ENERGETIC PLANTATIONS – POTENTIAL SOLUTION FOR EXPLOITATION OF FORMER INDUSTRIAL SITES

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Abstract. Contaminated sites with heavy metals are very common in the case of former industrial sites. These areas should not be neglected, but converted for the community benefit. To treat the soil pollution problem, one of the green remediation technologies that can be applied is phytoremediation. Because of the large areas that industrial zones usually occupy, other remediation measures become too expensive. If phytoremediation is combined with biomass production, the entire area can become a source of energy and a successful integration of a former industrial area. In addition, landscape architecture can be an asset in the design and redevelopment of the area that can increase the value of the studied areas. This will change the public perception and improve it economically, socially and aesthetically. The aim of this study is to analyze the possibilities of polluted areas exploitation using energetic plantation with a double function: energy producers and mean of soil treatment.

Keywords: energy crops, industrial sites, contaminated soil, phytoremediation.

INTRODUCTION

In the context of a world's population that is increasing and requires more and more resources, there comes a higher need of energy consumption. Nowadays, the energy is mostly coming from fossil carbon sources, especially oil, coal and natural gas. It assures day by day necessities like transport, heat, cooking, lighting, manufacturing, communication etc. contributing to the economic growth and development of the world. Unfortunately, this affected the environment in so many ways, carbon dioxide levels in the atmosphere becoming higher and higher producing climate impacts and economic losses. This is not sustainable for long term, so energy producing alternatives must be developed (Zarrilli, 2006).

Energy crops can be used in the case of former industrial sites in order to improve the environment by transforming the zone and conferring new meanings to the studied area. These types of plantations will be placed on arid land that will be exploited economically, socially, aesthetically.

Some of the well-known conventional energy crops are suntflower (*Helianthus annuus*), rapeseed (*Brassica napus*) and maize (*Zea mays*). Other plants that are promising and offer great expectations in energy production are hemp (*Cannabis sativa*), biomass sorghum (*Sorghum spp.*), Ethiopian mustard (*Brassica carinata*) and kenaf (*Hibiscus cannabinus*) (Zegada-Lizarazu and Monti, 2011).

A very fast developing phytoremediation approach is taking benefit of energy crops, mainly short rotation coppice plantations in the treatment of polluted soil (Rowe, 2009; Mleczek, 2010).

A combination of landscape architecture and energy crops will increase the value of the area and the land will be ameliorated ornamentally and ecologically by creating new ecosystems. Also, in order to capitalize the redesigned space touristic information boards will be placed for visitors.

In this research, we wanted to analyse if energetic plantations are a potential solution for polluted industrial sites that usually represent very large areas of abandoned land that can be converted for economic purposes.

BIOMASS AND BIOFUELS

Biofuels are any fuels that come from biomass. Some of the most used liquid biofuels are bioethanol and biodiesel. Plants that can be used to produce energy are the woody ones with a fast growth (*Miscanthus*, *Salix*, *Poplar*), the ones that produce oil which has a high calorific value (*Helianthus annuus*, *Glycine max*, *Brassica napus*, *Ricinus communis*) or plants which can be fermented because of the high sugar content (Zarrilli, 2006).

In the biomass category we can find: wood and processing of it, agricultural crops and products, products coming from the forest industry, organic fracture of waste and manure. Contaminated land can be a utilized to cultivate conventional energy crops or new types of crops that can maximise the yield per unit area of the plants dry matter (Rechberger and Lötjönen, 2009)

Biomass may come from wastes produced by forest industry, agriculture or green urban spaces, but mainly comes from the energetic plantations of perennial energy crops which is expected to have a high productivity rate and a high low heating value and ash content. Perennial crops are different in quality features as solid fuel and are separated in: wood, semi-wood and straw biomass. Harvest time and weather can influence the chemical and thermo-physical biomass features (Redei et al., 2008; Stolarski et al., 2008; Kollas et al., 2009; Fortier et al., 2010; Przyborowski et al., 2012; Stolarski et al. 2014).

As a renewable energy source, biomass has an important contribution to the energy supply. For 2020, EU sets the following targets: to increase the proportion of renewable energy sources with minimum 20 % and to increase the percent of biofuels used in transportation system with minimum 10 % (Ericsson, 2009). European Environment Agency presents a scenario concerning energy crops for 2020, situation that should be "environmentally compatible" (Fig. 1).

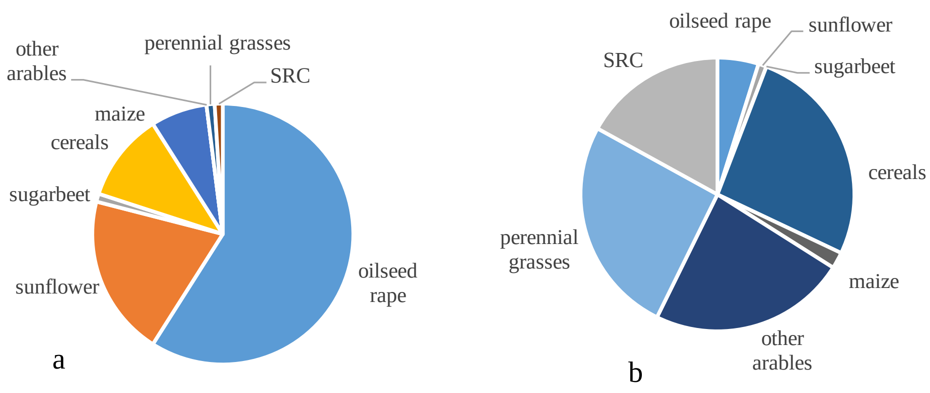

Fig. 1. Crop mix of energy plantations, data collected in the 2006 – 2008 period (a) and projections for 2020 (b) (http://www.eea.europa.eu/data-and-maps/figures/mix-of-energy-crops-200620132008#tab-european-data)

In order to give priority to further investigations in the biofuel field, EU developed a Strategy for Biofuels and The Biomass Action Plan. The aim for 2030 would be that a quarter of the European transport fuel to come from biofuels production (Fig. 2) (EC, 2006; Gomes, 2012).

In the biofuels category, biodiesel is used as transport fuel. There are several reasons why biodiesel should continuously be improved and developed, even if it cannot replace the petroleum-based diesel fuel: it makes the countries less dependent on imported petroleum; biodiesel is renewable and the emissions of CO_2 are reduced with 78 % compared to petroleum diesel; a market for excess in production of oil coming from vegetation and animal fats is created; if it is added to regular diesel fuel in 1 – 2 %, it converts some of the poor properties of it into a more acceptable fuel; there are lower exhaust emissions of carbon monoxide, unburned hydrocarbons and particulate emissions than classic diesel, but more emissions of oxides of nitrogen (Gerpen, 2005). Biodiesel can protect the environment and the use of it can reduce the acid rain which causes so much damage to the environment and human infrastructure. Also, the air pollution is reduced significantly (Huang et al., 2012).

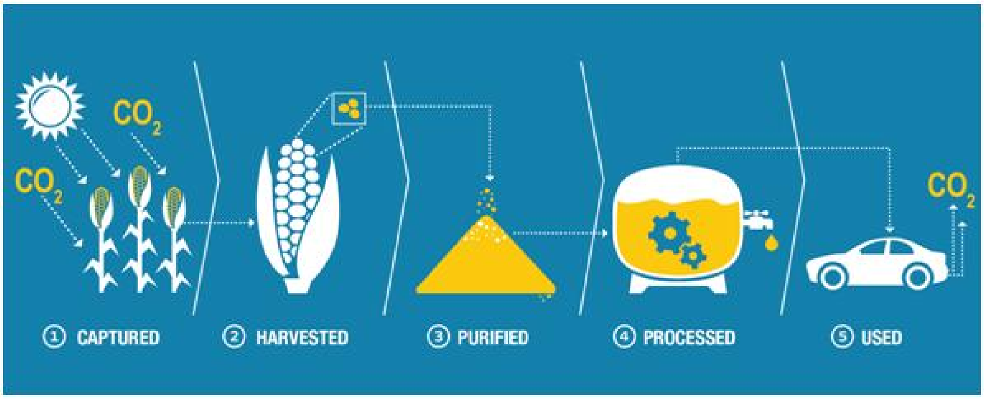

Fig. 2. Increase in energy production by using biofuel crops in the road transportation sector (http://engineeredhighenergycropspeis.com/img/biofuel_conversion.png)

PHYTOREMEDIATION AND ENERGY CROP PRODUCTION

Energy crops are intensive plantations that have a high rate of plant density and mechanization, plant cycles (not more than 20 years) and short rotation of 1 – 4 years (Fiorese and Guariso, 2010).

Phytoremediation, a technology that uses plants to treat different contaminants, in a combination with energy crops can be involved in removing heavy metals from contaminated soil in large industrial areas for long treatment periods. To enhance the uptake of heavy metals using energy crops, soil amendments can be used to increase the bioavailability of heavy metals. Depending on the chosen plants, microbes and mycorrhizal fungi can be stimulated to grow and improve the remediation process. This will ensure a faster uptake of heavy metals and a shorter soil treatment period.

Examples of energy crops and their distribution are presented below:

- Annuals: *Sorghum bicolor* – sweet sorghum, *Brassica napus* – rapeseed, *Brassica carinata* – Ethiopian mustard, *Hibiscus cannabinus* – kenaf;
- Perrenials:

- Agricultural: *Triticum aestivum* – wheat, *Beta vulgaris* – sugar beet, *Miscanthus giganteus* – miscanthus, *Cynara cardunculus* – cardoon, *Phalaris arundinacea* – canary reed grass, *Panicum virgatum* – switchgrass etc.;
- Forest: *Populus sp*. – poplars, *Salix sp*. – willows, *Robinia pseudoacacia* –black locust, *Eucalyptus camalduensis* and *E. globulus* – eucalyptus (Zabaniotou et al., 2008; Simpson et al., 2009; Gomes, 2012).

A plant that is suitable for energy production should summarize the following characteristics (Ceres, 2015):

- High biomass with an increased rate of growth;
- Fast and cheap propagation;
- Photosynthetic efficiency;
- Resistance to pests and diseases;
- Tolerance to salt;
- Delayed flowering;
- Deep roots to increase nutrient uptake, sequestration of carbon and tolerance to drought;
- Resistance to an early establishment: cold germination and growth;
- Improvement in structure and composition regarding an increase in fuel yield per ton;
- Compact planting and easy harvest;
- Perennials in terms of a higher fossil energy ratio and more efficient energy use.

In addition, plants that are used in the treatment of contaminants in the phytoremediation technology, need to have a heavy metal tolerance, ability to accumulate metals, non-consumable by humans and animals. The processes that are involved in the energy production starting with phytoremediation are presented in Fig. 3.

Some of the common plants that are used for energy production are poplars and willows. As an example, concerning the optimisation of the techniques for cultivating them, there is progress that was made in the following domains:

- Plantations establishment – it is done during spring using 20 – 30 cm cuttings that are transplanted mechanised with a 35000 per day capacity;
- Optimal coppice rotation – the identification of a crop that fits the pedo-climatic situation and can be harvested every other year, better than annual harvesting;
- Density of plantation – trees planted in single rows with a density of 7000 – 10000 plants / hectare for 2 -3 year harvest cycles or 2000 – 3000 plants / hectare for 5 years harvest cycles;
- Fertilisation – it should be done before planting by combing mineral and organic fertilisers or even nitrogen fertilisers after harvesting to promote growing of new shoots;
- Plantation removal – at the end of the cycle, plantations can be removed at a low price with the use of traditional forestry machinery (Lewandowski et al., 2006; Rechberger and Lötjönen, 2009).

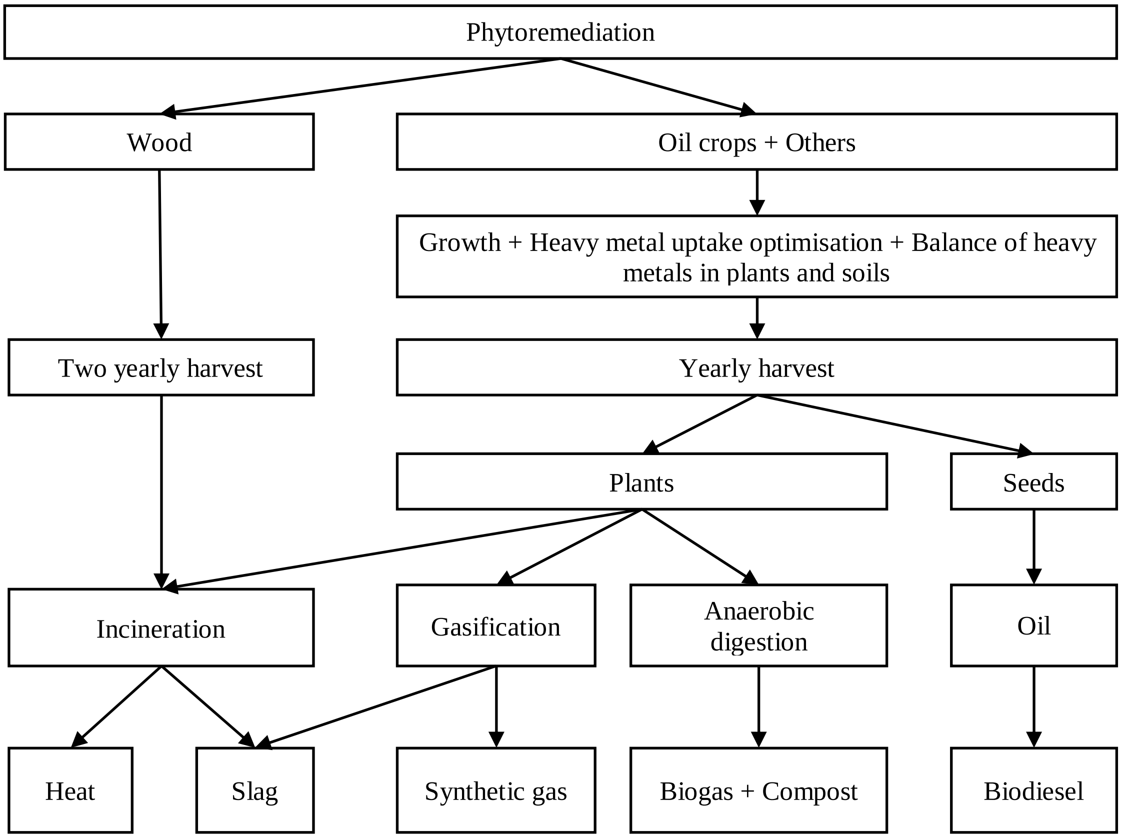

Fig. 3. Phytoremediation and production of energy model (Ginneken et al., 2007)

Many of the plants involved in energy production are well-known as having an important contribution in heavy metals treatment, being tolerant to contaminants like: *Salix sp*. – Cd, Cu, Zn, Ni, Pb, Fe (Wani, 2011); *Populus sp*. – As, Cd, Ni, Zn; *Triticum aestivum* – Cu, Zn, Pb; *Avena sativa* – Cu, Cd, Zn, Pb; *Zea mays* – Cd (Xu et al., 2013), Cu (Sheng et al., 2012) etc.

CONCLUSIONS

Energy crops are for future development a very important asset because of the improvement of the environment and the reduction of global resources. A novel approach in using energy crops is by combining it with phytoremediation on former industrial sites which are contaminated with heavy metals. The biomass production that results from this sites can be used as local energy source. Because other remediation technologies might be too expensive, for a long term treatment period, phytoremediation is the most suitable. The next step is to choose the proper energy crops and to convert the biofuel feedstock into energy. The biggest concern is to avoid the contaminated crops to enter the food chain and to secure the areas properly or to focus on choosing the plants that are able to sequestrate the heavy metals in the roots area and not transfer them to the above ground parts. The opportunity is to give the former industrial areas new functions, even though it comes with a higher cost of producing energy because of the supplementary processes of dealing with heavy metals after harvesting.

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