project (GA 101006717). We have evaluated the performance of *Phalaris, Miscanthus, Saccharum* and *Pennisetum* species for combined phyto-remediation and phyto-management of contaminated land during energy crop production in Brazil and Europe. Reed canarygrass (*Phalaris arundinacea*) is a native perennial rhizomatous C3 species suitable for non-agricultural or marginal lands and climatic zones such as Scotland (where *Miscanthus x giganteous* cannot grow). Our phytoremediation trials using *Phalaris* in Italy and Ukraine are the first we are aware of. In the UK the CERESiS project has utilised field trials originally established during the BioReGen (Biomass, Remediation, re-Generation: Reusing Brownfield Sites for renewable energy crops) EU Life demonstration Project (LIFE05 ENV/UK/000128) in 2007. These allowed direct comparison of the actual contaminant removal rates of three crop species: Although the biomass of *Miscanthus* and short-rotation coppice *Salix* contained higher concentrations of certain elements, *Phalaris* far out-performed these in terms of biomass, ease and economy of production[6]. Surprisingly, despite lower contaminant concentrations in *Phalaris*, such was the increased biomass that the total mass removed was still greater than for *Miscanthus* or *Salix*. This suggests that low-uptake phyto-excluding plants which can tolerate contaminated soils and grow productively may still represent the best and most economically viable option for clean-up of contaminated sites. Meanwhile this nature-based solution can simultaneously deliver a variety of wider societal and environmental benefits, such as greening-up derelict land or the enhanced storage of carbon in soils[7].

[1] Pérez & Eugenio (2018).

[2] Panagos et al. (2013).

[3] https://www.bbc.com/news/world-asia-china-27076645

[4] Searchinger et al. (2018).

[5] Mellor et al. (2021).

[6] Lord (2015).

[7] Lord & Sakrabani (2019).

How to cite: Lord, R., Nunn, B., Wright, B., Colantoni, A., Bianchini, L., Alemanno, R., Tryboi, O., Severino, M., and Leandro, W.: Growing perennial grasses on contaminated soils for phytoremediation and renewable energy: a nature-based solution to maximise energy and eco-system service provision?, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-3221, https://doi.org/10.5194/egusphere-egu23-3221, 2023.