Environmental impacts of SRWC

1. Energy and greenhouse gas balance

1.1. Introduction

Short Rotation Willow Coppice (SRWC) is an energy crop which must meet two needs : to produce energy as efficiently as possible and to save as much CO_2 as possible compared with non-renewable energies. Two tools were used to measure these factors : the energy balance, which is used to calculate the energy ratio (ratio of the amount of energy produced versus the amount of fossil energy used) and the greenhouse gas balance, which indicates the amount of greenhouse gas emitted by unit of energy or area. This latter balance gives the reduction in emissions compared with a heat and/or electricity production system using non-renewable energies.

These energy and CO_2 balances were prepared using data collected under the WILWATER programme. The missing data were taken from the literature or from working hypotheses. The balances were prepared for two types of plot, those which did not receive inputs and those receiving inputs of sewage sludge.

Details of the data and coefficients used in this study are available in the detailed report by the Catholic University of Louvain[1].

1.2. Methodology

The first thing to do when preparing a balance is to define the limits between which the balance is to be calculated. In this case, the energy and greenhouse gas balances relate to the production of willow chips, including establishment, maintenance, harvest up to transport and storage of the chipped wood. These balances do not include energy conversion and heat or electricity production.

The balance covers seven 3-year rotations with harvesting in the 3rd year in each case. The energy ratio and the amount of greenhouse gas emitted were calculated for the life of the crop, i.e. 21 years.

The energy balance is an input-output balance for the crop. T

he inputs include the amount of energy required to:

- produce fertilisers and herbicides
- produce cuttings
- produce the machines used
- carry out the cultivation operations (fuels)

The outputs are the amount of energy in the wood harvested.

These data can be used to calculate the energy ratio: $\text{ratio (energy efficiency)} = \dfrac{\sum \text{outputs}}{\sum \text{inputs}}$

[1] Bilan énergie et CO2 de la culture de TtCR de saule dans le cadre du projet WILWATER – UCL – 2007 [Energy and CO2 balance of SRWC willow crop under the WILWATER project – Catholic University of Louvain – 2007]

The greenhouse gas balance includes the amount of CO_2, CH_4 and N_2O emitted and can be used to calculate the CO_2 equivalent emission per quantity of energy produced.

For the energy balance, the functional unit is MJ/ha. For the greenhouse gas balance, the functional unit is kg($CO_{2\ eq}$)/ha (kg($CO_{2\ eq}$) is the kg of greenhouse gas emitted in terms of CO_2 equivalent). As a reminder, the global warming potential of methane and nitrous oxide is 21 times and 310 times greater than that of CO_2, respectively.

1.3. Results and discussion

1.3.1. Energy balance

The energy balance was calculated for eight sites under the WILWATER programme, four of which received sludge and four no input. The table below shows the mean energy ratios obtained.

Table 1 : Mean energy ratio with and without sludge application (MJ/ha)

	With sludge application	Without sludge application
Fuel	134861	97539
Machine production	23144	13875
Plant protection products	653	297
Production of cuttings	144	144
Total inputs	**158801**	**111854**
Total outputs (wood production)	**5012976**	**3759732**
Ratio [$MJ_{outputs}/MJ_{inputs}$]	***32***	***34***

The energy ratios for the sites with and without sludge application were not significantly different even though the sites with sludge application had higher inputs. This may be explained by the increase in crop yield, and therefore in outputs, as a result of the minerals input through sludge application.

The ratios calculated can be compared with other energy ratios from the literature:

- Heller et *al.* (3): 33 – 78 $MJ_{outputs}/MJ_{inputs}$
- Dubuisson and Sintzoff (10): 22 – 28 $MJ_{outputs}/MJ_{inputs}$

The calculated energy ratios are within the range of the values obtained by Heller *et al.* However, the Dubuisson and Sintzoff values are lower than those calculated here. This could be explained by the fact that Dubuisson and Sintzoff included inputs of artificial fertiliser, particularly nitrogen, which have high energy consumption (≈ 40 % of energy inputs).

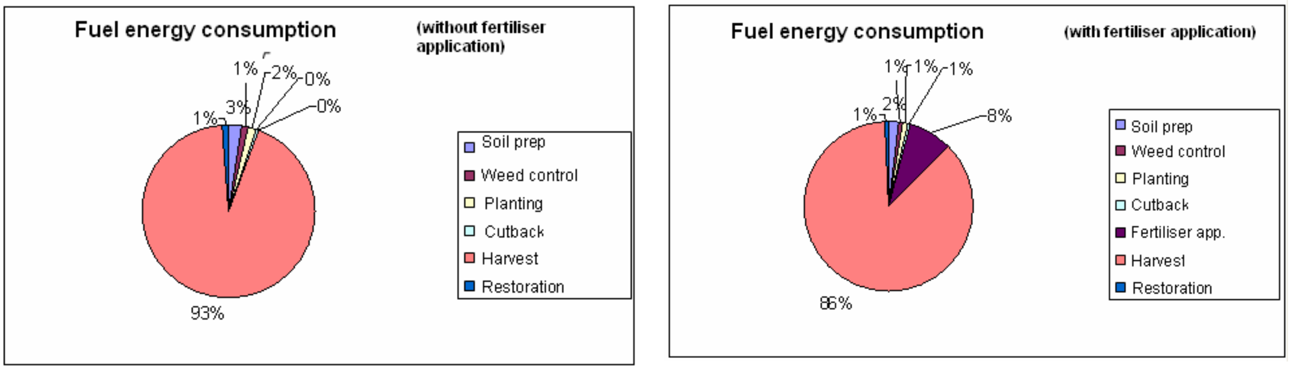

Figure 1: Fuel inputs for sites with and without sludge application

It was noted that fuel consumption represents the largest proportion of overall energy consumption (88% for sites without sludge application, 85% for sites with sludge application). The next largest is machinery construction (12% without sludge application, 15% with sludge application). The energy consumption for the production of cuttings and plant protection products is negligible. The distribution of the factors that influence fuel consumption is shown in the figures below.

Harvesting (which includes transport to the storage site) and fertiliser application, when used, are the largest consumers of fuel. These operations take place at least once every three years, unlike the other operations such as planting, cutback and stump removal. Note, however, that the harvesting method used (harvester + chopper with grab) has very high energy consumption.

1.3.2. Greenhouse gas balance

The greenhouse gas balance was calculated for the same plots as the energy balance. The table below shows the results.

Table 2 :Mean greenhouse gas ratio with and without sludge application [kg CO2 eq/ha]

	With sludge application	**Without sludge application**
Fuel	11055	7996
Machine production	1578	988
Plant protection products	27	12
Fertiliser application *	3635	1915
Production of cuttings	11	11
Total emissions	**16306**	**10922**
	3.25 g $CO_{2\ eq}/MJ_{outputs}$	**2.90 g $CO_{2\ eq}/MJ_{outputs}$**

* fertiliser application also includes N_2O emissions produced by leaf decomposition

Note that the emissions obtained are of the same order of magnitude as those in the literature:

- Heller et *al.* (3) : 3.3 g $CO_{2\ eq}/MJ_{outputs}$
- Dubuisson and Sintzoff (10): 3.7 – 6.2 g $CO_{2\ eq}/MJ_{outputs}$

The figures given below represent the distribution of CO_2 emissions for the different headings.

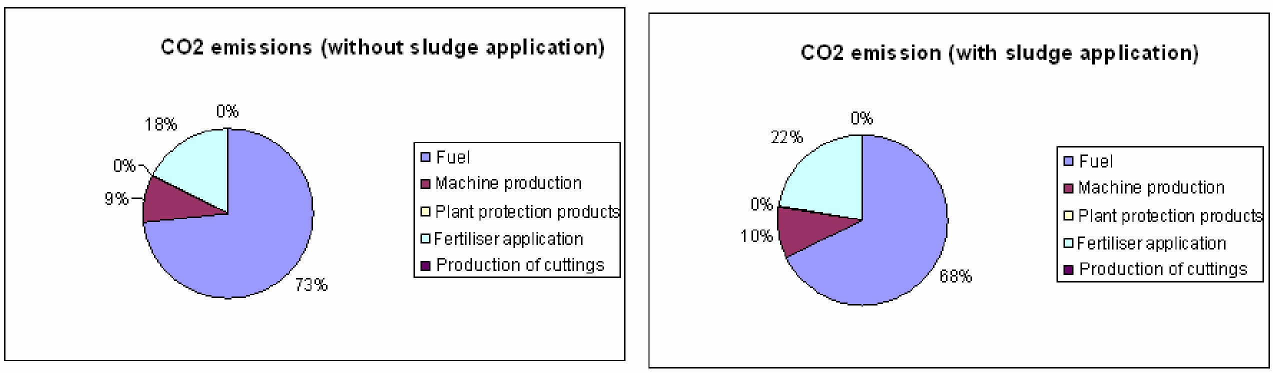

Figure 2 : Distribution of $CO_{2\ eq}$ emissions with and without sludge application

Fuel, used principally for harvesting of SRWC, represents the largest proportion of CO_2 emissions. The second highest CO_2 emissions are for fertiliser application. Application of sewage sludge and decomposition of the leaf litter produce emissions of N_2O, a greenhouse gas which is 310 times stronger than CO_2.

1.4. Conclusions and recommendations

In the energy balance, the largest source of energy consumption is harvesting and transport of willow chips. Optimisation of the energy ratio therefore requires rationalisation of harvest and transport (particularly by transporting the chips as short a distance as possible or avoiding split operations).

Nevertheless, the energy balance for willow cultivation is very good compared with other annual crops:

	SRWC willow	**Maize methanation**	**Oilseed rape** (oil production)
Energy efficiency	30-35	5	4-5

The highest CO_2 emissions are from fuel use, fertiliser application and decomposition of the leaf litter (N_2O emission). However, the difference in emissions between plots with and without sludge application is not very significant. Sludge may therefore be applied without causing excessive CO_2 emission.

2. Impact on biodiversity

2.1. Introduction

The impact of a willow plantation on biodiversity may be considered in three ways:

- Diversity of the plant and animal species found in the plantation
- The hydrological influence of the plantation on sites downstream (is there a risk of leaching affecting downstream locations? Does the plot have a protective role?)
- The role played by the plantation in the existing ecological network (is the plot isolated? Does it create new connections?)

Note that the impact of SRWC on biodiversity, whether positive or negative, will vary depending on the region, habitat modification (compared with the previous crop) and crop management.

Details of the findings and observations are available in the impact study report on SRWC and the environment[2]. The references cited are referred to in the bibliographical summary prepared by the Catholic University of Louvain[3].

2.2. Methodology

Detailed studies of the flora were carried out at six sites. The sites studied were visited in the spring of 2006. They were walked in a number of transects, the layout of which was selected on the basis of the principal ecological constraints (e.g. from top to bottom topographically, from dry to wet, etc.), the type of clone planted (if different clones were planted in the same plot), year of planting and, if necessary, type of effluent or quantity applied. Observations were made at regular intervals (every 10-15m). Each species found in the surrounding 3-4m^2 was identified and the density of population (coefficient of abundance/dominance) was also taken into account. Each site was revisited in 2007 to follow up changes in the flora.

This is a quick method of gaining a representative picture of the flora at a site. It enables identification of the type of habitat at each site according to the CORINE biotope code. Data relating to the flora were supplemented by observations of tracks (mainly left by mammals) to evaluate the host potential for fauna.

Finally, a global analysis was conducted to evaluate the risk of competition between the willows and sites of special interest.

2.3. Results

For the first few years after planting, the grass cover mainly consisted of weeds and commensals of the common crops which are found on all recently disturbed land.

In the second phase, species which are more characteristic of grassland appeared, with hygrophilous plants occasionally growing on the wettest plots. The shade-loving vegetation specific to shady areas and woodland fringes did not appear for three or four years. However, this move towards fringe vegetation is slowed by the regular harvests which re-open the habitat and encourage re-growth of the sun-loving species found on more open ground.

[2] Etude d'impact ex post des taillis à très courte rotation de saules [Ex post impact study on very short rotation coppicing of willow] Bureau d'étude ISL for AILE and WILWATER - 2007

[3] Etude de l'impact environnemental du TTCR dans le cadre du projet WILWATER – UCL – 2005 [Study of the environmental impact of SRWC under the WILWATER project – Catholic University of Louvain – 2005]

At the sites studied, the plant cover which developed under the willows, under one main heading: *83.3261:* Willow planting in very short rotation coppice, may be classified into four CORINE headings:

- *37.21: Atlantic and sub-Atlantic humid meadows*
- *37.72: Shady woodland edge fringes*
- *38.22: Medio-European lowland hay meadows*
- *87.1: Fallow fields*

Nearly all the plantations showed signs of regular visits by roe deer. This means that willows offer shelter for large fauna. There are many flowering plants under the willow cover. It is currently accepted that a highly diverse flora attracts many pollinating insects but this will have to be confirmed by specific studies which were not carried out under the programme.

According to the literature (UK and Sweden), there is an extremely low risk of hybridisation between S. viminalis and native willow species, mainly because propagation of willows is primarily vegetative (cuttings) and propagation by germination is very difficult. Willow seeds have a very short life. Studies in the UK and Sweden did not find any cases of large-scale seed dispersal. For example, Salix viminalis, which was introduced into Sweden 100 years ago, has not spread to the countryside around the plantations.

Under the WILWATER programme, none of the sites showed any signs of germination or colonisation of the fringes by SRWC clones.

2.4. Conclusions and recommendations

SRWC is primarily a cropping area dedicated to the production of wood and land application of effluents but it is very different from an annual crop. Although soil cultivation, chemical treatment and rotary cutting between the rows are necessary at planting, no further intervention is necessary apart from sludge application and harvesting. The flora is therefore generally more diverse under the willow cover than in an annual crop or on a recently established grassland.

It is more tricky to make the same comparison between SRWC and permanent grassland. Particular attention should be given to the risk of destroying permanent grassland which is of heritage interest, initially through SRWC planting operations but subsequently by the shade created as willows grow. The need to consider this type of risk has also been raised by Belgian environmental organisations.

A recommendation that habitats of ecological interest should be avoided when planting SRWC has also been formulated in several European countries. According to the Royal Society for the Protection of Birds (RSPB) (UK), SRWC is very promising for biodiversity but it must not be established in protected areas or areas of high ecological value (damp meadows, etc.). The risk to the biodiversity of humid meadows is all the greater as this type of habitat could be suitable for SRWC (moisture, low agricultural value).

The mixture of forest-loving and grassland species found under SRWC willow is also found beneath hedgerows. SRWC may therefore be compared with these even though the ecological constraints are different. SRWC could play a new role within the *bocage* patchwork as an intermediary and complement to the hedges by reinforcing the role of some hedges as an ecological corridor and increasing the reserve potential of wooded areas within the *bocage*. These roles are directly dependent on their position in the landscape and the size of the plots cultivated.

3. Impact on landscapes

3.1. Introduction and methodology

The study is based on a number of elements:

- An analysis of the initial status. This first approach aims to analyse the context of the landscape where the project is to be sited. It involves a general description of the sites and elements making up the landscape (buildings, hydrographic network, relief, vegetation).

- A landscape inventory. This inventory should make it possible to determine the general sensitivity of the landscape (users, frequency of visits, identify viewpoints) and its characteristic elements (guide lines, focal points).
- An evaluation of landscape integration of SRWC. This element of the study aims to assess the compatibility of willow plantations with their landscape environment. Landscape integration is evaluated at distinct points in the SRWC growing cycle in order to best identify the effect of the seasons and agricultural work (particularly harvesting).

The impact of the plantation on the landscape is assessed on the basis of the interplay between two indicators:

- The level of visual impact as a function of the compatibility of the plantation with the surrounding landscape elements; the contrast in scale and dominance of the position give a classification from low (plantation not very visible) to high (plantation very visible).
- The impact of the plantation, whether positive or negative, by looking at the impact on openness, heritage and diversity of the landscape.

Details of the findings and observations are available in the report on the impact study of SRWC on the environment[4]. The references cited are referred to in the bibliographical summary prepared by the Catholic University of Louvain[5].

3.2. Results

The characteristics of the landscape impact of a SRWC coppice plantation are as follows:

- Great variations over time in two phases: a gentle transition phase over several years while the trees grow, and an abrupt change at harvest (or cutback in the first year). This variation involves the parameters opening up/closing off of the landscape, colour and texture.
- A direct relationship with occupation of the soils around the plot: the presence of features which break up the landscape (hedges, tall crops, woodland) facilitates landscape integration of the plantation.
- A direct relationship with the presence or absence of users of the landscape: closing off a view from an inaccessible observation point does not have any real impact, but the opposite is true for closing off a view from a house, for example.

Ultimately, SRWC offers an intermediate landscape between traditional agricultural land (dense planting in lines, with well defined rows, regular harvesting) and long-term woodland (tall plantation in the year of harvesting). The landscape impact is therefore greater in open, flat landscapes than in wooded *bocage* landscapes. The shape and position of the plot are also important. If the plot is in a valley, the effect of closing off the landscape can be relatively high.

The positive or negative impact of the plantation is more difficult to assess and will always involve some subjectivity. However, the following grid is proposed:

<table>
<tr><th></th><th>Opening</th><th>Heritage</th><th>Diversity</th></tr>
<tr><td>In dense or wooded bocage landscape</td><td>Risk of further closing off the landscape</td><td colspan="2">A very regular plantation may contrast with spontaneous woodland</td></tr>
<tr><td>In more open bocage landscape</td><td colspan="2">May add continuity to the existing bocage (depending on plot shape)</td><td rowspan="2">Adds diversity to the landscape, the significance of which needs to be evaluated</td></tr>
<tr><td>In lowland landscapes</td><td colspan="2">A compact plot on a flat landscape may create an unpleasant, "postage stamp" effect.
A longer plot which follows the topography may create an effect similar to a copse or a hedge.</td></tr>
</table>

[4] Etude d'impact ex post des taillis à très courte rotation de saules [Ex post impact study on very short rotation coppicing of willow] Bureau d'étude ISL for AILE and WILWATER - 2007

[5] Etude de l'impact environnemental du TTCR dans le cadre du projet WILWATER – UCL – 2005 [Study of the environmental impact of SRWC under the WILWATER project – Catholic University of Louvain – 2005]

4. Conclusions and recommendations

Firstly, the expectations of people living very close to the plantation must be considered to ensure that their view does not become too closed-off.

It appears that *bocage* type landscapes can accommodate plantations relatively easily. The plantation is often less visible and can help to complete the existing network. However, care should be taken to avoid closing off the landscape too much.

In lowland areas, integration is more difficult because plantations are more visible; there is a danger of creating unpleasant discontinuities. By contrast, a plantation which takes advantage of the topography and plot shape can replace some heritage features in landscapes which are too open or monotonous.