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Biomass and Bioenergy 28 (2005) 219–228
BIOMASS & BIOENERGY
www.elsevier.com/locate/biombioe

Development of short-rotation willow coppice systems for environmental purposes in Sweden

Jaconette Mirck[a], J.G. Isebrands[b], Theo Verwijst[a,*], Stig Ledin[c]

[a]*Department of Short Rotation Forestry, Swedish University of Agricultural Sciences, P.O. Box 7016, S 750 07 Uppsala, Sweden*
[b]*Environmental Forestry Consultants, LLC, P.O. Box 54, New London, Wisconsin 54961, USA*
[c]*Department of Soil Sciences, Swedish University of Agricultural Sciences, P.O. Box 7014, Uppsala, Sweden*

Abstract

During the last three decades, driving forces behind the development of short-rotation willow coppice (SRWC) in Sweden have been changing from a primary focus on biomass production towards emphasis on environmental applications. In most cases, current commercial SRWC practice is geared towards a combination of biomass production for energy purposes and environmental goals. The latter goals range from decreasing the impact of specific contaminants in the environment to organic waste handling in a recycling system in urban and/or agricultural areas.

Where biomass production and pollutant management overlap, the science of phytoremediation has its practical application. Through phytoremediation, waste products that previously have been a burden for the society can be used as valuable resources to increase short-rotation willow biomass production.

In this paper we will present the terminology and definitions of different types of phytoremediation. We also give an overview of five different cases of phytoremediation activities with a potential for large-scale implementation. Some of the types of activities are already commercially used in Sweden; others seem promising but still need further development.

Keywords: Heavy metals; Phytoremediation; *Salix*; Sludge; Vegetation filter; Wastewater

1. Introduction

The original driving force for willow research in Sweden, which started in the late 1960s, was a predicted shortage of raw material for the pulp and paper industry. When that prediction appeared to be an artefact of national inventory methods, the energy crisis in the early 1970s provided a new motivation to continue research on willows [1]. In the 1980s, the need for non-fossil fuels started to increase and willow growing for energy was commercialised in Sweden [2].

*Corresponding author. Tel.: +46-18-672550; fax: +46-18-673440.
E-mail address: Theo.Verwijst@lto.slu.se (T. Verwijst).

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doi:10.1016/j.biombioe.2004.08.012

Agricultural policy, employment issues, and finally the growing concern for the environment were added to the forces that motivated an extensive research on willow growing systems in Sweden [3]. Consequently, research on short-rotation willow Coppice (SRWC) has been going on in Sweden for three decades, and this has led to a large theoretical knowledge base and variety of practical applications of willow growing systems, both for energy purposes and for other goals.

Large-scale implementation of SRWC for biomass production, in combination with environmental goals, is currently driven by the increasing needs to incorporate organic waste handling in a recycling concept, and by the notion that SRWC may play a function in redirecting heavy metals from the human food chain [4]. Environmental applications of SRWC are developing rapidly and exploit the heritable plant physiological characteristics of willow that govern the uptake and processing of water, nutrients and other elements [5].

Where biomass production and pollutant management overlap, the science of phytoremediation has its practical application (Fig. 1). Through phytoremediation, waste products that previously were regarded as a burden for the society can now be used as valuable resources to increase short-rotation willow biomass production. Depending on the fate of contaminant, the substrate type and the plant physiological processes involved, specific aspects of phytoremediation are addressed in different terms. This paper sets out to clarify the terminology associated with phytoremediation and gives some Swedish examples of practical implementation of SRWC for phytoremediation in combination with biomass production for energy purposes.

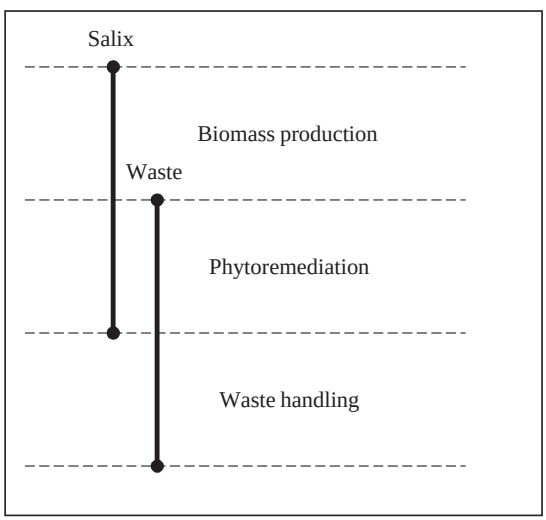

Fig. 1. Biomass production and waste handling can be combined in phytoremediation applications.

2. Phytoremediation in perspective

2.1. General definition of phytoremediation

Phytoremediation is the intentional use of living plants for remediation of contaminated soil, sludge, sediment and groundwater. Using a managed vegetation system, contaminants may be removed, degraded or stabilised, thereby improving the environment in the intended direction. Phytoremediation can be used to clean up environmental contamination by some heavy metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, radio nuclides and landfill leachates [6]. Phytoremediation may also provide a solution in the case of organic pollutants in agricultural soils.

2.2. Principles of phytoremediation

Phytoremediation is a general term for ways in which plants (*phyto* = plant) are used to decrease the impact of pollutants on the environment. From the plant's point of view pollutants may be considered as nutrition (macronutrients like N, P and K, and all micronutrients). In suitable concentrations, these may be used to increase biomass production, but can be harmful to the plants at higher concentrations. Pollutants may also contain a number of elements that are not essential for plant growth. This category never contributes to plant growth, but may have negative effects on biomass production.

To understand phytoremediation more specifically, and to address specific processes, substrate