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Economics of willow growing in Northern Ireland

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Abstract

This paper reviews the e economics of short rotation coppice willow as an energy crop in Northern Ireland. Gross margins are presented for willow production and compared with, in the particular circumstances of Northern Ireland, equivalent outputs from grain production, lowland sheep and suckler cow production. The model used indicated a gross margin of £45 ha^{-1} yr^{-1} for a 12 tDM ha^{-1} annual coppice crop without subsidies where the crop value was placed at £40 t^{-1}. This was equivalent to a 7 t winter wheat crop at £70 t^{-1} and compared favourably with both lowland sheep and suckler cows.

Currently the industry in Northern Ireland is at a very early stage of development and this imposes cost penalties on the pioneer growers. This situation is compared with the situation in Sweden where there is an established industry of 15,000 ha, where costs are significantly lower. Gross margin for the pioneer grower in Northern Ireland is about £100 ha^{-1} yr^{-1} less than for Swedish willow growers.
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1. Introduction

Interest in the production of energy from short rotation coppice (SRC) willow in Northern Ireland began with the oil crises of the mid-1970s in an attempt to address escalating prices and diversification of supply [1]. Whilst both these issues are still relevant, the significant drivers behind the development of alternative renewable energy supplies are environmental. In United Kingdom context, energy from short rotation coppice willow is seen as a significant contributor to the carbon dioxide abatement strategy to achieve the 12.5% reduction on the 1990 emission levels by 2012 required by the Kyoto protocol [2]. In addition, the UK government has a national target of a 20% reduction in the same time frame. This, together with the European Union target of 10% of energy

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supplies from renewable resources outlined in the Green Paper of 1998, gives significant political impetus to the development of the crop.

In Northern Ireland in addition to these more global objectives other local drivers are equally important. The predominant feature of Northern Ireland agriculture is grass production (85% of agricultural land) producing 70% of agricultural output from beef, milk and sheep enterprises. In the period 1995–1997 total farm income (TFI) declined by 38% from £305 to £190 m and a further drop of 52% to £91 m followed in 1998. Year 1999 is showing another reduction of 22% leaving TFI at £71 m, its lowest level since 1980 [3].

In these circumstances the provision of sustainable alternative systems is vital for the well being of the agricultural industry and the maintenance of rural communities. However, in Northern Ireland the choice of alternatives is restricted by a range of factors including small farm size (average 34 ha), the small proportion of arable land (6% of agricultural land area) and predominantly heavy soils. A cool, moist, wet oceanic climate further restricts choice.

With revisions in the common agricultural policy, it is possible that the total production of some conventional agricultural products will decline. In Northern Ireland terms, this is particularly relevant to beef production and the land no longer required for grazing or forage conservation could, in some instances, be used for grain production. It is therefore relevant to compare the relative profitability of grain and SRC willow production using the same cost estimation model.

In these circumstances the production of energy, for which Northern Ireland has no indigenous resource, from short rotation coppice offers a significant opportunity for agricultural diversification. In order properly to assess this opportunity, production costs and returns have to be established and whilst conditions on individual farms and other local factors will be major factors in establishing economic sustainability some general assumption can be made to arrive at comparative costs and returns. This paper, in the application of an economic model, considers three separate but related areas: (1) the basic economics of short rotation coppice willow production in Northern Ireland, (2) their comparison with the economics of grain, lowland sheep and suckler cow production in Northern Ireland and (3) the identification of the economic penalties of pioneer production of coppice energy.

2. Methods and data

2.1. The cost estimation model for different crops

A cost estimation model has been used which compares the profitability of annual versus perennial crops [4,5]. The cost estimation model can be used for different crops and agricultural techniques, with various cash flow from year to year.

The time aspect is taken into consideration for each cash flow. Each cash flow is multiplied by present value factors for incoming and outgoing transactions during the total life span of the crop and by the annuity factor of the interest rate and the life span of the crop in years.

By applying sensitivity analysis it is possible, with the help of the model, to show the economic outcome at farm level of different growing techniques, different yields, varying coppice life spans and energy prices, etc.

2.2. Assumptions

Assumptions about yield and return achieved from the energy produced are of basic importance in the calculations. In the example shown in this paper, the model makes the following assumptions about costs and incomes (Table 1).

It has also been assumed that short rotation coppice production has moved beyond the 'pioneer producer' stage to avoid the cost penalties involved in that situation. Most inputs to calculations come from "Farm Business Data 1999", [6] and "Farm Business Survey Gross Margin Results, 1997/1998" [7].

Where data for Northern Ireland are available, they have been used (Table 9). In calculations for grain production and SRC willow, the same sources for fertilizer prices and other inputs not specific to willow growing were used. Swedish

Table 1
Model cost and income assumptions for willows

* A real interest rate of 6%
* A yield level of 12 t DM ha^{-1} yr^{-1} from year 4 onwards
* A production period of 22 yr, 7 harvest cycles
* Work using farm labour at £4.5 hr^{-1}
* Opportunity cost of land is not included
* Distance of road transport 20 km
* Assumed price level of wood chips £40 t^{-1} DM
* No subsidies for establishment and no area subsidies
* Nitrogen fertilisation in most years
* All machinery and labour costs are included
* For machinery contractors price is used

values have been used for cutting price, costs for plantation establishment and machinery for fertilisation in a high growing crop. There is a shorter harvesting season in Northern Ireland than in Sweden, so a 20% increase in harvesting costs in Northern Ireland has been allowed for. In Sweden there is a developed market for wood-fuel chips for fuel, with a price for chips of £39 t^{-1} DM (t^{-1} dry matter). In the model a price of £40 t^{-1} DM has been used in the main calculation.

2.3. Gross margins

Crop- and animal-production are different in many aspects. They require different resources and for this reason it are difficult to compare them. Fixed costs in particular are very different depending on the enterprise and animal housing involved.

The comparisons between grain production and SRC willow have been made using the same economic model developed by Rosenqvist [4,5]. However, comparisons with animal production have been made using figures from The Department of Agriculture and Rural Development's farm business data and will inevitably include minor differences in cost measurements. Consequently these figures are not directly comparable but give a reasonably accurate indication of relative performance.

The main calculations in this paper are made without inclusion of opportunity cost for land or subsidy for growing the crop. All costs for workforce and machinery are included in the calculations.

Conacre rent is a system in Northern Ireland where land is rented on an annual basis for a period of 10 months, generally from April to January. Figures for conacre and animal production are taken from "Farm Business Data 1999", [6] and "Farm Business Survey Gross Margin Results, 1997/1998" [7].

Costs for suckler cow and sheep production include variable costs for feed, veterinary medicines and sundries in the gross margin before fixed costs. Fixed costs are determined by the type of farms and include depreciation of machinery, machinery running cost, electricity and heating fuel, depreciations of buildings and buildings repairs. Interest rate, labour and conacre costs are excluded from these calculations.

3. Results

3.1. Economics of willow growing

To underline the importance of yield and wood-fuel chip price the initial gross margin calculations are presented at yields varying from 6–18 tDM ha^{-1} and wood-fuel chip prices from £30–60 t DM^{-1}.

A major factor with a direct effect on the economic outcome of the established willow plantations is the price level of wood-fuel chips. It has been reported that the return for wood-fuel chips to SRC has decreased when the quantity of biofuels from other sources and the total market for wood fuel-chips increased [8]. To provide a positive gross margin return for wood-fuel chips in this calculation, the price must be in excess of £35 t^{-1} DM with 12 tDM yield.

The second major factor influencing profitability is yield. From the model, it was estimated that a yield of 9.2 tDM ha^{-1} yr^{-1} was required (from the second harvest cycle) to obtain a positive income from the land, at a price of £40 t^{-1} DM. With lower yield levels, it was not financially viable to cultivate willow. Thus, if the expected yield level was less than 9.2 tDM ha^{-1} yr^{-1}, the land should be used for other purposes or left fallow (Table 2).

However, alteration of other cost assumptions, such as lower costs for establishment and the wood-chip price, would have the effect of reducing this threshold yield level.

3.2. The importance of the life-span

The economic life-span of short rotation coppice plantations is unlikely to correspond to the biological life-span. There are many factors, which may influence this relationship. The availability of new and improved planting stock with higher yield potential and or reduced disease susceptibility may be an important issue in determining the economic life of a plantation. Similarly the dynamic situation involving today's political measures relating to agriculture may alter the situation with regard to relative prices and profitability of different enterprises.

The effects of varying life-spans and different yields on gross margins are illustrated in Table 3.

As the number of harvests taken from a plantation increases, the cost per tonne dry matter decreases and the gross margin becomes more positive. The model indicates that assuming a wood-fuel chip price of £40 t^{-1} DM, a minimum of five rotations (year 16) is necessary at a yield of 12 t ha^{-1} dry matter to ensure a positive gross margin.

3.3. Subsidies

The planting subsidy of £400 available under the Woodland grant scheme on set-aside land

Table 2
Gross margin (£ ha^{-1} yr^{-1}) for willow, without subsidies, for different yield levels (yield levels from second harvest cycle) and different fuel price levels

Yield tDM $ha^{-1}yr^{-1}$	Fuel chip price						
	£30/tDM	£35/tDM	£40/tDM	£45/tDM	£50/tDM	£55/tDM	£60/tDM
6	−100	−76	−51	−26	−2	23	47
8	−85	−52	−19	14	46	79	112
10	−69	−28	13	54	95	136	177
12	−54	−5	45	94	143	192	241
14	−38	19	76	134	191	249	306
16	−23	43	108	174	240	305	371
18	−7	66	140	214	288	362	436

Table 3
Gross margins (£ ha^{-1} yr^{-1}) and costs (£ t^{-1} DM) for a range of harvesting cycles exclusive of land rent for different cultivation life-spans without subsidies at yield levels of 10, 12 and 14 t ha^{-1} yr^{-1}

Number of 3 yr harvesting cycles	10 tDM GM£ ha^{-1} yr^{-1}	10 tDM £ t^{-1} DM	12 tDM GM£ ha^{-1} yr^{-1}	12 tDM £ t^{-1} DM	14 tDM GM£ ha^{-1} yr^{-1}	14 tDM £ t^{-1} DM
1	−328	104	−310	90	−291	80
2	−151	62	−126	56	−101	51
3	−76	50	−47	45	−19	42
4	−38	45	−8	41	22	38
5	−14	42	17	38	48	36
6	1	40	33	37	64	34
7	13	38	45	35	77	33
8	21	37	53	35	85	33
9	27	37	60	34	92	32

increases the gross margin by £31 yr^{-1}. The planting subsidy of £600 on non-set-aside land increases the gross margin by £47 yr^{-1}. In addition, on set-aside land the five-year arable payments of £306 ha^{-1} yr^{-1} available increases the gross margin by £107 ha^{-1} yr^{-1}. All these subsidies are excluded in the calculations in this paper.

4. Comparative financial outcomes for willow coppice and other agricultural enterprises

In the decision whether or not to diversify into energy production from short rotation coppice willow, two major questions have to be addressed — the relative profitability of other land uses and whether annual output from the coppice exceed the base line measure of profitability of 9.2 t ha^{-1} DM a price of £40 t^{-1} DM.

Table 4 illustrates the price of wood-fuel chips required for profitable willow cultivation at different opportunity costs for land and different yields.

4.1. Cereals

For the farmer there is always the question of which crops to grow to maximise economic results. On compulsory set-aside land there is no major competition from other crops against willow. However, on land outside compulsory set-aside, willow must have a relatively high yield to compete with grain crops, especially on the most fertile soils. The gross margin estimations for wheat and barley are made with the same model as that used to estimate the gross margins for willow coppice.

Grain prices are important in the comparison of the economics of grain production with willow production. Tables 2 and 3 illustrate the economics of willow growing with varying yields, wood-fuel chips prices and plantation life spans. These results can be compared with those for grain production (Tables 5 and 7) at different yields and grain prices. Table 6 shows the yield of willow that would be required to achieve the same gross margin as winter wheat, at varying yield and price levels for winter wheat. With a yield of 12 tDM and a chip price of £40 t^{-1} DM, the calculations for willow show a gross margin of £45 ha^{-1}.

The mean yield for winter wheat in Northern Ireland is 7.1 t ha^{-1}, winter barley 5.9 t ha^{-1} and

Table 4
Return for fuelchip (£ t^{-1}DM) required to cover production and opportunity costs at different yields

Opportunity cost £ ha^{-1}	Yield tDM ha^{-1}					
	6	8	10	12	14	16
0	50	43	38	35	33	32
50	61	51	45	41	37	36
100	71	58	51	46	42	39
150	81	66	57	51	46	43
200	91	73	63	56	51	47
250	101	81	69	61	55	51
300	111	89	75	66	59	55

Table 5
Gross margins excluding subsidies for a range of winter wheat yields at different price levels

Yield winter wheat	Grain prices £t^{-1} grain			
	60 GM£	70 GM£	80 GM£	90 GM£
5	−131	−81	−31	19
6	−81	−21	39	99
7	−31	39	109	179
8	19	99	179	259
9	69	159	248	339
10	119	219	319	419

Table 6
Yield levels required from willow (in tDM ha^{-1} yr^{-1}) to have the same profitability, without subsidy, as winter wheat (15% moisture content) at different yield and price levels

Yield winter wheat	Grain prices £ t^{-1} grain			
	60 TDM	70 tDM	80 tDM	90 tDM
5	1	4	7	10
6	4	8	12	15
7	7	12	16	20
8	10	15	20	25
9	14	19	25	30
10	17	23	29	35

Table 7
Gross margins (in £ ha^{-1}) for winter wheat, winter barley and spring barley at different grain prices in Northern Ireland

Cereal	Grain prices £ t^{-1} grain						
	60	65	70	75	80	85	90
Winter wheat	−26	9	45	80	116	151	187
Winter barley	9	38	68	97	127	156	186
Spring barley	−42	−20	1	22	44	65	87

spring barley 4.3 t ha^{-1}[6]. These are important factors in the comparative profitabilities of short rotation coppice willow and cereal production. The value of straw is included in the calculation with a value of £7.21 t^{-1} wheat. Table 7 shows that willow coppice can be competitive where grain prices were below £70 t^{-1}.

The average conacre rent for arable land in 1997 was £256 ha^{-1} [6]. Conacre rent includes value of subsidies. If the value of subsidies for land of £214 is removed from the conacre rent a gross margin of £42 without subsidies remains, which is similar to the margin of £45 ha^{-1} for willow growing without subsidies. Consequently there is not a large difference in real income without subsidies, between cereals and willow growing.

4.2. Feed production and animal production

About 85% of the farmland in Northern Ireland is grassland and only 6% is classified as arable. Hence the significant comparison in Northern Ireland for willow coppice production is with grassland enterprises.

The high proportion of land devoted to animal-based enterprises in Northern Ireland may present a further problem. Rosenqvist et al. [9] showed from statistics about Swedish farming that farms with animal production are not as interested in willow cultivation as cereal farms.

4.2.1. Grassland

Average conacre rents in 1997 were £261 for grass — cutting, grazing £207 and rough grazing £46[6]. The conacre rent is dependent on both land and animal based subsidies. At stocking rates of 8.51 ewes ha^{-1}, subsidy levels of £10.44 per ewe provide a total subsidity of £88.84 ha^{-1} for lowland sheep. Similarly, with two suckler cows ha^{-1} and an annual headage subsidy of £195 total subsidy levels of £390 ha^{-1} can be calculated per hectare for suckler cow production.

4.2.2. Lowland sheep enterprises

Breeding ewes on non-LFA (less favoured areas) gives a gross margin before fixed costs of £37.98 per ewe [7] and with 8.51 ewes ha^{-1}, the gross margin before fixed costs is £323.2 ha^{-1}. Fixed costs — without costs for labour and conacre — are £289 ha^{-1} including depreciation for buildings/work, etc. at £52 ha^{-1} [6], producing a gross margin after fixed costs of £34 ha^{-1}.

Sheep annual premium of £10.44 per ewe on non-LFA [7] was included in the gross margin before fixed costs of £37.98 per ewe. To compare the gross margins of willow coppice and lowland sheep production without subsidy the gross margin per ewe was reduced by the annual premium of £10.44 giving a gross margin before fixed costs of £234.4 ha^{-1} at stocking rates of 8.51 ewes ha^{-1}. The gross margin taking into account fixed costs was therefore £54.6 ha^{-1}.

4.2.3. Suckler cows

Suckler cows on non-LFA give a gross margin before fixed costs at £295 per suckler cow [7]. With two suckler cows ha^{-1} [6] the gross margin before fixed costs is £590 ha^{-1}. Including fixed costs of £289 ha^{-1} [6] produces a gross margin of £301 ha^{-1}.

Subsidies of £195 per suckler cow (mean farms) were included in the gross margin before fixed costs of £295 per suckler cow giving a gross margin per cow of £100 (£200 ha^{-1}) without subsidy. Allowing for fixed costs of £289 ha^{-1} a negative gross margin of £89 ha^{-1} was produced.

Hence, taking the unsubsidised gross margin for willow coppice of £45 ha^{-1} yr^{-1} (Table 2) which should be compared with the gross margin after fixed costs for sheep and suckler cow it can concluded that willow coppice production can be a economic alternative to grassland, where there is a market for willow chips.

5. Developmental stages for willow coppice

Where willow coppice production is still at a relatively undeveloped scale (less than 1000 ha) costs of production will be high in comparison with a region where there is significant activity in the coppice production sector. This produces economies of scale and it is important to separate these two situations, when discussing the economics of willow growing.

5.1. Pioneer willow growing in Northern Ireland

Comparison of the costs of planting and harvesting in countries with different areas of established willow coppice, can show a clear connection between the level of activity in the sector and the costs for growing. Example, the costs of £0.75 per cutting and planting costs of £250 ha^{-1} for the pioneer grower in Northern Ireland [10]. Compare with £0.26 per cutting and a planting cost of £90 ha^{-1} in Sweden [11]. In Sweden 15,000 ha of willow coppice have been established over a number of years and Northern Ireland the first large-scale plantings were made in 1997.

In Sweden costs for plantation establishment have decreased over the years due to improved technology and the increase in hectares planted with willows (Table 8).

This relationship between activity in the sector and costs is again clearly seen in Sweden when in 1997–1999 planting activity was reduced to a few 100 h yr^{-1} from a level of 3000 ha yr^{-1} in period 1991–1996. This reduction in planting activity was accompanied by a rise in cutting costs of 23% and an increase in planting costs of 50% [11]. Further confirmation is seen in the commercial costs for planting in 1999 in England and Sweden, which were £900 and £340, respectively using the same machinery [12]. Harvesting costs follow the same trend. Normal cost in Sweden (15,000 ha) was £170 ha^{-1} using a self-propelled chip harvester and in Denmark (590 ha [13]) using the same equipment harvesting costs had risen to £220 ha^{-1} [12] (Table 9).

Pioneer planting of willow coppice has about £90 ha^{-1} yr^{-1} lower gross margin in Northern Ireland (Table 9) compared with areas where there is significant activity in the sector. To this £90 an allowance of £10 ha^{-1} should be added to allow for higher information costs in the absence of any advisory or industry infrastructure or backup. Consequently, in the pioneer situation the gross margin will be approximately £100 lower per hectare per year, which is similar to a one-time payment in the first year of £1300.

Table 8
Planting costs (excl. cuttings) in Sweden during the pioneer stage of growing [5]

Year	In £ ha^{-1} Actual	In £ ha^{-1} Real terms based on 1992 value	Real yearly cost reduction in %
1988	320	390	31
1989	230	270	11
1990	220	240	12
1991	200	210	36
1992	140	140	9
1993	110	120	0
1994	110	120	

Table 9
Comparison between pioneer planting of willow coppice in Northern Ireland and expected cost for willow growing where economies of scale have reduced costs

Factors	Pioneer grower £ $ha^{-1}yr^{-1}$	Expected costs £ $ha^{-1}yr^{-1}$
Establishment	158[a]	100
Fertiliser	37[a]	37
Fertilisation spreading (high)	15[b]	11
Fertilisation spreading (low)	4[a]	4
Road transports	67[a]	67
Harvest	114[b]	88
Field transports	32[a]	32
Administration	7[a]	7
Winding up	5[b]	5
Sum of costs	437	349
Wood chips for fuel	394[b]	394
Gross margin	−43	45

[a]Real cost in small scale with information from Gilliland [10] and own estimates.
[b]Expected cost in small scale.

6. Discussion and conclusions

Short rotation coppice willow gives a gross margin of £45 ha^{-1} yr^{-1} with 12 tDM, ha^{-1} crop at a return of £40 t^{-1} DM over a 22 yr rotation. To provide a positive return, the price of willow chips must be at least £35 t^{-1} DM with a yield of 12 tDM ha^{-1}. This does not include an opportunity cost for the land or any subsidy payments.

From the model, it was estimated that a yield of 9.2 tDM ha^{-1} yr^{-1} was required (from the second harvest cycle) to obtain a positive income from the land with a wood chips price of £40 tDM. Thus, if the expected yield level was lower than 9.2 tDM ha^{-1} yr^{-1} the land should be used for other purposes or be left fallow. For each increase in the number of harvesting cycles taken, the calculated gross margins will increase and production costs per tonne DM will decrease. A minimum of five rotations (16 yr) is required to attain a positive income from the land.

In Northern Ireland, with average yields, grain production and SRC willow can show similar gross margins. However, grain price was an important factor in this comparison. Willow is competitive on average soils on Northern Ireland when the grain prices were lower than £70 t^{-1}. This study also shows that, with gross margins excluding subsidies for suckler cows and for lowland sheep, willow coppice can be competitive with or better than other grassland-based enterprises, depending on the individual circumstances on each farm.

When costs for planting and harvesting willow in countries with different areas of willow were compared, the connection between the established area of willow plantations and production costs can be seen clearly. The first farmer in Northern Ireland, who planted willow had much higher cost than a Swedish farmer who planted willow at the same time. In Sweden there are about 15 000 h of willow and in Northern Ireland there is only one farmer with commercial willow production for energy purposes. In the pioneer situation the gross margin will be about £100 lower per hectare per year, which is similar to a one-time payment in the first year of £1300. The costs for establishment decreases both through new technology and through the increasing numbers of hectares planted with willows.

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References

[1] Dawson WM, The social environmental and economic value of short rotation coppice willow (*Salix*) as an energy crop. In: Farm woodlands for the future Burgess PJ, et al., editors. Proceeding of a conference held at University of Cranfield, Silsoe Beds, UK: September 1999. p. 151–60.

[2] Anonymous Renewable energy in the millennium the Northern Ireland potential. Report published by Department of Economic Development, Belfast, N. Ireland: June 1999. pp. 69.

[3] Anonymous Statistical review of Northern Ireland Agriculture 1999. Report published by Department of Agriculture and Rural Development, Belfast, N. Ireland: March 2000. pp. 63.

[4] Rosenqvist H. Calculation method and economy in Salix production, Biomass for energy and environment. Proceedings of the 9th European Bioenergy Conference, Copenhagen: 1996. pp. 1967–72.

[5] Rosenqvist H. Salixodling—Kalkylmetoder och lönsamhet. Inst. För Skog-Industri-Marknad Studier. Sveriges Lantbruksuniversitet. Silvestria 24. Uppsala, Sweden: 1997 (in Swedish).

[6] Crawford A, Patterson H. Farm Business Data 1999, Economics and Statistics Division, Department of Agriculture (NI), Dundonald House, Belfast, Great Britain: 1999.

[7] Anonymous Farm Business Survey Gross margin results, 1997/1998. Economics and Statistics Division, Department of Agriculture for Northern Ireland, Great Britain: 1998.

[8] Hillring B. Price trends in the Swedish wood-fuel market. Biomass and Bioenergy 1997;12(1):41–51.

[9] Rosenqvist H, Roos A, Ling E, Hektor B. Willow growers in Sweden. Biomass and Bioenergy 2000;18:137–45.

[10] Gilliland J. Willow growing farmer. Northern Ireland: 1999, personal communications.

[11] Melin G. Agrobränsle AB. Sweden: 1999, personal communications.

[12] Henriksson G. Henriksson Salix AB. Sweden: 1999, personal communications.

[13] Jörgensen U. Danish institute of plant and soil science. Denmark: 2000, personal communications.