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The Determinants of Farmer's Intended Behaviour Towards the Adoption of Energy Crops in Southern Spain: an Application of the Classification Tree-Method

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Abstract. Despite growing interest in biomass over the last number of years, bio-energy derived from biomass currently contributes to a very small share of the total Spanish energy market. How individual farmers choose to respond to the opportunities presented by these relatively novel crops has still received scarce attention. In this paper, farmers' intentions towards the adoption of energy crops are analyzed. A survey of 201 farm-households in Southern Spain is explored using a non-parametric approach based on classification tree algorithms. The main outcome of this analysis is that off-farm labour factor affects the adoption of energy crops on farm, together with farm specializations, size of owned land and farmer's education. While the study confirms the relevance of the main determinants available from the literature, need for further research is emphasised.

Keywords. Farmer behaviour, energy crops, classification tree, adoption of innovation

JEL-codes. D22, Q00, Q491.

1. Introduction and objective

The use of biomass as an energy source has undergone a revival in industrial societies during the last 15 years. With the strong growth in human populations worldwide, global energy consumption is beginning to exhaust conventional fossil energy resources. In addition, the release of CO2 from the burning of fossil energy has led to global climate change. Increased use of biomass for energy is therefore considered a potential solution as it offers moderate to significant greenhouse gas (GHG) savings compared with the use of fossil energy. Indeed, biomass could contribute to rural development through job creation and improved competitiveness in rural areas (Fischer *et al.*, 2005). For this purpose, bio-energy is being promoted through the most recent EU Directive (2009/28/EC) as well as national policy (Renewable Energies Plan 2005-2010, Spain).

Despite growing interest in biomass in recent years, bio-energy derived from biomass currently contributes to a very small share of the total Spanish energy market. Indeed, approximately 77% of the primary energy used in Spain in 2010 was fossil fuel

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based. Only 11.3% of total Spanish primary energy production came from renewable sources. Of these, biomass accounted for a mere 3.8%, far from the established objective (IDAE, 2010). Through the Renewable Energies Plan 2005-2010, Spain has fixed the objective of covering 29.67% of the total renewable energy production from biomass.

Of the three main biomass sources (agriculture, forest and waste), agriculture biomass production is generally considered to have the greatest energy potential (EEA, 2006). Agricultural biomass includes biomass produced directly from agricultural activities, such as cereal grains, sugar crops, oilseeds and other arable crops, as well as farm forestry in short rotation (e.g. willow and poplar). At the same time agricultural biomass includes crop residues such as straw, and livestock wastes, for instance manure and animals fats. Nevertheless, for biomass to play a significant role in the world's energy future, dedicated energy crops are essential (Evans *et al.*, 2010). Energy crops on farmland can produce biomass from fast-growing species in high densities and can be collected in short cycles.

Many studies have been conducted in several areas of Spain, on the assessment (technical and environmental) of bio-energy production by means of energy crops, but in the assessment analysis only the off-farm chain has been considered. Biomass potential has often been evaluated on the basis of agronomic and climatic conditions (Gómez *et al.*, 2011), in terms of the global feasibility of a bio-energy system (Gasol *et al.*, 2009; Martínez-Lozano *et al.*, 2009), as well as environmental issues (Butnar *et al.*, 2010; Sevigne *et al.*, 2011). Yet, none of the studies conducted to date have looked at the farm economics, preferring to focus on the agronomic and technical feasibility of these crops. Generally, there is a lack of research on the farm economic issues and little is known about farmers' attitudes towards the adoption of bio-energy crops.

Growing energy crops is a non-traditional land use option (i.e. crop farming) which could be considered as innovation (Villamil *et al.*, 2008). Energy crops face competition from other, arguably more standard uses of farmland, and if not seen as profitable to individual farmers, they will not be grown. Farmers' decisions are therefore a key constraint to potential supply. For instance, Sherrington *et al.* (2008), analysed barriers to adopting new cropping systems (i.e. dedicated energy crops) at the farm gate level in UK. The authors found several barriers to widespread adoption, such as financial returns, and the fact that competing activities were much more rewarding - in particular, wheat due to the increasing price a few years before. In addition, farmers need trusted information to make decisions (Sherrington *et al.*, 2008), somewhat through differentiated channels (Villamil *et al.*, 2008). The authors found that, in the areas studied, farmers need reliable information about technical and agronomic aspects of cultivation, as well as economic returns and contract agreements to produce energy crops. In general, farmers' attitudes and intentions towards the adoption of energy crops on their farmland have still received scarce attention. To the best knowledge of the authors, there is not a single study focusing on farmers' attitudes towards the adoption of energy crops in Spain.

In this context, this paper seeks to analyse farmers' intentions towards the adoption of energy crops in Spain. The research aims to explore farmers' attitudes towards energy crops assuming that the other external driver factors remain constant. It should be stressed that in the geographic area under consideration energy crops are still not cultivated, therefore adoption of energy crops is seen as product innovation. In addition, all consequences in terms of land and water use, as well as changes in farming practices are outside the scope of this paper.

The analysis is based on the stated preferences theory and relies on a sample of 201 farm-households in Andalusia (Southern Spain) carried out in 2009. A non-parametric approach based on classification tree algorithms is used to identify the main socio-economic determinants of farmers' intentions towards the adoption of energy crops.

The remainder of the paper is organised as follows: in Section 2 the area study and sample descriptions are provided, followed in Section 3 by the methodology. Section 4 illustrates the results, and finally concluding remarks are provided.

2. Materials

2.1 Area description

Andalusia is the most populous and the second largest, in terms of land area, of the seventeen Spanish autonomous communities. Figure 1 reports a map of Spain.

Figure 1. Map of case study

The agricultural utilized area amounts to 4,974,173 ha accounting for 57% of total surface. In 2009 GDP from the agricultural sector was around 6%, with an employment rate of 7% (Department of Agriculture and Fisheries, 2010).

The main climatic constraint for agricultural activities is water shortage. The rainfall pattern is typically Mediterranean, with wet winters and, hot and dry summer seasons. The average annual precipitation is 560 mm, but drought periods are quite common. As a result, irrigation is the most important economic factor. While only 25% of the total cultivated area is irrigated land, more than 60% of total agricultural GDP comes from irrigated crops. With respect to farm size, there is the classical dualism between the number of farmers and farm size. The majority of farmers (60%) cover a very small portion of farmland (7.5%).

Concerning the cropping pattern, arable land accounts for 32% of farmland. A rain fed system consisting of winter cereals and sunflower prevails. In other tilled areas where water is available, cotton and sugar beet are commonly grown. However, due to the last CAP (Common Agricultural Policy) reform in 2006 the prevalence of both crops has decreased considerably. From 2005 to 2009 they have seen a decrease of 44%. On the other hand, permanent crops are quite extensive (33%) with olive grove systems being the most important. Citrus, fruit and grapes are also cultivated. In addition, there are permanent meadows called 'dehesa' for pig rearing that cover 26% of total utilized area. Finally, fresh cut crops (i.e. irrigated horticulture) and other secondary field crops cover a small percentage (Department of Agriculture and Fisheries, 2010). The region also includes a protected zone with 27% of total area belonging to the Natura 2000 red, which is the largest area of this kind in the European Union.

2.2 Farm-household sample

In the spring of 2009, farm-households across 3 main provinces of Andalusia (Jaen, Córdoba and Seville, accounting for 57% of farmland and 52% of farm-households for the Andalusia region) were surveyed by way of a questionnaire and a dataset of 201 interviews was collected. Data was collected through face to face interviews. The questionnaire was divided into the following sections: a) Information about the household; b) Information about the farm; and c) Planned behaviour about a number of issues, including towards energy activity.

The survey questionnaire was developed in order to analyze farmers' intentions towards the adoption of energy crops with the rest of the external driver factors being constant. The horizon fixed was 2020 and the scenario (next ten years) was defined assuming as constant circumstances with regard to prices, employment opportunities and other conditions (e.g. water availability) would remain stable at January 2009 levels. Moreover, it was assumed that the CAP would continue as it is currently planned, particularly with regard to the Single Farm Scheme (SFS), Rural Development Policy (RDP), and other instruments such as milk quotas and cross-compliance. All of these factors and existing differences from farm to farm were also considered stable.

The objectives of the survey were: a) to understand the farmers' plans with respect to energy crops; and b) what factors explain differences in farmers' intentions.

Care was taken to gain broad representation of the farming community age, farm size, and type of crop specialization.

The main features and representativeness of the data sample are reported in Table 1.

The main farm specialization covered by the sample was specialist olive groves accounting for 30% of surveyed farmers. Otherwise, the group of arable crops reached 45%, special-

Table 1. Comparison between area study and sample

	Total study area		Sample	
Total Surface (ha)		%		%
Plain	2361900	57.19%	13267.4	66.41%
Hill and Mountain	1767600	42.80%	6711	33.59%
Total	4129500	100%	19978.4	100%
Farm specialization	*farm*			
COP*	25630	16.47%	38	18.91%
General field crops	26420	22.05%	54	26.87%
Olive grove	71655	46.06%	61	30.35%
Other permanent	25830	16.60%	21	10.45%
Livestock and field crops	23785	15.29%	27	13.43%
Total	155570	100%	201	100%
Farm classified by class of size	*farm*			
0 - 5	115259	62.55%	42	20.90%
5-20	45753	24.83%	57	28.36%
20-50	12243	6.64%	48	23.88%
> 50	11009	5.97%	54	26.87%
Total	184264	100%	201	100%
	ha			
0 - 5	209413	7.40%	90.9	0.45%
5-20	243893	8.61%	707.5	3.54%
20-50	350319	12.37%	1598.5	8.00%
> 50	1845788	65.19%	17581.5	88.00%
Total	2831240	100%	19978.4	100%
Livestock	*Number of unit*			
Cattle	324873	10.52%	1715	11.72%
Sheep and goats	1645406	53.27%	7797	53.29%
Pigs	1118260	36.21%	5120	34.99%
Total	3088539	100%	14632	100%
Farmer's age (mean of years)	56		54	

*Cereals, Oil seed, and Protein.

ist COP crops covered 19%, general field crops accounted for 27%; and other permanent crops and, mixed livestock with others crops, represented 10 and 13% respectively.

The representativeness of sample is fair with prevalence being for farmers specialized in olive grove systems and other permanent crops. However, it should be stressed that arable crop farmers are overvalued mainly with general field crops meanwhile class of farm size above 50 ha is overrated. As a whole the farmers sampled manage approximately 20 000 ha. Finally, the average farmer age in the survey is 54 years, with 56 years being the average in the study area.

3. Methodology

The methodology used is a classification tree method, aimed at classifying farmers according to their attitudes (adopt *vs* reject) in order to identify and profile potential energy crop growers.

Firstly, discussion on the nature and elicitation of stated intentions is set, then the methodology used in the scope of paper as well as the variables considered as determinants are reported.

The use of stated reactions as a good indicator of actual behaviour is a debated issue in the literature. This approach was chosen given that at the time of the study reliable information about the farmer adoption of energy crops was not yet available. Indeed, when the questionnaire was set, energy crops were still inexistent in the area (AAE, 2008). Consequently, *ex-post* econometric regression in order to underline an adoption pattern of energy crops was discarded in favour of an *ex-ante* analysis based on the stated responses. In this context, according to attitude theory, and empirical data, behavioural intention is a better predictor of behaviour than any other measures (Ajzen, 1991; Viaggi *et al.*, 2011a).

The information about stated adoption intentions was collected through a closed question formulated as follows: Within the next ten years, will there be any energy crops on your farm? The options were 'Yes' or 'No'; in addition, farmers' responses that were not clearly stated (i.e. they did not answer and, they did not know what they would do) were also collected. In addition, it should be stressed that this analysis concerns adoption intentions and, consequently, we are not able to discuss the level of adoption, or in other words what surface area will be devoted to energy crops. Finally, the question did not include an explicit reference to a comparison between different crops, farming practices (e.g. rotation, irrigation, fertilization) and other relevant aspects of energy crops farming. These explicit references were considered complicated and unpredictable at the time of surveying given the lack of energy crops in the area.

In the following analysis only the stated answer concerning reactions in terms of on-farm adoption is considered as a dependent variable. The dependent variable derived from the question concerning the energy cropping described above, and used in this paper, is quantified as $I = [0,1]$. Value 1 is assigned if the answer to the option of the question was 'Yes', and 0 if 'No'. Other unclear responses were discarded. Indeed, of the 201 farm-households interviews, 154 observations had a valid value.

For the purpose of research, the methodology applied is a non-parametric method based on classification tree algorithms. Tree-based methods split the sample step by step into smaller and smaller groups according to a mathematical condition. There are several variants of tree-based methods with different splitting criteria (i.e. algorithm). For example, the oldest tree classification algorithm, the CHAID (Chi-square Automatic Interaction Detector) technique uses a χ^2 test to decide which group to split (Kass, 1980). However, the algorithm hints a misappropriation in using continuous variables.

The CART (Classification and regression trees) is used here. It was firstly proposed by Breiman *et al.* (1984). The CART algorithm uses both continuous and categorical attributes for building the decision tree. The splitting measure in selecting the splitting attribute is *Gini* index. Usually, it is claimed that CART is most suitable for forecasting, while CHAID is better for data analysis. In addition, CART algorithm gives a room to manage missing value. Anyanwu and Shiva (2009) found that the CART algorithm is largely used as a decision tree technique with high classification and prediction accuracy. For these reasons the CART algorithm is chosen.

By using the CART algorithm the tree is obtained in two phases: firstly the tree is built using an algorithm that recursively divides the sample in smaller sub-samples as the tree grows. The procedure takes into account all available variables from the sample and checks if there is any statistically significant difference within the pair with respect to the target variable (in our case the adoption of crop energy). This procedure may result in a too complex tree achieved by growing an overly large tree. Then the second phase goes namely the pruning procedure, where 'unreliable' branches are pruned in order to minimize over-fitting (Anyanwu and Shiva, 2009). The pruning technique we used follows the post-pruning approach as the one used in system CART (Breiman *et al.*, 1984).

The process results in a tree-like structure of groups, also called nodes, in which each node has two child nodes. Terminal nodes, also called branches of the tree, define the classification of subjects.

In this case, the classification tree was built by splitting each node until its child nodes contained less than six observations. We made this choice based on the size of sample and, essentially taking into account the shortage of adopters. A minimum of 20% of adopters in a branch of the tree was seen as the most convenient splitting result.

Tree classification has been commonly used in medicine (Witbrodt and Kaskutas, 2005), veterinary science (Nagy *et al.*, 2010) and agricultural economics (Viaggi *et al.*, 2011b).

The variables considered as determinants are all those derived from the questionnaire. The questionnaire was designed following a review of the literature on farms adopting innovation, even if specific literature concerning energy crops is still scarce. In particular, several farmer characteristics emerge related to an adoption attitude. For instance it is assumed that the younger the farmers, the more likely they are to adopt innovations early in their respective life cycles (Rogers, 1995). Formal education level is also recognized among farmers' human capital linked with the adoption of innovation (e.g. Fernandez-Cornejo *et al.*, 1994; Breustedt *et al.*, 2008). It is assumed here that better and more educated farmers will increase adoption. On the other hand, it is well documented that farm structural features (e.g. farm size, land ownership, farm specialization) have a strong influence on the farmers' adoption process (e.g. Cutforth *et al.*, 2001; Breustedt *et al.*, 2008; Villamil *et al.*, 2008; Keelen *et al.*, 2009). In addition, it has been claimed that off-farm jobs may be related to the farmer's attitudes towards new activities. The flexibility of the farmer's scheduling as well as the complexity of new crops may have a significant bearing on the decision to adopt new farming pattern (Hipple and Duffy, 2002; Fernandez-Cornejo *et al.*, 2005; Keelen *et al.*, 2009).

The full list of variables used, and the way each variable was measured, is shown in Table 2.

Only 21% of the farm-households interviewed stated the intention to adopt energy crops on farm, which is the dependent variable chosen.

The farm characteristic variables are related to current farm size in terms of owned land and land rented-in. Renting plays a major role in land availability, particularly for annual crops and livestock; about a half of farms rent-in some land. Farming specialization covers the main agricultural crop systems across the study area, namely specialized

COP farm (i.e. winter cereal, sunflower and leguminous crops usually cropped in annual rotation), other general arable crops labelled field crops, olive grove systems, other permanent crops which cover citrus, orchard fruit and vineyards, and finally livestock systems. The latter category covers both specialist livestock and livestock farming with field crops. There are also the farm features related to geographic characteristics, such as altitude.

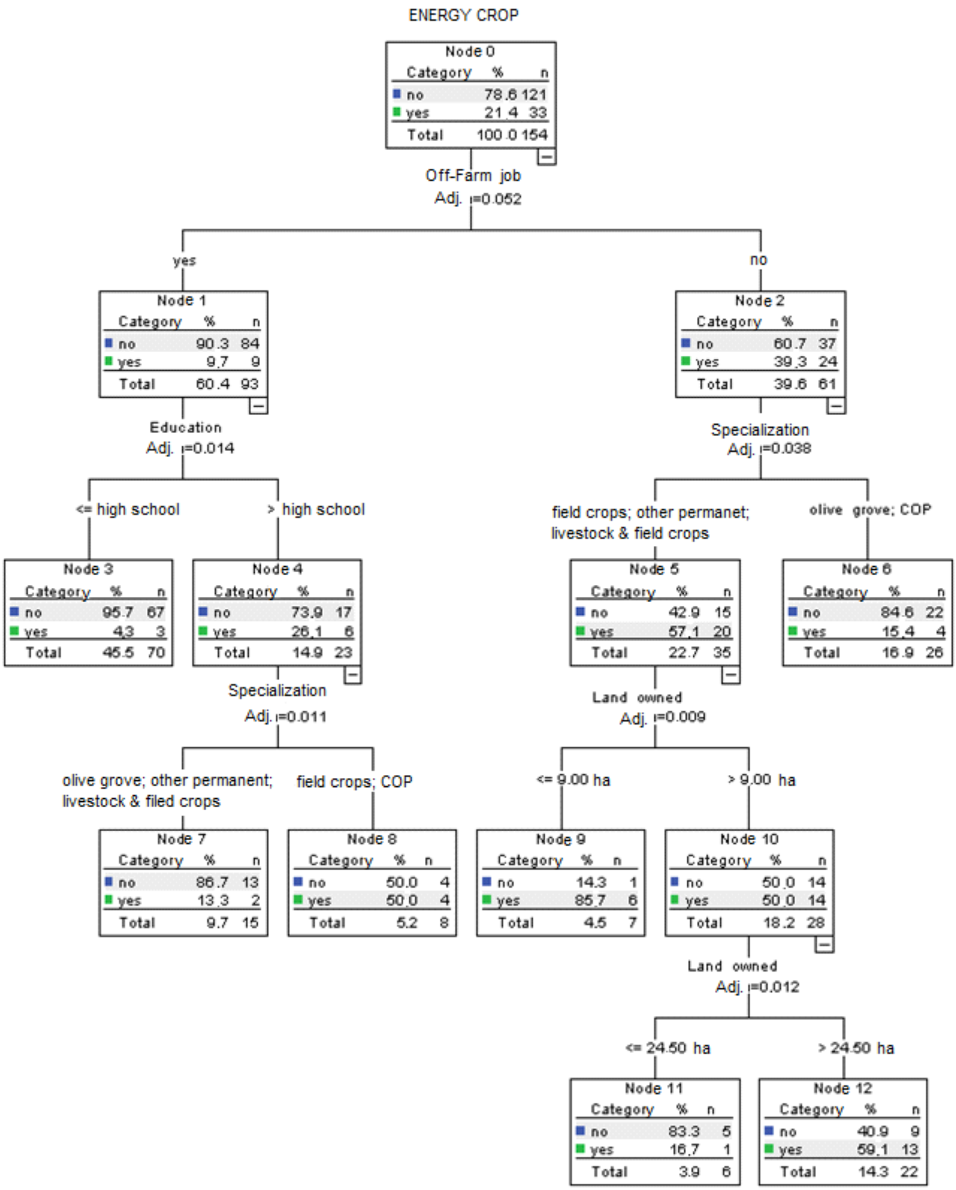
Table 2. List of variables used as determinants

	Code	Variable description	Coding	Mean	S.D.
Farm features	Land owned	Total land owned (ha)		78.29	269.34
	Land rent IN (dummy)	Land rent-in	0 = no, 1 = yes	0.45	0.49
	Off-farm job (dummy)	Off-farm labour by household members including farm head	0 = no, 1 = yes	0.60	0.49
	Specialization	Main farm specialisation	COP Field crops Olive grove Other permanent Livestock systems	16.3% 26.8% 34.6% 10.5% 11.8%	–
	Altitude (dummy)	Location of the farm with respect to the altitude	0=Plain, 1=Hill/Mountain	0.24	0.43
Farmer's features	Age	Age of farm head (years)	Age	52.02	13.01
	Education	Education level of farm head	Elementary school, primary school, high school, master, degree, Ph.D.	50% 2.6% 24.7% 12.3% 9.1% 1.3%	–
	Extension service (dummy)	Farmer assisted by an extension service	0 = no, 1 = yes	0.92	0.14
	Farmer union (dummy)	Membership of farmer union	0 = no, 1 = yes	0.41	0.49
	Share Gross Revenue	Share of farm income from agricultural activity over total household income (%)	less than 10% 10-29% 30-49% 50-69% 70-89% more than 89%	21.5% 21.5% 9% 10.4% 10.4% 27%	–

Note: 154 observations (only valid answers).

Indicators connected to off-farm jobs by a household member reports a mean of 0.60. The remaining variables concern the age of the farm owner, his/her education level, the use of extension services and membership in a farm union. Finally, there is the share of farm income with respect to the total household income accounting for six levels, ranging from less than 10% to higher than 89%.

Figure 2. Classification tree for the adoption of energy crops on-farm



4. Results

Figure 2 shows the variables selected by the CART algorithm. The first ramification point represents the first determinant of adoption selected by the procedure. It tells us that the prevalence of adoption behaviour is higher amongst farmers who do not have off-farm jobs compared to those who do. Although only 21.4% of the farms would adopt the energy crops in the group, this share is highly differentiated between farmers who have off-farm jobs and those who do not. While the right route represents 39.6% of surveyed farmers (61 out of 154 observations), of these 24 would adopt new crops on farm by 2020, which in turn covers the largest share of stated adoption behaviour. In fact, this first ramification accounts for 24 out of 33 farmers who would adopt energy crops.

In this route the next ramification point, that is, the next predictive factor found by the procedure, was farm specialization. While specialized COP and olive grove farms demonstrate the smallest share of willingness to adopt (only 4 out of 24 farmers), specializations such as general field crops, other permanent crops and, livestock with other crops, account for the majority of adopters. Indeed, Node 5 accounts for 60.6% (20 over 33) of those who would adopt energy crops in the next ten years.

At this point of the tree, Node 6 is also a branch of this tree ramification. By contrast, Node 5 was additionally split with the size of farm land being the selecting factor. Land owned emerges as a relevant factor in the farmer's decision to adopt energy crops. Node 10, where farms with larger land sizes were selected, accounts for 42.4% (14 over 33) of total adopters. Although this node covers only 18.2% (28 respondents) of the total sample it constitutes half of those who would adopt energy crops. On the other hand, in Node 9, the grouping of smaller farms, there are 6 adopters out of 33 (18%).This route tree ramification follows with two additional nodes, namely Node 11 and Node 12. These nodes are branches of this tree ramification, which in turn means that non additional ramifications are possible considering all the available variables. Once again, the splitting variable is the size of land owned. Likewise, the larger the farm, the higher the number of adopters. As a whole, Node 12 is the branch node with the higher number of adopters. Almost 40% of all farmers who would adopt energy crops (13 over 33) are at this terminal node. Let us turn now to the left side of tree ramification, where farmers who have an off-farm job were further divided by the algorithm according to education level. As a result, the sub-group of farmers who have an off-farm job was split into two nodes, respectively Node 3 for those who have less than a high school education and Node 4 for those who held a higher level of education. In this regard, the findings show that amongst farmers who have an off-farm job, those with a higher level of formal education seem to be more amenable to adopt energy crops on farm. Indeed, 6 out of 9 in this ramification fell into Node 4. While Node 3 is a branch of tree, Node 4 was split into two additional nodes, namely Node 7 and Node 8. The splitting variable was farm specialization. Basically, in this ramification the level of farmer education and farm specializations, such as field crops and COP, are the most important features related to the farmers' adoption.

With respect to the overall sample, the results show that only 33 of the 154 farmers interviewed, namely 21.4%, are willing to adopt energy crops on farm. Most of these fall into Node 2, with off-farm jobs being the discriminating variable. Terminal nodes performed by the tree classification method also show that the largest sub-group is Node 3, where the majority of rejections are covered with the farmer's education being the selecting variable. The CART algorithm also performs a ranking of importance for each independent variable of the tree. Farm specialization, farm size, off-farm job and farmer's education were respectively ordered from major to minor importance.

The performance of the classification tree was rather good and in line with the experience of other authors (Viaggi *et al.*, 2011b; Nagy *et al.*, 2010) with about 84% of the choices correctly predicted. Indeed, 88.4% of farmer's rejection behaviour and 69.7% of adoption was correctly classified.

5. Concluding remarks

The main outcome of this analysis is that farm features such as the off-farm labour factor together with specializations and the size of land owned affect the adoption of energy crops on farm. In addition, personal features such as farmer education levels are also relevant. A large number of southern Spanish farmers have jobs off-the-farm. Farming activities and practices that create scheduling conflicts between on-farm management and off-farm employment discourage adoption of alternatives. This aspect of compatibility is discussed in the literature. Likewise, formal education level is also recognized among farmers' human capital linked with the adoption of innovation. These findings are in line with the literature on innovation adoption. At the same time, energy crops face competition from other arguably more standard crops in the study area, such as olive grove systems therefore these specialized farms do not seem to perceive energy crops to be as attractive as other specializations. The result of this attitude is that most of the farms in the study area would not adopt energy crops. On the other hand, specializations such as field crops appear to be relevant in the study area. Among the field crops cultivated in the area, cotton and sugar beet are most common. It should be stressed that by mean of the last Common Agricultural Policy reform started in 2006 both crops have been constrained by national entitlements. This means that each EU member can produce a maximum area of these crops at a subsided price. As a result, those farmers that were obliged to reduce the amount of farmland devoted to these crops might be more willing to adopt energy crops. Similar results have been obtained regarding French farmers who have retreated from sugar beet production and who would be more likely to participate in miscanthus activity (Bocquého *et al.*, 2011).

Finally, farm land size was significant in the tree classification. Generally, the adoption of energy crops would be more likely on larger farms. Contrary to expectations, factors such as farmer age do not appear here. It should be emphasised that farmer age and education level are strictly correlated with the younger farmers being those who reach higher education levels. In addition, since the sample here is very small it could well be biased. However, according to the results, only the education factor is significant.

According to the findings further research should be carried out taking into account for instance the age of assets and the actual available liquidity of farm-households. Moreover, farmer's expectation about market price and job opportunity could well be related to the adoption of energy crops. These latter factors could be relevant in the adoption process, affecting the profitability of food and fibre crops as a whole, and obviously, energy crops. Moreover, in times of market price volatility, energy crops might also be considered to be a risk reducing crop through diversification.

More insights are also needed with respect to the influence of the Common Agricultural Policy reforms. Indeed, incentives for energy crops, as well as other changes in the scheme of support, should be addressed. This aspect is also related to idle/marginal lands and the change in the crop-mix that could arise as a result of policy amendments. Energy crops could be very interesting alternatives on marginal lands, as Campbell *et al.* (2008) emphasize.

This research aimed to explore farmer attitudes and responses towards a new cropping activity, namely energy crops, in a study area that lacked existing examples. The results should be considered as preliminary findings. Other aspects related to energy crops, such as potential social (food competition) and environmental (water and land use) threats (Evans *et al.*, 2010), need to be analysed. The latter could be relevant in the study area (i.e. water availability) dealing with farm choices.

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References

AAE (2008). *Situación de la biomasa en Andalucía. Agencia Andaluza de Energía, Sevilla*, <www.agenciaandaluzadelaenergia.es>, accessed 15 June 2008.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50: 179-211.

Anyanwu, M.N. and Shiva, S. G. (2009). Comparative Analysis of Serial Decision Tree Classification Algorithms. *International Journal of Computer Science and Security*, 3 (3): 230-240.

Breiman, L., Friedman, J., Olshen, L. and Stone, J. (1984). *Classification and Regression trees*, Wadsworth Statistics/Probability series. Florida, USA: CRC press Boca Raton.

Bocquého, G., Jacquet, F., Reynaud, A. (2011). Determinants of miscanthus adoption: an empirical investigation among French farmers. Paper submitted to the 5th "Journées de recherches en sciences sociales", Dijon, France, December 8-9.

Breustedt, G., Muller-Scheesel, J., Latacz-Lohmann, U. (2008). Forecasting the adoption of GM oilseed rape: Evidence from a discrete choice experiment in Germany. *Journal of Agricultural Economics*, 59 (2): 237-256.

Butnar, I., Rodrigo, J., Gasol, C.M., Castells, F. (2010). Life-cycle assessment of electricity from biomass: Case studies of two biocrops in Spain. *Biomass and Bioenergy,* 34: 1780-1788.

Cutforth, L.B., Francis, C.A., Lynne, G.D., Mortensen, D.A., Eskridge, K.M. (2001). Factors affecting farmers' crop diversity decisions: an integrated approach. *American Journal of Alternative Agriculture*, 16: 168-176.

European Parliament and Council (2009). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Brussels.

EEA (European Environment Agency), (2006). *How much bioenergy can Europe produce without harming the environment?*. Report no. 7/2006, Copenhagen, <http//:www.eea.europa.eu>, accessed 15 June 2008.

Evans, A., Strezov, V., Evans, T.J. (2010). Sustainable considerations for electricity generation from biomass. *Renewable and Sustainable Energy Reviews*, 14: 1419-1427.

Fernandez-Cornejo, J., Daberkow, S., Huang, W-H. (1994). The adoption of IPM techniques by vegetable growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics*, 26 (1): 158-172.

Fernandez-Cornejo, J., Hendricks, C., Mishra, A. (2005). Technology adoption and off-farm household income: The case of herbicide-tolerant soybeans. *Journal of Agricultural and Applied Economics*, 37: 549-563.

Fischer, G., Prieler, S., Van Velthuizen, H. (2005). Biomass potentials of Miscanthus, Willow and Populus spp.: results and policy implications for Eastern Europe, Northern and Central Asia. *Biomass and Bioenergy,* 28: 119-132.

Gasol, C.M., Martínez, S., Rigola, M., Rieradevall, J., Anton, A., Carrasco, J., Ciria, P., Gabarrell, X. (2009). Feasibility assessment of poplar bioenergy systems in the Southern Europe. *Renewable and Sustainable Energy Reviews*, 13: 801-812.

Gómez, A., Rodrigues, M., Montañés, C., Dopazo, C., Fueyo, N. (2011). The technical potential of first-generation biofuels obtained from energy crops in Spain. *Biomass and Bioenergy*, 35: 2143-2155.

Hipple, P.C. and Duffy, M.D. (2002). Farmers' Motivations for Adoption of Switchgrass. In: Janick, J. and Whipkey, A. (eds.), *Trends in new crops and new uses*, Alexandria: ASHS Press.

IDAE - Instituto para la Diversificación y Ahorro de la Energía, <http//:www.idae.es/>, accessed 15 October 2010.

Kass, G.V. (1980). An Exploratory Technique for Investigating Large Quantities of Categorical Data. *Applied Statistics*, 29 (2): 119-127.

Keelen, C., Thorne, F.S., Flanagan, P., Newman, C., Mullins, E. (2009). Predicted willingness of Irish farmers to adopt GM technology. *AgBioForu*m, 12 (3/4): 394-403.

Martínez-Lozano, S., Gasol, C.M., Rigola, M., Rieradevall, J., Anton, A., Carrasco, J., Ciria, P., Gabarrell, X. (2099). Feasibility assessment of Brassica carinata bioenergy systems in Southern Europe. *Renewable Energy*, 34: 2528-2535.

Nagy, K., Reiczigel, J., Harnos, A., Schrott, A., Kabai, P. (2010). Tree-Based Methods as an Alternative to Logistic Regression in Revealing Risk Factors of Crib-Biting in Horses. *Journal of Equine Veterinary Science*, 30 (1): 21-26.

Department of Agriculture and Fisheries (2010). Regional statistics, <http://www.juntadeandalucia.es/agriculturaypesca/portal/index.html>, accessed 30 November 2010.

Rogers, E. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

Sevigne, E., Gasol, C.M., Brun, F., Rovira, L., Pagés, S.M., Camps, F., Rieradevall, J., Gabarrell, X. (2011). Water and energy consumption of Populus spp. bioenergy systems: A case study in Southern Europe. *Renewable and Sustainable Energy Reviews*, 15: 1133-1140.

Sherrington, C., Bartley, J., Moran, D. (2008). Farm-level constraints on the domestic supply of perennial energy crops in the UK. *Energy Policy*, 36: 2504-2512.

Viaggi, D., Raggi, M., Gomez y Paloma, S. (2011a). Farm-household investment behaviour and the CAP decoupling: methodological issues in assessing policy impact. *Journal of Policy Modelling*, 33 (1): 127-145.

Viaggi, D., Raggi, M., Gomez y Paloma, S. (2011b). Understanding the determinants of investment reactions to decoupling of the Common Agricultural Policy. *Land Use Policy*, 28: 495–505.

Villamil, M.B., Heinze Silvis, A., Bollero, G.A. (2008). Potential miscanthus' adoption in Illinois: Information needs and preferred information channels. *Biomass and Bioenergy*, 32: 1338-1348.

Witbrodt, J. and Kaskutas, L.A. (2005). Does diagnosis matter? Differential effects of 12-step participation and social networks on abstinence. *American Journal of Drug Alcohol Abuse*, 31 (4): 685-707.