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3.2.13. Agronomic feasibility of bioenergy crop cultivation on polluted soils: Insights and opportunities for land use design and environmental suitability

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Abstract

The FORBIO consortium applied integrated evaluation to assess the agronomic and techno-economic potential of the selected advanced bioenergy value chains in the identified sites of the target countries not used for supply food and feed. In the Italian study area (Sulcis district), a detailed database on bioenergy crops suitable for the region based on literature was created. The agronomic potentials and yield potentials were compared, with the aim of further developing a landscape design based on GIS multi-criteria evaluation for land environmental suitability and production potential. The study provides a quantitative comprehensive assessment for providing biomass and raw materials in the supply chain for a biorefinery in one of the most polluted industrial areas in Italy, framing the basis for realistic industry's feedstock demand and sustainable land use actions for reducing heavy metal accumulation on polluted soils

Keywords: Polluted land, agronomic feasibility, bioenergy production, sustainability

Introduction, scope and main objectives

Anthropogenic soil diffuse pollution with heavy metals is of increasing question because of its potential effects on environment and ecosystem, as well as human health and safety. Heavy metal accumulation in agricultural and productive soils can be transferred to the food and feed or dispersed and lixiviated on freshwater, ground water, and rivers. The cultivation of dedicated energy crops across unavailable soils for food production could be a possible pathway for restoring contaminated and polluted soils, fostering land amelioration and rural development, responding to the European Union (EU) 20-20-20 targets and the EU's Renewable Energy Directive. A recent

study suggests that in EU at least 50,0000 hectares are eligible as suitable sites for growing energy crops on contaminated soils (Allen *et al.*, 2014).

This work reports the results of the agronomic feasibility of bioenergy crop cultivation on polluted land in the Sulcis area (Sardinia, Italy) (Figure 1) within the framework of the EU project FORBIO (Fostering Sustainable feedstock Production for Advanced Biofuels on underutilized land in Europe). The FORBIO consortium applied integrated evaluation to assess the agronomic and techno-economic potential of the selected advanced bioenergy value chains in the identified sites of the target countries not used for supply food and feed.

In the Italian study area (Sulcis district) we develop three major steps: (1) development of a detailed database on bioenergy crops suitable for the region based on literature search and field results; (2) comparison of agronomic aspects and yield potentials; (3) landscape design based on GIS multi-criteria evaluation for land environmental suitability and production potential. The results of the study will provide a useful reference for the overall feasibility of sustainable biomass cultivation on polluted soils in this region.

Methodology

The study area is located in the largest Site of National Interest (SIN) in Italy (about 22.000 ha), contaminated with heavy metals (Pb, Cu, Zn, Co, As) from industrial plants located in the municipality of Portoscuso (Figure 1). Today operates a coal power generation plant, while in the past industrial pollution derives from bauxite and aluminum production, as well as by old previous mining activities. The most polluted area is annually checked by ARPAS (Agenzia Regionale per la Protezione dell'Ambiente della Sardegna) with a monitoring network of soils, water, air, and vegetation.

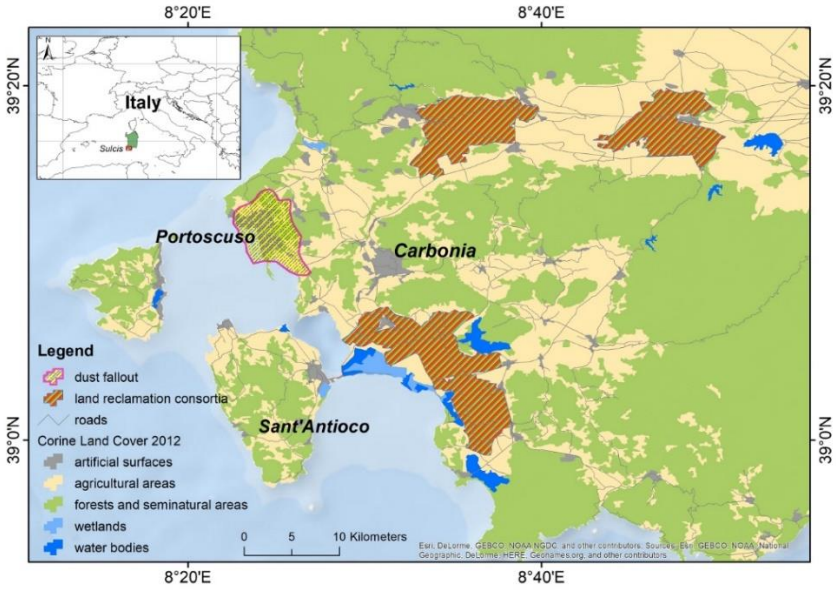

Figure 1. Overview of the study area.

In the first phase, in order to establish the most suitable bioenergy crops, relevant results from scientific studies and field trials regarding bioenergy crops conducted in Sardinia were collected. We identified and analyzed in detail the main agronomic traits of these crops: yield, dry matter, cultivar, fermentable sugars, irrigation, fertilization, soil texture and pH, elevation, growing

seasons. All relevant information was implemented in a relational database implemented in MySQL. The database includes 451 observations, for a total of 19 sites for 17 different crops. In the second phase, we develop a comparison of agronomic aspects and yield potentials of the agronomic traits, with a final short list of suitable energy crops that could be cultivated on polluted soils. In the final phase, we implement a multi-criteria decision making approach based on GIS procedure to accurately spatialize and identify the most suitable areas for the cultivation of bioenergy crops. The dataset used comprises land use map, digital elevation model, soil map, meteorological data, and ancillary data. A conservative landscape management approach was chosen, excluding from the model the most vulnerable and fragile areas such as rivers, lakes, meadows, and forests.

Results

According to the data analyzed, the most suitable annual crops for bioenergy cultivation on polluted soils are milk thistle (*Silybum marianum* L. Gaertn.), sorghum (*Sorghum bicolor* L.) and maize ((*Zea mais* L.) (Table 1). Among perennial crops, the most productive and interesting are smilo grass ((*Piptatherum miliaceum* (L.) Coss.), giant reed (*Arundo donax* L.), cocksfoots (*Dactylis glomerata* L.) and cardoon (*Cynara cardunculus* L. *var.altilis*).

Table 1. Biomass yield for the most suitable crops for bioenergy production in the Sulcis area.

Typology	**Herbaceous plants**		
	Annual	**Perenial**	
Lignocellulosic crops	Globe-artichoke Milk thistle	Giant reed Miscanthus Swichgrass Smilo grass Tall fescue Ryegrass Cocksfoot Cardoon	Eucalyptus
Oleaginous crops	Rapeseed		
Sugar crops	Sweet-sorghum		
Starch crops	Maize Durum-wheat Triticale		

According to the GIS-based suitability model (Figure 2), the available surface for biomass cultivation is approximately 1000 ha with regard to the most polluted soils (unequipped area for irrigation), 5700 ha in the surrounding area equipped for irrigation within the Land Reclamation and Irrigation Consortium (Figure 1), while the total suitable area amounted to 51.000 ha, hypothesizing a supply radius of 70 km from the biorefinery located on Portovesme.

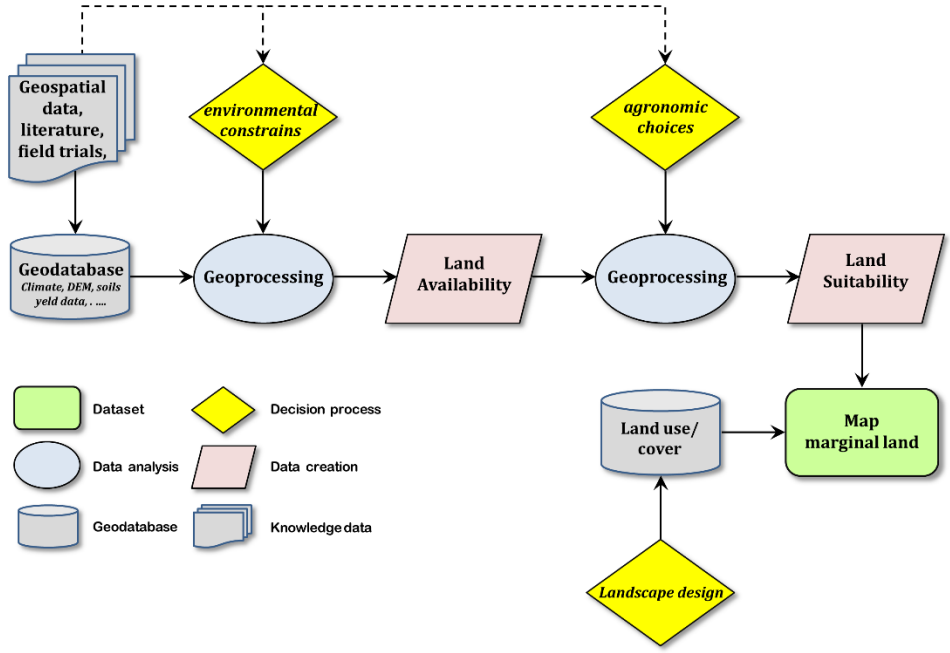

Figure 2. Flowchart of the suitability analysis

Discussion

Based on the findings gathered in this study, annual bioenergy crops most suitable for grown on polluted soils in the Sulcis area are milk thistle and sorghum thanks their phenotypic plasticity in terms of drought tolerance, water demand and evapotranspiration rate, especially. Recent results are accord with our findings that indicate that *Cardueae* species are versatile and promising crops for long-term cropping systems thanks to the attributable stable productions under low input (nitrogen application and minimum tillage) and water use efficiency (Deligios *et al.*, 2017; Gominho *et al.*, 2018; Ledda *et al.*, 2013). Among perennial crops, giant reed and native germoplasm of perennial grasses are the most suitable considering their stable biomass yields, low input, fermentable sugars, and adaptability in the Mediterranean environment (Cosentino *et al.*, 2014; Sulas *et al.*, 2015). In addition, a number of studies suggest that giant reed as great adaptability and phytoremediation capacity on polluted soils, with phytoextraction and accumulation in the hypogeal part (Barbosa *et al.*, 2015; Fiorentino *et al.*, 2013). These results have encouraging implications for soil restoration and remediation, coupling of phytoremediation with sustainable bioenergy production. In fact, considering the outcome of the GIS-based suitability approach can be produced 15.000 tons dry biomass in the most polluted area, assuming a mean biomass productivity of 15 dry tons/ha. Moreover, can be produced about 142.000 tons dry biomass in the surrounding area equipped for irrigation (biomass productivity 25 dry tons/ha), in accordance with agronomic inputs and crop management.

Conclusions

The aim of the present research was to examine the agronomic feasibility for the cultivation of bioenergy crops on polluted and underutilized soils located in the Sulcis area (Italy), and evaluate the land suitability and production potential with a GIS-based methodology. Based on the findings gathered in this study, the following conclusions can be drawn:

- Dedicated bioenergy crops such as giant reed and *Cardueae* species can be potentially grown on polluted soil for providing biomass and raw materials in the supply chain for a biorefinery;

- According to our GIS-based multi criteria approach, the most contaminated area, unequipped for irrigation, is suitable only for rainfed crops.

The present study provides a quantitative comprehensive assessment for providing biomass and raw materials in the supply chain for a biorefinery in one of the most polluted industrial areas in Italy, framing the basis for realistic industry's feedstock demand and sustainable land use actions for reducing heavy metal accumulation on polluted soils.

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3.2.14. Bioremediation of crude oil contaminated soil

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Abstract

This study aims to develop certain perspectives based on the principle of on-site remediation of the soil through biological means which is known as "bioremediation" against soil pollution issues resulting from fuel contamination in our country and to reveal the fatty acid profile in the final soils. The fatty acid profile of the soils was pointed out by testing the activity of three basic bioremediation applications (biological multiplication, biological excitation and the combined application of these two approaches) established in the laboratory environment for this aim. Under biological multiplication applications, 6 strains of bacteria were selected which exhibit the highest growth in crude oil environment isolated from oil-contaminated soils of Adana, Batman and Adıyaman and which have the highest levels of crude oil degradation. *(Pseudomons aeruginosa, Pseudomonas putida biotype A, Citrobacter amalonaticus-GC subgroup A, Acinetobacter genomospecies)*. Under biological excitation applications, the organic materials being humic-fulvic acid and, in combined applications, different combinations of bacteria mixture and organic materials were examined as to the amount of crude oil they degrade in an incubation period of 120 days by qualitative hydrocarbon-type analyses. The highest level of oil degradation, being %56, occurred under biological multiplication applications where the bacteria mixture was applied. Under biological excitation conditions where various organic materials were applied to the contaminated soil, degradation to %18 was observed. In combined applications, oil degradation was achieved to %30.

Keywords: Soil, crude oil, bacteria, bioremediation

Introduction, scope and main objectives

Several researchers explained that in soil, number and types of existing microorganisms are affected by biological and physicochemical events including soil properties such as suitable conditions for microbial decomposition (oxygen, food substance, temperature and pH), microbial decomposition of hydrocarbons, quantity and quality of contaminants and its biological usefulness and particle distribution. (Atlas 1981, Atlas and Bartha 1992, Steffan *et al.* 1997; Morgan and Watkinson 1989; Margesin and Schinner 1997a).

Although there are many studies made on microorganisms which head for individual hydrocarbons or hydrocarbon groups forming structure of petroleum and petroleum products