Impacts of promoting perennial crops in the French agriculture

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Abstract

This paper is devoted to a quantitative analysis of the introduction of perennial crop in a short-term supply model. The analysis provides assessment of impacts regarding land use and N-input demand. We show that a variation in yield or the subsidy amount of miscanthus leads to a significant change in land use and N-input.

Keywords: lignocellulosic perennial crop; bio-energ; mathmatical linear programming; land use; N-input demand;

1 Introduction

Originated from energy crops, biofuels are increasingly being considered as a sustainable energy source when compared with fossil carbon sources. Interrelated factors have led to increased demand for this green energy. Factors include increased energy demand due to resource depletion and instability in oil producing regions, recent technological breakthroughts in agriculture and concerns over environmental impacts such as climate change (Hall et al., 2009). Biofuel development is in addition driven by rural development, job creation (Kraeussl et al., 2004), increasing energy self-sufficiency and improving competitiveness (EC, 1996, 1997). In Europe, conventional energy crops appear like widely marketed productions, after Brazil and the USA. This expansion has been spurred by the Kyoto Protocol signed in December 1997 and by the European energy policy. Neverthless, food crops and residues from forestry and agriculture cannot provide all biomass needed to fulfill the high future demand. As a result, second generation biofuels originated from perennial biomass crops has been developed. These crops are characterized by a high land use effeciency and their production indicates a substantial reduction in GreenHouse Gas (GHG) emissions. Among others these crops are annually harvested perennial crops like miscanthus.

Miscanthus *(Miscanthus x Giganteus)*[1] is a perennial rhizomatous grass which has its origins in the tropics and subtropics, but different species are found throughout a wide climatics range in East Asia (Greef & Deuter, 1993). The remarkable adaptability of miscanthus to different environment (Numata, 1974) makes it suitable for establishment and distribution under a range of European and North American climatic conditions (Lewandowski et al., 2000). Physiologically, miscanthus, like maize, is a C_4 species, fixing carbon by multiple metabolic path-ways with a high water use efficiency (Koshi et al., 1982; Moss et al., 1969). Miscanthus roots can penetrate to a depth of around 2 meters, which can provide a good protection against soil erosion. Even though its high biomass yield potential, this crop requires low input level and therefore involves decreasing risk of ground water pollution by pesticides and nitrates. Miscanthus is generally harvested in early spring, which allows for good combustion quality due to low water content in addition to the fact that it contains low ash, N, chloride, potassium (Lewandowski et al., 2003).

According to the Renewable Energy Directive, the French government is committed to have a mandotory 10% target of energy from renewable sources in transport by 2020 (EU, 2009). To achieve this target, additional land should be allocated to crops required to produce biofuels. Indeed, either marginal and grass lands will be used or existing cropland will be converted into lands dedicated to biofuels. The introduction of lignocellulosic perennial crop i.e miscanthus in farming systems may lead to two main effects: i) changes in land use regarding direct allocation for miscanthus and re-allocation among other crops, and ii) changes in input demand and related environmental impacts partcularily due to low N-needs. A variation in yield or subsidy levels of miscanthus may alter these changes.

This paper aims to analyse the impact of the introduction of miscanthus on land use and N-input demand. The annual agricultural supply model - AROPAj- used in our analysis cover the European Union by the way of a large set of representative farm groups. The model is improved by the implementation of functions of dose-response linking the N-input and the crop yield. There is need to compute the Net Present Value (NPV) of this crop. The determination of this value is based on

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[1] Miscanthus x Giganteus is a steril hybrid between *M. Sinensis* and *M. Sacchariflorus.*

"the Faustmann" rule used in the case of perennial crop with annual harvest. A generic function of natural biomass is used to calculate the average miscanthus yield in a deterministic case. This function is calibrated on few data available from the works of Miguez et al. (2008), Clifton-Brown et al. (2007), and Christian et al. (2008), and adjusted to the average yield of a traditional annual crop such as wheat, which is used as a control plant.

The paper is organised as follows. Section 2 decribes the modelling chain, specially the introduction of the perennial activity in the static short term model dedicated to agricultural supply. Section 3 presents results in term of land use in France and changes in environmental impacts in northern France.

2 Methodology

2.1 The agricultural supply model

The AROPAj model, developed by INRA, is an annual mathematical programming model devoted to the European agricultural supply. it belongs to a class of models based on a micro-economic approach (Arfini, 2001). It describes the annual supply choices of the European farmers in term of surface allocation, animal production and on-farm consumption. Farmers are clustred into farm groups according to the techno-economic orientations within each region, the economic size, and the altitude class. Each farm group which is staticscally representative of the different production systems is assumed to select the supply level and input demand in order to maximize the total gross margin. The feasible production set is limited by several constraints: land endowment, animal demography, livestock limit, animal feeding, and Common Agricultural Policy (CAP) requisites including milk and sugar quotas. The AROPAj model has been used to study the successive reforms of the CAP (Jayet & Labonne, 2005), i.e. Luxembourg reform in which many of the direct payments that have been linked to production are decoupled and instead delivered through an provided in the form of a area payment. Different model versions were developed among them are the V_2 covering the European Union (EU) - 15, and V_3 version convering EU - 25. For France, there are 157 farm group coverin the 22 French regions. Results in this paper are obtained from V_2 for which "N-yield" functions are now available. In this version, the model represents a large part of the used agricultural area devoted to "grandes cultures" (soft wheat, durum wheat, barley, corn, rice, oats, rye, other cereals, rapeseed, sunflower, soya, potatoes, sugar beet, peas, other proteins), forages, grasslands, and major animal productions (bovine, goat and sheep herds, poultry and pigs).

2.2 Insertion of miscanthus in the model

For the introduction of miscanthus in the model, two main elements should be calculated: the average yield Y^* and the average Net Present Value VPN^*. A generic growth function is used to calculate Y^*. This function is calibrated thanks to data provided by the works of Miguez et al. (2008), Clifton-Brown et al. (2007), Christian et al. (2008) and agricultural experts. Due to the lack of data at farm group level regarding perennial crops, we develop a two-step procedure to feed the model with appropriate informations. The first step is devoted to the selection of a continuous time yield function, when the average yield is correlated to a control plant yield. The second step is a computation step based on a simple dynamic approach aiming at computing of the rotation duration, the average yield and discounted annual costs.

2.3 Recovery of perennial crop characteristics

2.3.1 Determination of the generic growth function: $Y(t)$

Basing on researchs of Miguez et al. (2008), Clifton-Brown et al. (2007) and Christian et al. (2008), a model growth model for miscanthus was built. In this model, let a be the maximum biomass yield, b the inflection point in which biomass yield reaches a half of the maximum biomass yield, c the spreading parameter, d the attenuation coefficient.

The model is given by the following equation:

$$Y(t) = [a/(1 + \exp((b - t)/c) - a/(1 + \exp((b)/c))] \exp(-dt) \tag{1}$$

As shown in Figure 1, three phases are identified: a) installation phase where the yield increases, b) maturity phase where the biomass reaches its maximum, and c) decline phase showing the decrease of the miscanthus growth.

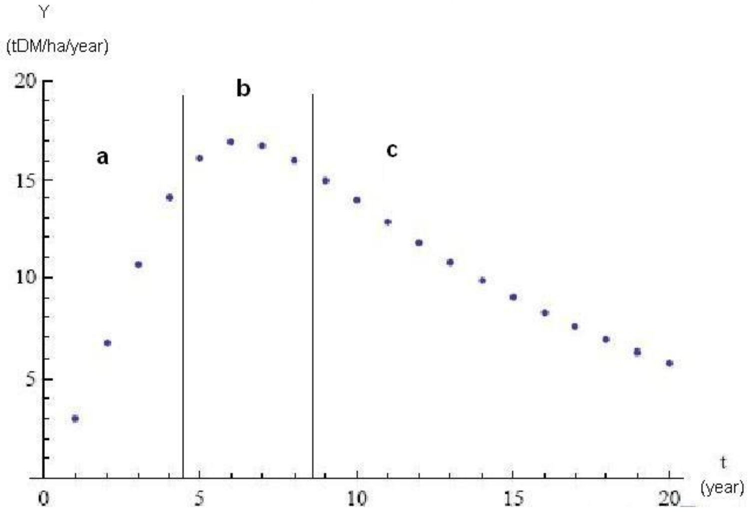
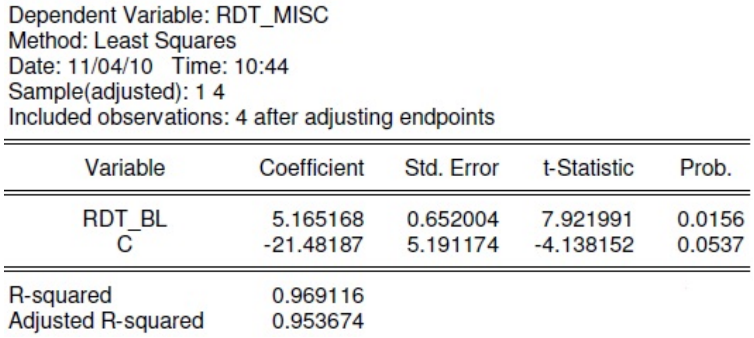


Figure 1: Miscanthus Growth Curve

2.3.2 From dynamic approach to static framework

To introduce miscanthus in the AROPAj, we needed to compute its yield level for each farm group. However, miscanthus crop has been recently introduced in France and informations about yield for the full rotation period (15-20 years) are therefore not available. Thus, we supposed that miscanthus yield increases with the quality of the land, like wheat which is a traditionnal crop presented for the majority of farm group into AROPAj. We proceed therefore to an adjustement of the average regional yield of miscanthus to the average regional yield of a traditional crop presentend in the four-fifths of french farm groups. Regional miscanthus yield data are provided by the French Biomass Project REGIX. Figure 2 which shows the significant correlationship between miscanthus and wheat.



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Dependent Variable: RDT_MISC
Method: Least Squares
Date: 11/04/10   Time: 10:44
Sample(adjusted): 1 4
Included observations: 4 after adjusting endpoints

        Variable      Coefficient    Std. Error    t-Statistic    Prob.

         RDT_BL        5.165168      0.652004      7.921991      0.0156
            C         -21.48187      5.191174     -4.138152      0.0537

R-squared              0.969116
Adjusted R-squared     0.953674
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Figure 2: Correlation between the average yield of miscanthus and the average yield of wheat.

2.3.3 Determination of the Net Present Value: VPN

We suppose that miscanthus plantations are typically grown as an even-aged monoculture. Prices and costs rise at continuous time about 1.5% per year and the discount rate δ is fixed at 5% for perennial grasses in France. Establishment cost (EC), paid off over T years (rotation) in an infinite sequence as established by Faustmann's criterion, happens in year zero. Fixed at 3000 €/ha, the activities or operations that compose this cost are: rhizome purchase, planting, cultivation, herbicides for a weed control. Production costs (PC) happen one year after the establishment and will be appealing to each T years until the infinite. They correspond to variable costs and include expenses made for fertilization, weed control, and harvest. They are fixed at 400 €/ha/year. All cost data are acquired by experts. We consider that the crop is harvested annually (several times) in a rotation of T years. Indeed, Gross margin (GM) happens in every year during a rotation, after the establishment year. At year t, its value is obtained by multiplying miscanthus yield harvested at t ($Y(t)$) in tons of dry matter (tDM), by its price (P) fixed by Bical Biomasse France (BBF) at 70 €/tDM, i.e., $GR(t) = P * Y(t)$.

The NPV of miscanthus is obtained by maximizing the discounted profit infinite sequence, at time $t = 1$. Therefore, the discounted value of the net income is equal to

$$NPV(t) = (-EC + \sum_{t=2}^{T} (GR(t)\exp(-\alpha) - PC\exp(-\alpha))\exp(-\delta t)/(1 - \exp(-\delta T)) \qquad (2)$$

where α is the inflation rate.

3 Preliminary results and discussion

This section provides the impacts of the introduction of miscanthus in the AROPAj model, when both the yield and the subsidy amount of miscanthus varied.

The yield and the subsidy of miscanthus varied from -10 to +30% around an average expected yield equals to 11 tDM/ha [2] and from 0 to 250 € respectively.

Mapped examples of the different scenarios presented in figure 3 show that miscanthus can be essentially located in the majority of seine basin regions. Thanks to its root system, miscanthus crop could decrease the level of nitrates at the output of collection point, and the purification effort for water companies could therefore decrease.

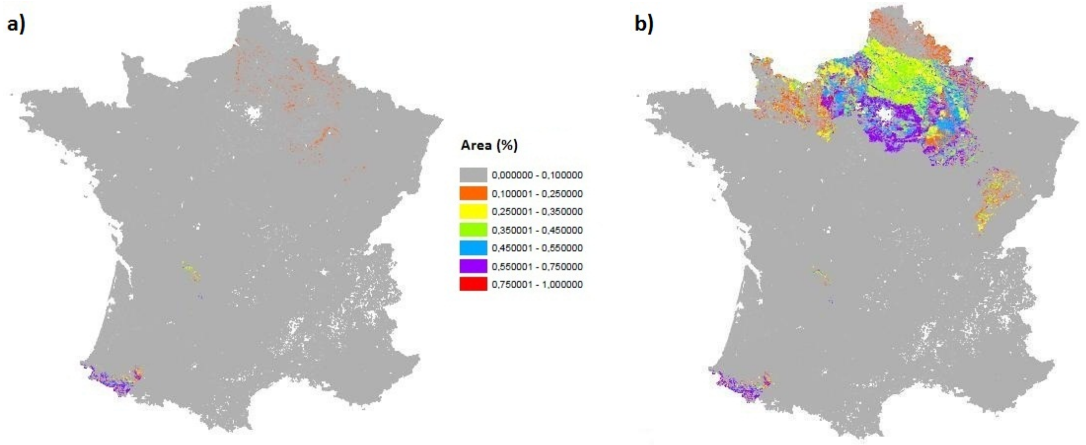

Figure 3: Miscanthus area for France for the scenarios: a) Baseline Y^*, b) increase in Y^* by 20%.

Results show also that the variation of yield and subsidy amount of miscanthus leads to changes in land use and N-input demand.

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[2] The average expected yield is calculated by Faustmann rule for each farm-type

3.1 Impacts on land use

The modification of subsidy and yield levels changes significantly the farmer income (Figure4). For high levels of subsidy and yield, the total net margin increases by 4%.

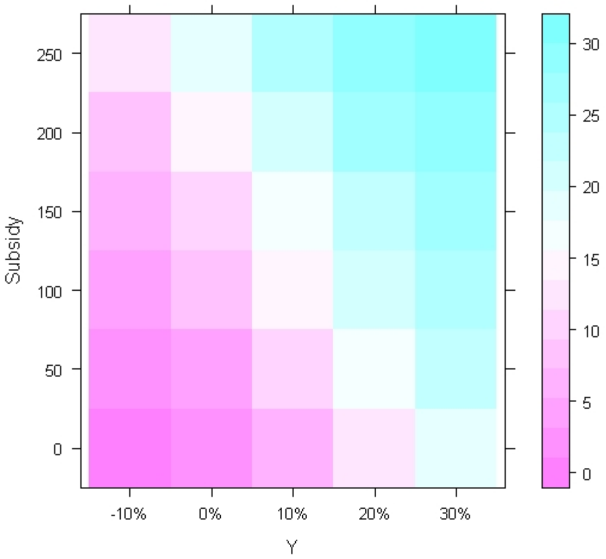

Figure 4: Total net margin of french farm-type at different level of subsidy and yield

For low levels of yield, miscanthus is cultivated on small areas even if the subsidy amount increases (Figure 5). Nevertheless, miscanthus areas increase by 5%, if subsidy and yield levels are high. This expansion leads to considerable change in land allocation (Figure 6).

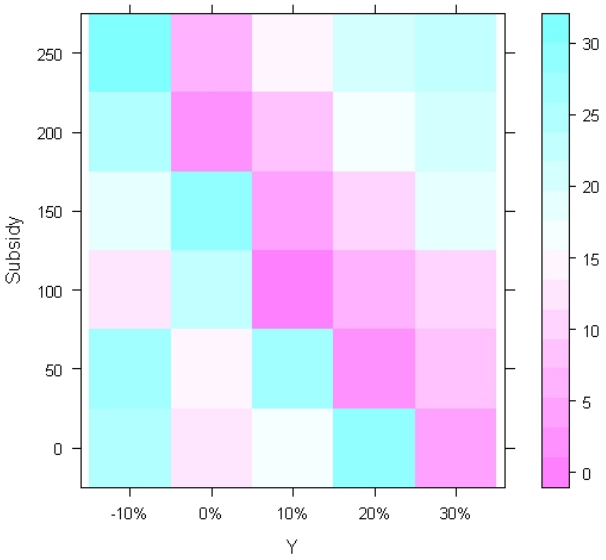

Figure 5: Miscanthus areas at different levels of subsidy and yield

As shown in Figure 5, the introduction of miscanthus in the farming system alters mainly the areas dedicated for cereal crops. We notice a decrease by 3% in cereal areas four a high level of subsidy with a yield level fixed at 11 tDM/ha. Moreover, we observe a decrease in areas dedicated for Agro industrial crops (by 2%) and corn, potato, grasslands and marginal areas (by 1%). The decrease in grasslands induce a reduction in livestock unit if miscanthus is introduced with high yield levels, which leads to an increase in farm consumption level (Figure 7).

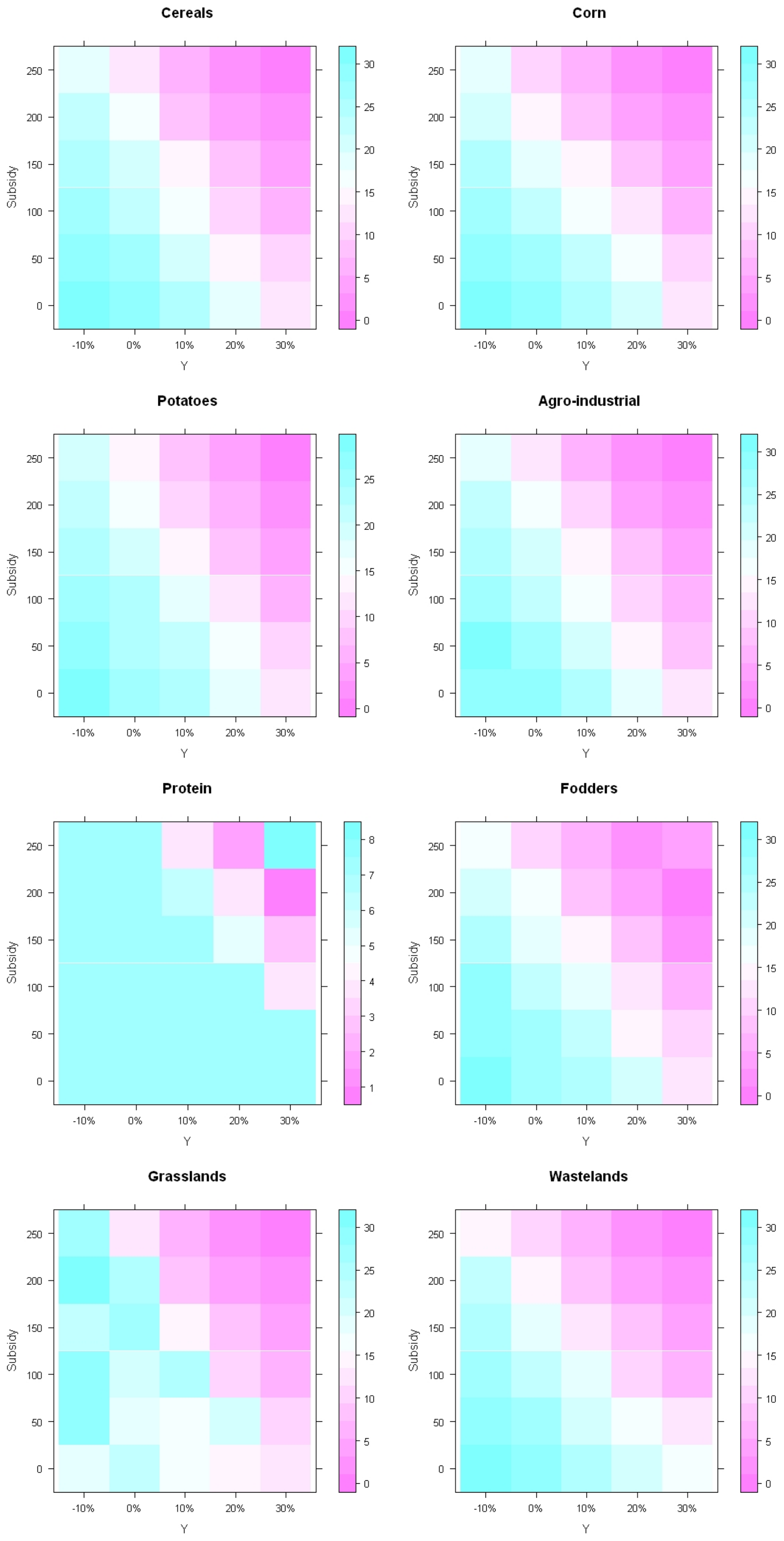

Figure 6: Changes in land allocation in France at different levels of subsidy and yields - results given by $AROPAj - model$.

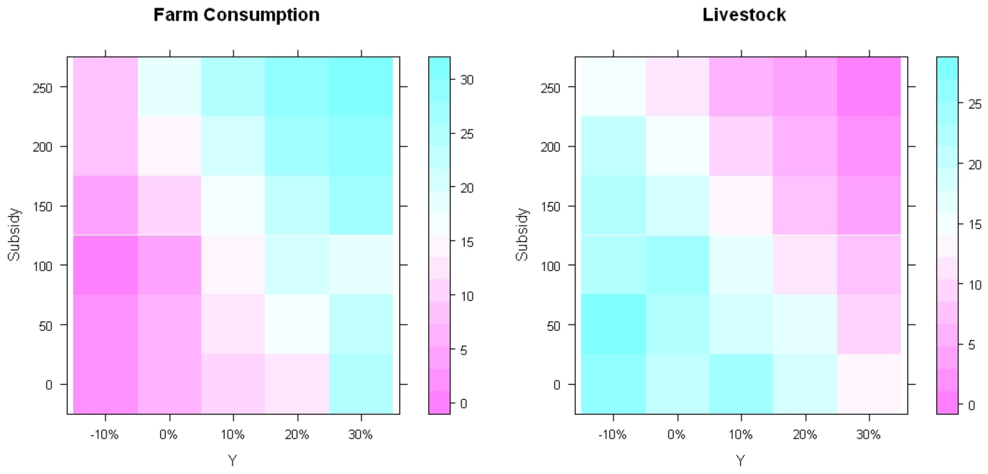

Figure 7: Livestock Unit and farm consumption levels when subsidy and yield levels change.

3.2 Impacts on N-input demand in the north of France

Fertilizers are known to have negative environmental impact, which can be altered by the introduction of an environmentally friendly crop like miscanthus. Table 1 shows that the N-Input demand decreases when yield levels increase. Moreover, lower N-Input levels are reached by subsidizing this crop. This result is explained by the decrease in arable areas dedicated to crops which are characterized by high N-input demand i.e cereal crops. Therefore, the decreased N-demand leads to a reduction in N-losses (Figure8)

% Variation in Y	N-Input demand (unite)
-10%	11046
0%	10920
10%	10861
20%	10253
30%	9993

Subsidy (Euros)	N-Input demand (unite)
0	10920
50	10891
100	10631
150	10342
200	10147

Table 1: Impacts of Variation in subsidy and yield levels of miscanthus on N-Input demand

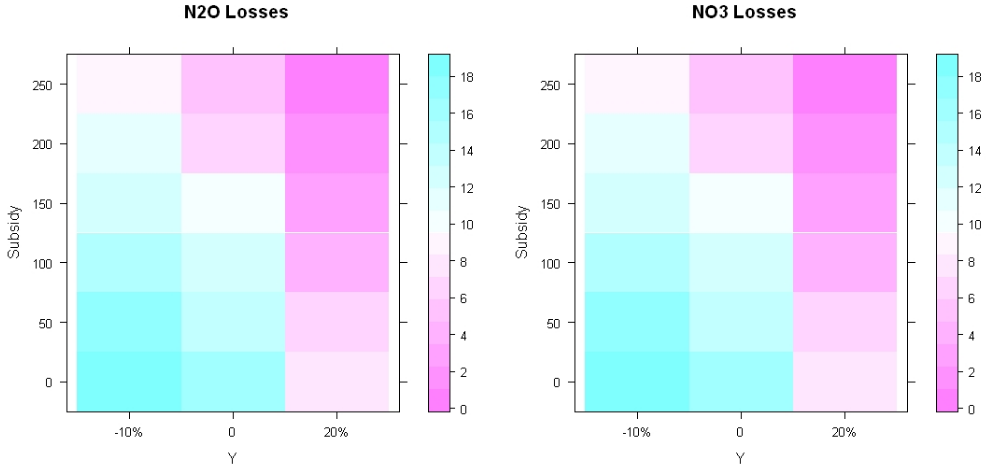

Figure 8: N-losses when subsidy and yield levels change.

By way of conclusion, significant expansion of cellulosic biofuel production will require more land tocultivate dedicated energy crop (Song et al., 2010). Therefore, arable grasslands and marginal areas are considered as potential areas for biomass production. Thus, the re-allocation of land reduces the N-input demand and therefore the N-losses. Neverthless, Fischer et al. (2010) are shown that arable land can be used for all types of biomass crop but grassland should only be considered for producing herbaceous lignocellulosic feedstocks in order to respect environmental and Green House Gas (GHG) concerns (Fischer et al., 2010). In addition to biofuels, these biomass crops are also suitable for conversion to heat and electricity. Developing this options will create a more diverse and increased production for lignocellulosic crops, and therefore more land for cultivating perennial grasses. However, the substitution of annual crop lands into perennial lignocellulosic energy plantations neeeds serious considerations beyond economic factors. Indeed, competition for resources may increase prices of land in factor markets and may alter production costs and therefore the competitive position of food and feed commodities produced (Fischer et al., 2010).

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