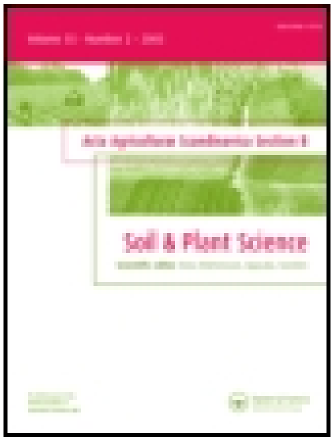

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Farm-related Factors Influencing the Adoption of Short-rotation Willow Coppice Production Among Swedish Farmers

Roos, A., Rosenqvist, H., Ling, E. and Hektor, B. (Department of Forest Management and Products, Swedish University of Agricultural Sciences, P.O. Box 7060, SE-750 07 Uppsala, Sweden). Farm-related factors influencing the adoption of short-rotation willow coppice production among Swedish farmers. Accepted February 24, 2000. Acta Agric. Scand., Sect. B, Soil and Plant Sci. 50: 28–34, 2000.

The area of short-rotation willow coppice energy plantations on Swedish farmland increased quickly in the early 1990s because of subsidies for energy crop production, an increased CO_2 tax on fossil fuel and an already existing biofuel market in the country. In this study farm-related determinants for the adoption of short-rotation willow coppice production among Swedish farmers are identified and estimated. A Tobit model is applied to cross-sectional data on Swedish farmers in 1995. The results show that the decision to plant willow and the areas planted depend positively on arable land area, forest land area, the area of other land types, leasing out of arable land and tractor ownership. Negative factors are pasture area, tenancy and animal production. Differences in willow growing between ownership types, age groups and geographical regions are also important. The policy implications of the results are discussed.

Anders Roos*, Håkan Rosenqvist, Erik Ling and Bo Hektor
Department of Forest Management and Products, Swedish University of Agricultural Sciences, P.O. Box 7060, SE-750 07 Uppsala, Sweden

Key words: adoption, bioenergy, energy crops, Tobit model.

Introduction

Short-rotation energy crop production is considered in many countries as one possible means of living up to the commitments in the 1997 Kyoto Protocol for countering global climate change. Energy crops could also become alternative non-food cash crops for farmers across Europe if support for foodcrop production were reduced. According to the White Paper by the European Commission, the share of bioenergy of the total energy production of the European (EU15) countries has the potential to increase from 3% to 8.5% by 2010. Half of this quantity would derive from energy crops. Most countries in the European Union have set targets for raising bioenergy production (European Commission, 1997).

Energy crops are also being investigated in the USA, where 8–16 Mha of arable land can be used for biomass production in the future (Hohenstein & Wright, 1994). The Energy Information Administration of the Department of Energy in the USA expects an annual growth of 0.8% for renewables until 2020, where biomass from energy crops and wood accounts for more than half the energy production. Several programmes support private bioenergy investments (EIA, 1998).

Commercial willow plantations in Sweden expanded in the early 1990s, for several reasons. First, the implementation phase of a deregulated food policy between 1991 and 1996 implied subsidies for

*Corresponding author.

planting willows amounting to 1200 ECU ha^{-1} and 480 ECU ha^{-1} for fencing (Proposition 1989/90, 146). Secondly, taxes on sulphur and CO_2 for fossil fuels in heat production increased considerably in 1991, improving the competitiveness of biofuels in the energy market (Larsson & Rosenqvist, 1997). Thirdly, a large biofuel market already exists in Sweden, based on the demand from the district heating plants of wood fuel from the forest sector. The fourth positive factor for the expansion of commercial willow plantations is the extensive research and plant breeding programmes of willow since the 1970s (Christersson & Senneby-Forsse, 1994).

Since the two issues of how to increase the share of renewable energy and how to reduce surplus food production are relevant in many countries, realistic predictions about prospective energy-crop growers are needed. Better knowledge about the adoption patterns of willow production in Sweden during the early 1990s could help policy makers and decision makers in Sweden, and in other countries where short-rotation energy forests are discussed, to design effective energy and agricultural policies and identify clear-cut target groups for information campaigns.

National estimates of land availability and of the technical and economic status of short-rotation energy crop production are found in several studies for the USA (e.g. Wright & Hohenstein, 1994) and for Sweden (SOU, 1992). Several studies in the USA and in Europe use Geographical Information Systems (GIS) to describe possible spatial aspects of future bioenergy systems (e.g. Liu et al., 1993; Dagnell, 1995; Downing & Graham, 1996). Most studies to date have, however, been unable to include knowledge about adoption patterns for energy crops, specifically among the farmers, simply because such empirical data do not exist.

Studies of adoption patterns by farmers are numerous, ranging from analyses of tillage practices (Gould et al., 1989; Lexmon & Andersson, 1998) to innovations (Saha et al., 1994) and the use of crop varieties

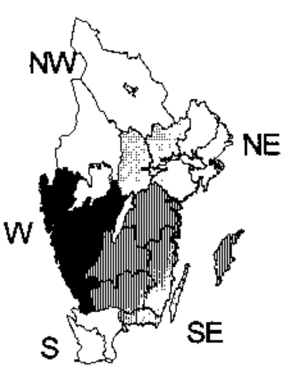

Fig. 1. Area of the study showing the regions. NE, North-east; NW, north-west; SE, south-east; SW, south-west; S, south.

and fertilizers (Mbata, 1997). Limited dependent-variable models have often been used in these studies. The inspection of the adoption literature led to the conclusion that there is a proven methodology available for analysing the adoption by Swedish farmers of short-rotation willow production.

The aim of this study was to identify the farm-related factors that influence the adoption of willow production by Swedish farmers. The study was geographically restricted to farm enterprises in southern and central Sweden (Götaland and Svealand) that were growing willow in 1995 (see map in Fig. 1). Northern Sweden is excluded from the study since a harsh climate for willow production makes dedicated energy plantations less suitable in this part of the country.

Materials and methods

Theoretical model

An adapted theoretical model used by Saha et al. (1994) was applied. It was assumed that the farmer, or farm enterprise, can choose to combine willow cultivation with alternative profit-maximizing activities. Let the farm enterprise be described by a profit function that includes the profits of both willow growing and other activities on the farm:

$$\pi = by + p^e y f(x) - c(p, y, x) + \pi^{s-}(p, A - y, x) \quad (1)$$

Total profits, π, depend on: per hectare subsidies discounted to present value, b, times the willow area, y; the present value of woodfuel prices, p^e, multiplied by the area under willow production, y, times the wood fuel produced on 1 ha of willow land, $f(.)$, which is a function of a vector of farm (and farmer) attributes, x; discounted costs for planting, managing and harvesting the willow plantations, $c(.)$, which is a function of discounted netput prices, p, willow area, y, and farm attributes, x; and finally, on the profits from non-willow production on the farm, π^{s-}. The latter expression is a function of the discounted price vector for outputs and inputs, p, total crop area minus the willow area, $A - y$, and attributes of the farm, x. The first-order condition for profit maximization with regard to y will then be:

$$b + p^e f(x) - c_y(p, y, x) + \pi_y^{s-}(p, A - y, x) = 0 \quad (2)$$

The expression describes how the marginal benefits from an increasing willow production consist of revenues from subsidies and present values of future willow woodchip sales. One cost is production costs for planning, planting, management and harvesting, where $c_y(.) > 0$. Another cost is the "cost" for non-willow profits foregone, where $\pi_y^{s-} < 0$.

The optimal choice of willow area can then be described as:

$$y^* = y^*(b, p^e, p, x, A) \tag{3}$$

The optimal solution of willow cultivation is a function of subsidies offered, woodfuel prices, prices for inputs and non-biofuel outputs, farm and farmer attributes, and total arable land area on the farm. This study focuses on how size and farm characteristics influence the willingness to grow willow and the area planted. The effects of different economic factors, e.g. prices, subsidies and other macroeconomic factors, could not be analysed since the planting year was not known.

The above analysis assumes interior solutions to the optimization problem, but it is clear that the non-interior solution $y^* = 0$ is feasible, i.e. that no willows are grown. Theoretically, the opposite solution is also possible, i.e. that 100% of the arable land is used for willow plantations. This situation is, however, rare and not a primary issue for this analysis.

The Tobit model

The great majority of Swedish farmers does not grow willows. In technical terms this means that the dependent variable in this study, willow area on the farm, is left-censored at zero since the value cannot be negative. The Tobit model is a common method for analysing censored samples of this type. It has been used in several agricultural adoption studies (e.g. Gould et al., 1989; Goodwin & Schroeder, 1994; Mbata, 1997).

The Tobit model (Tobin, 1958), adapted for analysis of the factors influencing willow growing, can be defined as:

$$y_i = \beta x_i + \varepsilon_i \text{ if } \; y_i > 0$$

$$y_i = 0 \text{ otherwise} \tag{4}$$

where y_i is the willow plantation area on farm i, x_i is the vector of explanatory variables, β is a coefficient vector and ε_i is the error term.

Maximum-likelihood procedures are available to produce consistent and asymptotically normal parameter estimates for Tobit models (Amemiya, 1973).

If the error terms are independent and $N(0, \sigma^2)$, the expected woodfuel use can be written as:

$$E[y_i] = \Phi(z_i)E(y_i | y_i > 0)$$

$$\text{where } z_i = \frac{\beta x_i}{\sigma} \tag{5}$$

In Eqn (5), $\Phi(z_i)$ denotes the probability that farm i is growing willows for biofuels, and the second term on the right-hand side describes the expected willow area, conditional on being over the "limit", i.e. that more than 0 ha of willows are being grown.

Differentiations of the estimated results will allow us to obtain for different values of x_i: (1) the expected energy willow area, (2) the willow area conditional to being above the limit, (3) and the probability of being above the limit (McDonald & Moffitt, 1980).

The model implies the assumption that the decisions to grow willow and how many hectares to plant are made simultaneously.

Data

Based on the general conclusions of previous adoption studies (Saha et al., 1994; Mbata, 1997; Lexmon & Andersson, 1998), the variables in the present model describe the farmer, the farm, farm size, land use, production and location.

Data on all 1158 farms in southern Sweden with a farming area of more than 2 ha growing more than 0.1 ha of willows were obtained from the 1995 Farm Register (FR) compiled by Statistics Sweden (1995). For comparison, a stratified sample from 1995 of 535 non-willow farmers from the same geographical region was also used.

The definitions of the variables are presented in Table 1.

It is reasonable for two reasons to assume that the independent variables included in the model are exogenous. First, the decision to grow willows was made after 1990, generally after decisions about other traditional farm production orientations had already been made. Secondly, the areas of arable land, pasture, forests and other uses depend on fundamental conditions which are likely to change very little over the space of a few years. However, variables describing uses of arable land other than for growing willows have not been included owing to potential endogenity problems that would otherwise yield biased results.

A positive sign for the untransformed arable land area variable is expected, simply because the range of different crops and varieties is expected to be wider on a large farm than on a small farm. Few additional hypotheses can be formulated about the sign of the model coefficients.

Results and discussion

The estimation results are presented in Table 2. To avoid the "dummy-variable trap" of perfect collinearity, the dummies representing zero areas of forest land, pasture land and other land were removed, as were the variables for owner ages 35–50 years and the geographical dummy symbolizing farms in the

Table 1. Definitions of variables

Variable	Definition
Willows	Willow area (ha)
Arable land	Arable land area (ha)
Arable land2	Arable land area squared
For0	1 if forest area = 0, 0 otherwise
For1	1 if forest area 0–25 ha, 0 otherwise
For2	1 if forest area 25–80 ha, 0 otherwise
For3	1 if forest area 80 ha–, 0 otherwise
Past0	1 if pasture area = 0, 0 otherwise
Past1	1 if pasture area 0–7 ha, 0 otherwise
Past2	1 if pasture area 7 ha–, 0 otherwise
Oth0	1 if other land area = 0, 0 otherwise
Oth1	1 if other land area 0–7 ha, 0 otherwise
Oth2	1 if other land area 7 ha–, 0 otherwise
Leasout	1 if arable land is leased out; 0 otherwise
Tenancy	1 if arable land is leased; 0 otherwise
Inst/Ltd	1 if owner is a limited company or institution; 0 otherwise (if the owner is a person)
<35 y	1 if owner age <35 years; 0 otherwise
35–50 y	1 if owner age 35–50 years; 0 otherwise
50–65 y	1 if owner age 50–65 years; 0 otherwise
65 y+	1 if owner age $\geqslant 65$ years; 0 otherwise
Horses	1 if horses; 0 otherwise
Cows	1 if milk cows; 0 otherwise
Cattle	1 if other cattle; 0 otherwise
Pigs	1 if pigs; 0 otherwise
Sheep	1 if sheep; 0 otherwise
Tractor	Number of tractors
Harvester	1 if harvester; 0 otherwise
Irrigation	1 if irrigation; 0 otherwise
Ecological	1 if ecological production; 0 otherwise
Hours	Estimated work hours
Northeast	1 if in north-east; 0 otherwise
Northwest	1 if in north-west; 0 otherwise
Southeast	1 if in south-east; 0 otherwise
West	1 if in south-west; 0 otherwise
South	1 if in south; 0 otherwise

southernmost part of the area. Likelihood ratio (LR) tests were conducted to check the relevance of the variables symbolizing owner class (institutional and limited owners)/age groups, geographical situation. The whole model in Table 2 was also tested against the alternative with all coefficients, except the intercept, restricted at zero. All LR tests described above provide support for the model presented in Table 2. The McFadden pseudo-R statistic (Maddala, 1983), 0.110, is not notably different from what has been recorded in similar investigations.

The model results include coefficients for 29 independent variables, 19 of which were significant at the 1% level, one at the 5% level and two at the 10% level. Seven coefficients were insignificant.

As expected, the sign of the arable land area coefficient was positive, although the marginal influence of the variable decreased, as indicated by the negative sign of the squared arable-land coefficient. The influence of forest area on willow growing was equally positive, suggesting that forest owners have a better general knowledge than other farmers about growing long-rotation varieties, such as trees. They may even already have experience of selling wood fuel in the form of logging residues. For pasture areas of more than 7 ha a negative relationship with willow growing was detected. This may be due to the fact that farmers with animals usually try to keep land available for both pasture and fodder production, which is not compatible with willow growing. Medium-sized

Table 2. Tobit estimations

Variable	Coefficient	SD	P-value
Intercept	−700.55***	17.67	0.0001
Arable land	0.0235***	0.0011	0.0001
Arable land2	−2.15E-7***	1.359E-8	0.0001
For1	2.8673	11.3542	0.8006
For2	98.5222***	12.6762	0.0001
For3	106.661***	14.7483	0.0001
Past1	−6.8463	9.3379	0.46
Past2	−68.8454***	11.8247	0.0001
Oth1	34.0404***	9.1939	0.0003
Oth2	−3.3320	12.2648	0.79
Leasout	32.4583***	12.4959	0.0094
Tenancy	−33.3419***	8.6504	0.0001
Inst/Ltd	26.4386*	13.9672	0.058
–35 y	−36.5587*	20.8936	0.080
50–65 y	35.0230***	9.4312	0.0002
65 y–	−80.4911***	12.6901	0.0001
Horses	−20.9750**	9.9912	0.036
Cows	−151.513***	17.3181	0.0001
Cattle	−73.9290***	10.0900	0.0001
Pigs	−35.5978***	12.4298	0.0042
Sheep	−13.0963	11.6193	0.230
Harvester	−9.9022	9.7626	0.310
Tractors	0.8229***	0.2608	0.0016
Irrigation	53.6132***	13.7265	0.0001
Ecological	13.0593	17.9349	0.467
Hours	0.000044	0.000218	0.841
NE	134.136***	12.8786	0.0001
NW	−61.1990***	17.8603	0.0006
SE	−59.0333***	15.6666	0.0002
W	−67.9900***	13.6976	0.0001
σ	278.0836	6.8881	

Estimated mean values for untransformed variables.
Base case: No forest, pasture or other land, age 35–50 y, South.
Significant values: $*P<0.1$; $**P<0.05$; $***P<0.01$.

areas of other land types (e.g. housing land, unproductive land) were positively correlated with willow cultivation, whereas the same relationship was negative and insignificant for larger areas of other land types. Leasing out of land was positively associated with willow growing. The explanation may be that both land uses are complementary reactions to a situation of surplus land ownership relative to other production factors. Tenancy had a negative relationship with willows for just the opposite reason: that land is primarily needed for other, less land-intensive production than willow growing.

The results show that the institutional/limited ownership category, together with the age span of 50–65 years, was the most adoption-prone owner group, even when other variables had been accounted for. Institutional owners may be interested in willow production because they have adopted a more aggressive management style. The fact that the work on these farms is often carried out by employees may ease the move towards more extensive crop production (willows) since the owner more easily than the family farmer can compensate for the reduced input of labour by reducing the number of employees. The low willow-planting activity in the oldest owner age group was similar to the observations of other adoption studies (e.g. Mbata, 1997; Lexmon & Andersson, 1998). The negative sign for the coefficient representing owner ages under 35 years was more surprising, as earlier adoption studies found that young farmers are more eager to adopt new methods than older farmers. This result could reflect a situation where limited financial resources among the youngest group makes it risk averse. In the intermediate age groups, however, both a stable economic situation and a positive attitude towards new crops may contribute to a high adoption rate.

All variables symbolizing animal production had negative correlations with willow production. Crop-producing farms may have more easily selected parcels that qualified to receive subsidies for willow-planting activities. Furthermore, on farms that concentrate on animal or milk production, land is needed for fodder production and manure deposition. Although willows are being tested by researchers as vegetation filters for sewage plants, few applicable and cost-effective methods exist today for applying manure on land under willow cultivation.

The positive sign of the irrigation coefficient might be confusing. The use of irrigation might be a sign of low rainfall and coarse-textured soils, which are less suitable for willow. However, our results suggest that the relative suitability of willow on these soils when compared with grain crops is still good. Furthermore, irrigation and tractor ownership could also be associated with an active management style with a more positive attitude towards new technologies in general. It would be interesting to measure the effect of total work hours by family members and employees on willow growing on the farm. This variable was, however, too unreliable and was therefore not included in the analysis.

The differences in willow-growing intensity between the different geographical regions probably reflect variations in several aspects, the biofuel market, soils, infrastructure and climate. In the north-eastern region of the studied area, a high population density and large demand for biomass fuels are combined with a well-developed woodfuel sector based on residues from the forest sector and a high woodfuel consumption in the surrounding district heating plants. This may have induced farmers to have more confidence in a future market for willow chips. The north-eastern region also includes large areas of medium-quality agricultural land which is probably suitable for willows.

In the western parts of the investigated area, a less developed woodfuel market has probably reduced the interest in growing willows. A high supply of wood fuels from the forest sector has a similar effect in the south-east. Farmers in these areas are probably less confident about the future demand for wood chips from willow coppice plantations. Low rainfall during the growth season and coarse-textured soils in this region could also have reduced willow production. In the extreme south however, a somewhat higher willow-planting activity could again be due to the high population density and the potential for a high woodfuel demand. Willow growing in the north-east and the south could finally be due partly to a good infrastructure in these areas of advisors and specialized companies who can manage the willow plantations. The role of local advisors has been shown previously by Ling (1996).

An illustration of the effect of age, geographical location, milk cows and forest land on expected willow area, given that the farmer is a willow grower, and on the probability of adopting willow cultivation, is shown in Figs 2 and 3.

An increased arable land area, from 30 to 150 ha, leads to a higher probability of willow production (Fig 2) and to willow production on a greater area (Fig 3). Figs 2 and 3 also show that changes in the independent variables have a stronger effect on the probability of adopting willow than on the area of willow cultivated.

Conclusions

This study shows that several variables describing the farmer, the farm type, land use and geographical

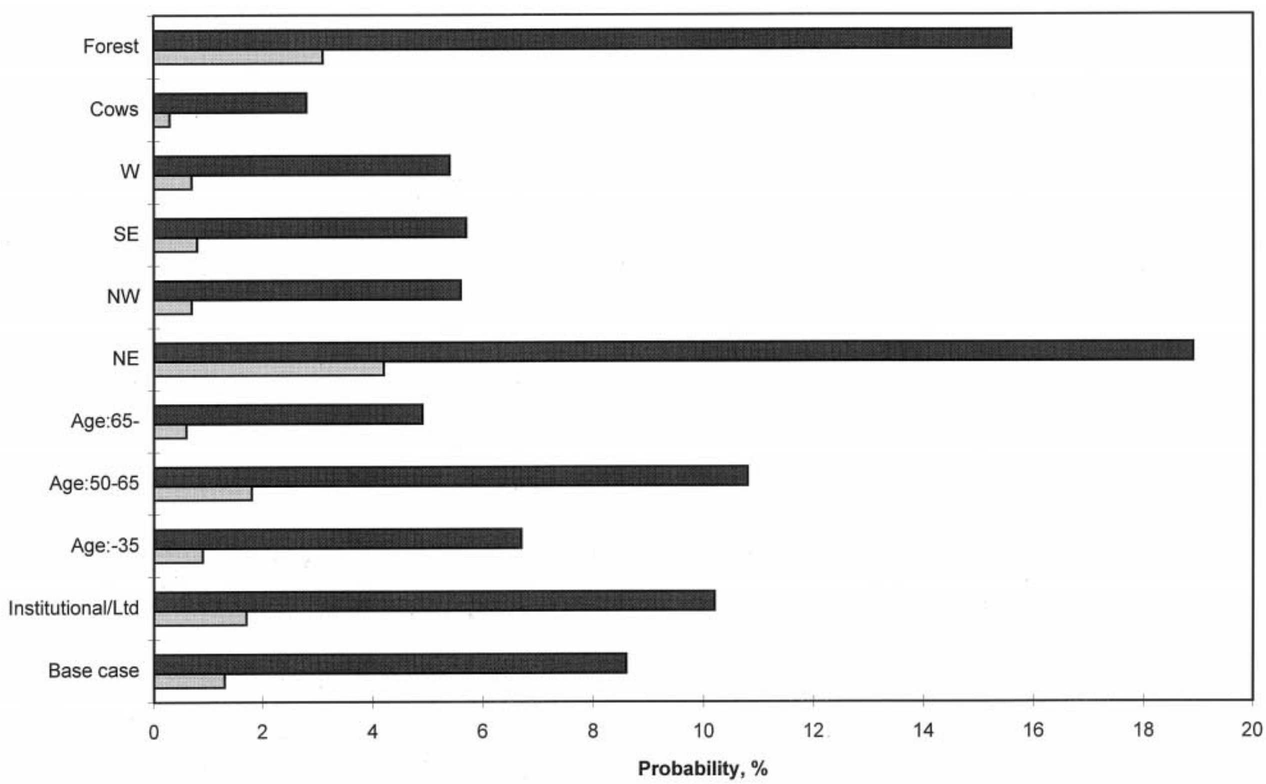

Fig. 2. Probability of growing willows. NE, North-east; NW, north-west; SE, south-east; SW, south-west; S, south. Base case: no forest, pasture or other land, age group 35–50, S. Dark bars: 150 ha; lighter bars: 30 ha.

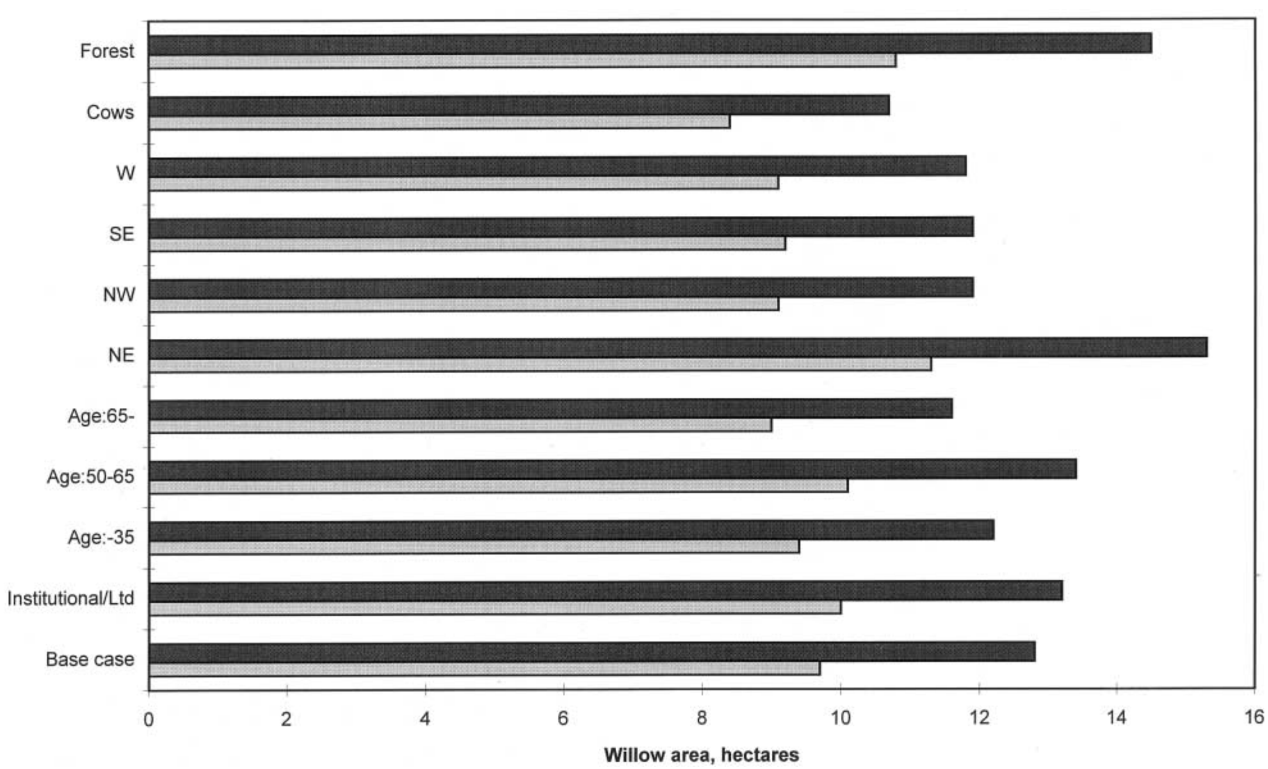

Fig. 3. Expected willow area for willow growers. NE, north-east; NW, north-west; SE, south-east; SW, south-west; S, south. Base case: no forest, pasture or other land, age group 35–50, S. Dark bars: 150 ha; lighter bars: 30 ha.

situation influence the decisions of Swedish farmers to adopt willow cultivation.

The results of the study have policy implication both for Sweden and for other countries that are planning to increase energy crop production. Adoption patterns of energy crops can be predicted. This is particularly true for the introduction phase. The results also help policy makers and players on the market to focus on the right farmers in information and marketing efforts. Furthermore, if there is a policy goal to increase energy crop adoption among farmers with low adoption rates, e.g. small-scale farmers, the results suggest that the barriers to adoption first must be identified. Tailor-made incentive programmes will probably have to be introduced in such cases. The results can also be useful for assessing biofuel production in different regions and for locating conversion plants based on energy coppice. A heating plant based on willow may, for instance, be more appropriate in a region with many large farms than in a region with small-scale diary farms. Caution should, however, accompany every translation of these results to other countries. It is still likely that the adoption pattern of energy crops in most regions and countries will vary between different types of farm.

Future studies could investigate further the energy crop adoption process, especially concerning the importance of locational aspects (e.g. soil type, local biofuel market volume). A technique to produce regional biofuel supply projections based on empirical data could also be developed.

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