Heterogeneous Economic and Behavioural Drivers of the Farm Afforestation Decision

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Abstract

Using Ireland as a case study, this paper examines the farm afforestation decision in the context of incentivising farm afforestation to provide ecosystem services such as carbon sequestration to mitigate greenhouse gas production. Farm incomes and characteristics are observed using a longitudinal dataset and forest incomes are modelled in a life-cycle theoretical framework. The results show that there is a relationship between financial drivers and the likelihood of planting but we also find that there is a cohort of older smaller farmers that will never plant, and for whom negative cultural attitudes are stronger than financial drivers. In addition, this paper also identifies a cohort of large, younger farmers who might plant if the forest income is greater than the agricultural income. We also find that for many farmers the afforestation decision involves a wider complex of contemporaneous farm decisions. With this information, conclusions are drawn as to the drivers of afforestation for farmers who "might plant" in future. This paper concludes that a "one size fits all" programme based solely on financial incentives may not be the most appropriate means to encourage further farm afforestation.

Key Words: Afforestation decision, life-cycle analysis, afforestation policy incentives,

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1. INTRODUCTION

The conversion of land from agriculture to forest is an important policy objective across many EU countries (EU Commission 2013), although the success rate has been relatively modest in countries such as Belgium, Netherlands, Ireland, Wales, Scotland and England (Van Gossum et al. 2010 and 2012; Edwards and Guyer 1992; Forestry Commission 2013). While the drivers of these policies are based on the broad range of multifunctional timber and ecosystem benefits provided by forests, the potential for afforestation to mitigate agricultural greenhouse gases has recently gained in prominence. In the UK, a target of 23,000 hectares (ha) of additional forest annually for 40 years is needed to contribute to climate change mitigation (Read et al. 2009).

Ireland's recent forest policy review (DAFM 2014a) calls for an afforestation rate of 15,000 ha/yr to avoid a significant supply slump in future wood supply. Analysis of the impact of afforestation rates on forest sinks in Ireland shows a significant fall off in the strength of the forest sink post 2035. In order to attenuate this, annual afforestation rates would need to be maintained at around 10,000 ha for the period up to 2035 and beyond (Hendrick and Black 2008). However, despite significant and prolonged financial incentive programmes aimed primarily at farmers, annual afforestation in Ireland has consistently been below 7,000 hectares in recent years (DAFM 2014b).

While financial objectives such as maximising profits are important to farmers, they may not in many instances be the core or the sole motivation for farming (Vanclay 1992). Vanclay (2004) highlights the importance of the socio-cultural nature of farming as the primary motivating factor for farmers …"farming becomes a way of life". A recent synthesis of the literature which was carried out by Lawrence and Dandy (2014), explores 42 studies on the decisions and behaviours of private forest owners internationally in order to understand the factors behind the low level of uptake of policy incentives for both woodland creation and woodland management in the UK. In relation to afforestation/woodland creation, common factors include insufficient financial incentives, the long time period associated with forest returns and a cultural gap between farming and forestry that often manifests as a resistance to forest (Lawrence and Dandy 2014). The review concludes that a land use change such as afforestation is more widely embedded in socio-cultural factors than previously acknowledged.

Commercial forestry is less reliant on site quality than other potential land uses and high productivity levels can be attained in areas considered marginal for agriculture (Farrelly 2011). The returns to agriculture on a given farm type also depend on the intensity (measured as Livestock Units (LU/ha)), efficiency of management and on the agricultural subsidies available. The availability of afforestation subsidies (grants and annual premium payments) makes forestry a financially attractive enterprise for many farmers but particularly for those farmers engaged in extensive livestock rearing (Breen et al. 2010; Upton et al. 2013). For this reason, this paper focuses on livestock enterprises.

There is a growing literature on the psychology of farmers' decision-making that suggests that while financial gain is important, it may not be the core motivation for farmers (see Edwards-Jones 1998; Willock et al. 1999; Edwards-Jones 2006). In research on the uptake of agri-environment (AE) schemes summarised by Davies and Hodge (2006), adoption decisions hinge on the "goodness of fit between farmers' own management plans (based on available resources and personal preferences) and the incentives and restrictions on offer. Additionally, Wilson and Hart (2000) in interviewing participants in 10 EU countries, find that while financial considerations are important, the fact that proposed AE schemes fit well with existing farm management plans, is also important for the majority of farmers.

In specifically addressing the motivations of farmers undertaking afforestation, Key (2005) and Key and Roberts (2009) describe how attributes associated with farming such as independence and pride associated with business ownership are valuable to farmers and these attributes may not be achievable in other work areas. Howley et al. (2015) find that positive perceptions regarding lifestyle benefits associated with farming may act as a barrier for farmers in taking up employment outside the farm. The “styles of farming” approach to understanding diversity in farming communities attempts to explain the social nature of diversity in agriculture (Vanclay et al. 2006). This leads to the consideration of how farmers react to the reduction in grazing area following afforestation, in order to gain insight into the longer term motivations and plans of farmers who afforest part of their grazing land.

However, many of the studies that relate to the afforestation decision tend to have a narrow focus on either the economic or socio-cultural aspects of the decision and treat the decision as a straightforward land use substitution. In this paper we focus primarily on the complexity of the afforestation decision at individual farm level and the relative importance of financial drivers and socio-cultural barriers. We would specifically like to explore (a) whether a disaggregation of the components of agricultural and forest income streams would reveal new information on the role of financial drivers in the overall decision at individual level and (b) whether the decision may actually involve a more complex interaction of financial, physical and socio-cultural factors than has been previously considered in the literature.

Due to the dearth of data providing information on afforestation at individual farm level, existing studies are based on averages across farm systems. Approaches which utilise averages do not take account of both farm and farmer efficiencies at the individual farm level. In reality however, there may not be any “average” farmers so the information that can be gleaned from using average values is limited. Lawrence and Dandy (2014) report “the diversity and complexity of farm and farmer characteristics and behaviour in relation to farm afforestation” as a key finding of a recent review undertaken by of 42 international studies on decisions and behaviour in relation to afforestation. According to Moffitt (1990) it is important in policy design to know the distribution of individuals over the constraint, as different people on different parts of the constraint react to changes in different ways: “the net effect of a policy change may well depend critically on the relative numbers of individuals located at different points.”

This paper first defines a theoretical framework to suit the context of the afforestation decision based on international literature and adapting existing frameworks. In the methodology and data sections we generate forest datasets using a forest subsidies model and a forest bio-economic model developed by the authors. A panel dataset of farm level micro data is used to generate farm incomes and subsidies. We characterise farmers who have planted according to the level of farming intensity after planting and according to whether income per hectare would be higher from forestry or agriculture, given their individual farm environmental conditions. Next we estimate regression models using net present value (NPV) to incorporate the life-cycle financial attributes. We also analyse the characteristics of those who will never plant and use these variables to estimate binary logit models to examine the characteristics of those farms that have higher forest income streams. Ultimately we draw conclusions about the types of farms and farmers that are primarily motivated by financial drivers.

2. THEORETICAL FRAMEWORK

Analysis of the change in intensity of farming after planting could reveal valuable information on the motivation for afforestation i.e. what changes are made on farms as a result of planting? While the afforestation of former tillage land involves a straight land-use swap, the afforestation of grassland has consequences for overall farm livestock density as taking land out of grassland reduces the utilisable agricultural area (UAA) of the farm and leaves farmers with a number of choices in relation to livestock density. Thus the afforestation decision on livestock farms (farms in the specialised dairy, dairy other, cattle rearing, cattle other and sheep farm systems) warrants examination in greater detail.

Post afforestation stocking density changes on livestock farms

This study hypothesises that livestock farmers make one of three contemporaneous choices as a result of the reduction in UAA after planting.

- On less intensive farms, farmers may choose to replace the livestock with forestry (on a hectare for hectare basis), thus reducing livestock density or livestock units per hectare. These farms essentially use the afforestation income to subsidise the loss of agricultural income and also reduce their hours worked.
- On intensive farms, farmers may increase stock numbers on the reduced grazing area, resulting in an increase in costs and hours worked but this is compensated for by an increase in agricultural income, in addition to the afforestation subsidy income.
- A third category of farms may choose to maintain the livestock density on the farm by increasing intensity on the remaining grazing land. These farms are not likely to be highly stocked and thus have sufficient grazing land to maintain stock numbers while also benefiting from the afforestation income.

These contemporaneous land-use decisions are examined in greater detail to determine the numbers of farmers who intensify or de-intensify and whether there is a relationship between these contemporaneous decisions and soil class.

In addition to financial, physical and socio-cultural factors, the afforestation of agricultural land is further complicated by the long-term nature of the decision (Newman et al. 1993; Ananda and Herath 2009; Alig et al. 1999; Adams et al. 1996). Farmers who plant are essentially making an inter-temporal choice by electing to have their land and capital tied up for a period of from 30 to 100 years (depending on soil quality and tree species planted). As there is a legal requirement to re-plant forests after harvesting in Ireland, this is essentially an irreversible land use change. A financial decision is considered “irreversible “if it reduces for a long time the variety of choices that would be possible in the future” (Henry 1974). Because of the inter-temporal nature of this decision, the financial consequences of different land use choices available to the farmer must be analysed using an approach that looks at the decision as a life-cycle investment.

The theoretical framework adopted in this paper draws on the life-cycle model originated by Modigliani and Brumberg (1954). Although the classic life-cycle theoretical framework has been in existence for many years, it is widely used today and is still largely consistent with the theory of consumer choice (Deaton 2005). The theoretical framework was developed around life-cycle decisions based on the underlying assumption that people make rational, consistent, inter-temporal plans, and act as if they are maximizing a utility function defined over the periods of life. In this context, farm level characteristics are utilised to look at both agricultural and forest income streams on the basis of the relative life-cycle income accruing to the farmer from choosing to either remain in agriculture or convert the land (permanently) to forestry. Using the life-cycle approach facilitates the incorporation of net present value (NPV) as an explanatory variable in the analysis.

The variables included in the life-cycle model include financial incentives, land quality, opportunity cost of planting, consequences of planting on farm livestock density, along with a range of socio-economic farm and farmer characteristics. The literature suggests that factors such as farm system, family farm income ($\mathrm{FFI\ ha^{-1}}$), intensity of farming ($\mathrm{LU\ ha^{-1}}$), farm size and farmer age to be significant in relation to afforestation. These variables allow for the exploration of how the productivity of farms dictates the financial potential for either agriculture or forestry. Additionally, farms with forests are characterised on the basis of subsequent livestock density change.

3. METHODOLOGY

The purpose of this paper is to relate the forest planting decision and other contemporaneous farm decisions to the heterogeneous characteristics of farms. In planting land, farmers forego agricultural market income and farm subsidies (agricultural opportunity cost) but benefit from forest market income and forest subsidies. For the purpose of this analysis, it is assumed that farmers who afforests land, reduce average land use equally across all their enterprises, rather than selecting the lowest gross margin enterprise. In relation to opportunity cost, this essentially means that farmers planting a portion of their land still retain the overhead costs that relate to the farm as a whole as they continue with their former agricultural enterprises.

Key to understanding the financial drivers within an inter-temporal decision is the calculation of the net present value of a marginal change in land use to forestry. This paper employs a cost benefit analysis (CBA) to generate cost and revenue streams for livestock farm systems on a range of soil types reflecting a range of conifer forest productivity options. Agricultural and forest life-cycle income streams are presented as the net present value (NPV) of income which discounts the costs and revenues that occur during the rotation to present day values to allow for the comparison of net revenue streams assuming the same or broadly similar investment periods. This paper considers pre-tax incomes only and does not take into account the preferential tax treatment of afforestation subsidies as this would involve additional complexity.

For the purpose of this analysis, the net present value (NPV) of the actual forest income stream (including the agricultural opportunity cost) is calculated for the period to the first harvesting and second planting. This period n_j for farm j is dependent on the soil conditions of the farm. Although the afforestation decision is permanent, the time period t is sufficiently long at around 40 years to the first harvesting, that this approximation is reasonable.

Generation of relative life-cycle incomes for agriculture and forestry

In order to compare the relativity of agricultural and forest life cycle incomes, it is necessary to generate comparable income streams for both types of enterprise. This ultimately allows for the generation of a binary variable for farms that would have a higher income stream from forestry than from agriculture, namely $\mathrm{For} > \mathrm{Ag}$ (taking the value of 1 if forestry income is greater than agricultural income). A complementary variable is also generated for farms that would have a higher income from agriculture than from forestry ($\text{Ag} > \text{For}$).

Forest income is comprised largely of forest market and subsidy income. The third component of forest income is the agricultural opportunity cost, which is essentially the agricultural income stream for the enterprise being superseded. The agricultural income streams are also comprised of market and subsidy income. Therefore the market and subsidy components of farm and forest income (on a per hectare basis) are initially disaggregated. Thus the model contains separate sub-modules for each of four financial drivers:

- agricultural market income
- agricultural subsidies
- forest market income
- forest subsidies.

A range of income measures such as family farm income (FFI) (a measure of total income) is used to calculate agricultural incomes (Hennessy et al. 2013). It is necessary to generate forest income streams that incorporate the agricultural opportunity cost. Therefore the overall annual total (net) impact of land conversion from agriculture to forestry is examined on a per hectare basis. Total income can be defined as follows:

$$\text{Total Income} = \text{Market Gross Output} + \text{Subsidies} - \text{Direct Costs} - \text{Overhead Costs}$$

As farm afforestation generally takes place on an existing farm with existing overheads, (primarily in relation to pre-existing sunk costs), the overhead costs for afforestation should also include a component to account for the farm enterprise. Specifically therefore for the forest enterprise:

$$\begin{aligned}\text{Total Income} = {} & \text{Market Gross Output} + \text{Subsidies} - \text{Direct Costs} \\ & - \text{Forest Overhead Costs} - \text{Farm Overhead Costs}\end{aligned}$$

To summarise, this can be re-written as

$$\text{Total Income} = \text{Net Margin} + \text{Subsidies} - \text{Farm Overhead Costs (OC)}$$

In order to assess the sensitivity of the method of calculation of opportunity cost, different methods of calculating the NPV of afforestation are employed. The net cost of planting assumes full substitution. The most comprehensive definition incorporates the NPV of Forest Market Income (net margin) less Overhead Costs plus Forest Subsidies, treating the opportunity cost as the Gross (market) Margin (defined as Output minus Direct Costs) less Overhead Costs plus Farm Subsidies ($\boldsymbol{NPV}\ \mathbf{0}\ ha_j^{-1}$ (equation 1)). All amounts are expressed on a per hectare basis and discounted at a discount rate (r).

$$\boldsymbol{NPV\ 0}\ ha_j^{-1} = \left(\left(\sum_{t=0}^{n_j} \frac{ForestNM\ ha_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{FarmOheadCosts\ ha_j^{-1}}{(1+r)^t}\right) + \sum_{t=0}^{n_j} \frac{ForestSubsidyha^{-1}{}_h}{(1+r)^t}\right) - \left(\left(\sum_{t=0}^{n_j} \frac{GM\ ha_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{FarmOheadCostsha_j^{-1}}{(1+r)^t}\right) + \sum_{t=0}^{n_j} \frac{FarmSubsidy\ \ ha_j^{-1}}{(1+r)^t}\right) \quad (1)$$

In reality, it is evident from the dataset that farmers plant only a portion of their farms, therefore, a farmer will still incur agricultural overhead costs on a per hectare basis after planting. However, these costs cancel each other out and on this basis, $NPV0$ (GM+Subs-OH) simplifies to $NPV1$ (GM+Subs) as presented in equation 2.

$$\boldsymbol{NPV\ 1}\ \ ha_j^{-1} = \sum_{t=0}^{n} \frac{ForestNM\ \ ha_j^{-1}}{(1+r)^t} + \sum_{t=0}^{n_j} \frac{ForestySubsidy\ \ \ ha_j^{-1}}{(1+r)^t} - \left(\sum_{t=0}^{n_j} \frac{GM\ \ ha_j^{-1}}{(1+r)^t} + \sum_{t=0}^{n_j} \frac{FarmSubsidy\ \ ha_j^{-1}}{(1+r)^t}\right) \quad (2)$$

Research has shown that the level of afforestation has been affected by the range and relativity of agricultural and forest subsidies available to farmers (Ryan et al. 2014a). The farm gross margin excludes subsidies, even prior to decoupling when subsidies were coupled to production. In general terms, agricultural subsidies were historically paid on the basis of livestock numbers and were not paid on afforested land. For the purpose of this analysis it is assumed that a farmer who afforested land prior to the introduction of Single Farm Payment (SFP) in 2005 would only have considered forestry if he/she was farming extensively and had scope to carry existing livestock numbers on less land, thereby not suffering a significant loss in subsidies which were based on animal numbers (O'Connor and Kearney 1993). However, farmers planting since 2000 didn't lose SFP as they were able to "consolidate" their single farm payment entitlements and farmers planting land since 2008 are eligible for SFP. On the other hand, farmers in an agri-environment (AE) scheme (REPS - Rural Environment Protection Scheme) who planted some of their land, lost REPS payments on that land. The possible loss of REPS however, was considered to be a factor in the reluctance of many farmers to plant (Breen et al. 2010). It is recognised that the exclusion of the consequential change in agricultural subsidies and direct payments as a result of afforestation is a limitation of this study, but inclusion would be complex and is beyond the scope of this paper. Therefore we also consider a version of the net present value, NPV2 (GM) in equation 3 which ignores farm level subsidies.

$$\boldsymbol{NPV\,2}\ \ ha_j^{-1} = \sum_{t=0}^{n_j} \frac{ForestNM\ \ ha_j^{-1}}{(1+r)^t} + \sum_{t=0}^{n_j} \frac{ForestSubsidy\ \ ha_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{GM\ \ ha_j^{-1}}{(1+r)^t} \tag{3}$$

The calculation of the NPV of the opportunity cost using the two farm income measures GM incl. Subs (NPV1) and MGM (NPV2) will enable the testing of the significance of the effect of inclusion/exclusion of agricultural subsidies in the calculation of agricultural opportunity cost.

NFS Supplementary Survey (2012)

The literature suggests that there is a cohort of farmers who choose not to plant, regardless of the relativity of forest and agricultural income streams. From the literature and drawing on previous work based on average incomes across farm systems (Breen et al. 2010; Upton et al. 2013), it is expected that higher income dairy farmers are likely to intensify and older farmers with large farms are likely to de-intensify. Additional information is available from an NFS Supplementary Survey conducted in 2012, which provides information on the characteristics of these farms. All of these variables are utilised to estimate logistic regression models of the characteristics of farms that might plant/will never plant in relation to their relative forest and agricultural incomes. Finally, the consequences of planting some of the farm are examined in relation to the decision to intensify or de-intensify agricultural production on the remaining land.

Forest subsidies and forest market income

Forest subsidies by planting category and year are generated by the ForSubs forest subsidy model developed by Ryan et al (2014) which captures the historical and current forest subsidy payments paid to farmers for the relevant species composition of forests over the period 1984 to 2014.

Forest market income streams also need to be modelled to reflect the soil quality and consequent timber yields on individual farms. This is achieved using the ForBES (Forest Bio-Economic Systems) model developed by Ryan et al. (2016) in which the productivity of a given soil type dictates the type and profitability of farm or forest enterprise possible. The relative productivity of land under agriculture and forestry is taken into account in ForBES by assigning average NPVs for soil type and species to an individual farm, based on the farm soil code. The ForBES model then generates timber yield, cost and income projections using static yield models (Edwards and Christie 1981). The inputs include forest establishment and maintenance costs, afforestation subsidies, harvested timber volumes and ten year average timber prices. Income streams are presented in terms of annual equivalised NPV to allow for the inclusion of the agricultural opportunity cost on a comparable basis. On the farms that chose to afforest, forest market income streams are simulated on the basis of planting Sitka spruce (*Picea sitchensis* (Bong.) (Carr)) which, along with up to 20% of another conifer species, represents the most common composition of afforested land over the period (DAFM 2014b).

Modelling Choices

There is therefore sufficient information to determine NPV's for the forest or agriculture actual choices made on farms. However, it would also be useful to investigate whether individual farms would generate higher income streams from agriculture or from forestry, given the physical and production constraints of individual farms. Microsimulation techniques are utilised to generate income streams to represent the alternative (counterfactual) choices. Microsimulation models are evaluation tools that generate synthetic micro-level data which represent counterfactual situations that would prevail under alternative conditions, *ceteris paribus* (O'Donoghue 2014). A variety of models have been developed internationally that have simulated biological, market and policy changes at farm-level that can be used to compare the relative competitiveness of different farming systems, (Thorne and Fingleton 2006) and are particularly suitable where there is a paucity of micro data such as in relation to organic farming (Zander et al. 2007). A static microsimulation model is utilised here to generate counterfactual forest incomes for the farms that chose not to plant (on a per hectare basis) based on planting 10-20% of total farm area. Counterfactual agricultural income streams are also generated for farms that afforested land and these are also brought to a 10-20% forest share. These income streams are then used to generate a binary variable which takes the value 1 if the forest income is greater than the agricultural income (For>Ag).

4. DATA

From the literature, it is evident that there is a multitude of factors involved in the afforestation decision. In order to understand the relativity of the drivers of planting behaviour over time, while incorporating heterogeneous characteristics, requires the following data:

- Complementary actions at the time of planting re intensification/de-intensification.
- Farm income for existing farms with forests
- Farm income for existing farms without forests
- Financial determinants of agricultural decisions
- Financial factors of forest management decisions
- Socio-economic and environmental characteristics of farms
- Attitudes towards forestry

Understanding the contemporaneous farm decisions made at the time of planting should inform the degree to which forestry is merely a substitute land use or whether it is part of an intensification or diversification strategy. Given the relatively low planting rate of about 1% of farms per year and because of the need to incorporate market and policy variability, it is necessary to combine data from a number of years. On the basis that afforestation is generally a once-off land use change, a pooled dataset is utilised.

Teagasc National Farm Survey (NFS)

The primary data source (containing most of the attributes required for this analysis), is the Teagasc NFS which is Ireland's contribution to the EU Farm Accountancy Data Network (FADN) and collects detailed information from a representative sample of farms in Ireland. The study utilizes a time series of NFS micro data from 1985 to 2013 inclusive which contains farm and farmer characteristics of farms that chose to afforest land over the period as well as those that chose not to afforest. NFS data are used to generate long-term agricultural cost and revenue streams for each of six agricultural systems (dairy, cattle rearing, cattle other, sheep, tillage and mixed livestock) on six soil types. In this paper, the focus is primarily on livestock farms during the period from the early 1990s when policy incentives were developed at farm level (Ryan et al. 2014a). The consumer price index (CPI) for 2013 is applied to all incomes to make them comparable.

Data were also utilised from an NFS supplementary survey conducted in 2012, which collected additional questions which included whether farmers would plant if financial incentives were increased and whether they were aware of the permanency of the afforestation decision.

Agricultural market income and subsidies

Actual farm micro data are used to calculate farm incomes per hectare. As detailed in Paper 6, four measures of farm income/opportunity cost are calculated, namely family farm income (FFI), farm net margin (NM), total gross margin (GM) and market gross margin (MGM) (Hennessy et al 2013). However, for the purpose of this analysis, two methods of calculating the agricultural opportunity cost are examined, namely

- NPV1: market gross margin plus agricultural subsidies (GM (incl. subs)
- NPV2: market gross margin (MGM) only.

Summary Statistics 1: Relativity of forest and agriculture life-cycle income streams

The first disaggregation is into farms on the basis of whether the agricultural or forest income life cycle streams are greater over time for each farm in the population (Table 1). This categorisation is at the heart of this analysis as it is expected that the relativity of these life cycle incomes is a major driver in the afforestation decision. Therefore the variables Ag > For and For > Ag are generated, where life cycle forest income streams are defined as annual equivalised NPV of market plus subsidy income (on a per hectare basis).

Table 1. Relativity of agriculture and forest incomes contingent on the presence of farm forestry

	NPV1 – GM incl. subs		NPV2 - MGM	
	Frequency	%	Frequency	%
Ag>For / No For	23,546	66	18,772	52
Ag>For / Has For	3,385	9	2,648	7
For>Ag / No For	7,394	21	12,168	34
For>Ag / Has For	1,439	4	2,176	6
Total	35,764	100	35,764	100

Note: Income Components are on a per hectare basis. NPV's are adjusted to annualised definition, dividing by $\sum_{t=0}^{n_j} \frac{1}{(1+r)^t}$, varying with the forest rotation for the relevant yield class and soil type.

Agricultural life cycle income streams are defined as annual equivalised NPV of farm gross margin with and without subsidies (on a per hectare basis). Farms are further categorised on the basis of having farm forests i.e. "Has Forest" and "No Forest."

As these variables are likely to be critical in enabling an understanding of afforestation behaviour, the sensitivity of calculation method of gross margin is tested by comparing the variables $\text{For} > \text{Ag NPV1}$ (which includes agricultural subsidy payments) and $\text{For} > \text{Ag NPV2}$ (which represents only market gross margin).

Only 13% of farms in the pooled dataset have forests. The majority of farms have higher agricultural incomes yet haven't afforested land. This is consistent with expectations *a priori* expectations as these farms have a high opportunity cost of planting. The next largest group for both measures has higher forest incomes but these farms don't have forests. The smallest group describes farms where the forest income is higher than the agricultural income but these farmers have forests.

Summary Statistics 2: Farms with and without Forests

In examining the characteristics of the farms with and without forests as presented in Table 2, it is evident that farms with higher agricultural income streams have the highest family farm income (FFI ha^{-1}) and the largest number of dairy livestock units (LU ha^{-1}) and hours worked on-farm. These are the most intensive farmers who have the highest opportunity cost of converting land from an agricultural enterprise to forestry.

Table 2. Summary Statistics Relative to Has Forest/No Forest

	Aware of Irreversibility	Average Land Value over time (ratio) t	Farm FFI (€ ha^{-1})	Dairy LU ha^{-1}	Labour Units	Av Age	Farm Size	Teagasc client	Has REPS	Has Off-Farm Job	Medium Soil	Best Soil	Worst Soil
Ag>For / No For[2]	0.77	1.06	702	1.1	1.2	50	37.5	0.48	0.21	0.23	0.39	0.55	0.06
Ag>For / Has For	0.78	1.00	657	1.3	1.4	50	55.5	0.59	0.28	0.12	0.35	0.57	0.08
For>Ag / No For	0.68	0.90	273	0.1	1.0	55	31.5	0.36	0.34	0.42	0.43	0.42	0.15
For>Ag / Has For[3]	0.81	0.84	298	0.1	1.1	55	51.7	0.52	0.41	0.34	0.44	0.42	0.14

The highest (self-reported) land value[4] is reported by farms that have a higher agricultural income and don't have a forest. Conversely, the lowest land value is reported by farms with higher forest income, who have already planted. Critically, in relation to self-assessed land value, farms with forests reduce the self-reported land value after planting. This is likely to reflect the loss of flexibility of land use caused by the permanence of the land use change to forestry. In addition, the high level of awareness of the irreversibility of the afforestation decision across all groups is likely to be a factor in the low level of afforestation. Farms with forests have a marginally higher awareness of the permanence of afforestation.

[2] Agricultural income stream greater than Forest income stream – No forest on farm
[3] Forest income greater than Agricultural income – Has Forest
[4] Each year NFS survey farms are asked to value their land

As expected, farms with higher agricultural income streams have a higher proportion of better land on average and farms with higher forest income streams have the highest proportion of medium quality land (which is marginal for agriculture but highly productive in forestry). Those farms with forests are larger and are more likely to be participating in agri-environment (AE) schemes such as REPS and are also more likely to have an extension contract.

The characteristics of the cohort of farms with greater forest income but who haven't planted is particularly interesting. These farms are the smallest on average, are least likely to have an extension contract, are the oldest farmers, work least hours and are more likely to have an off-farm job. This size of this cohort is significant as it accounts for between 20 and 30% of the population of farmers (depending on method of calculation of opportunity cost). This cohort has a lower average FFI, and would be better off financially if they were to afforest a portion of their land, but they haven't done so.

The literature surrounding farmer attitudes towards afforestation reflects a wide divergence of views. One of the negative attitudes is a cultural bias against forestry. On this basis it makes sense that is a cohort of farmers who choose not to plant, regardless of the relativity of forest and agricultural income streams. This apparent contradiction has been commented on previously in the Irish farm afforestation context (see Breen et al. 2010; Upton et al. 2013; Howley et al. 2012, 2015), however the size of this cohort of farmers has not previously been determined.

Summary Statistics 3: Characteristics of farmers who Might Plant / will Never Plant

An examination of the data from the 2012 NFS supplementary survey shows that over 84% of farms will never plant even when the forest NPV is higher than the agricultural NPV (Table 3). Less than 16% of farms would consider planting in the future, depending on the level of subsidy offered. Again the impact of the inclusion of agricultural subsidies in the NPV calculation is evident, although it is difficult to infer causality. On the basis of this information, farms are categorised in relation to whether farmers will consider planting i.e. "Might Plant" and "Never Plant".

Table 3. Farms in 2012 NFS Supplementary Survey farms categorised according to intention to plant and by relative Agriculture and Forest incomes under different NPV measures

	Total	Ag >For	For>Ag	Ag >For	For>Ag
		NPV1 (GM incl. subs)		NPV2 (MGM)	
Might plant	15.8	9.7	6.1	5.8	10.0
Never plant	84.2	54.1	30.1	28.8	55.4
Total	100.0	63.8	36.3	34.6	65.4

To get a deeper understanding of the impact of these financial drivers, these farms are further categorised relative to their respective forest and agriculture income streams. The results are presented in Table 4. In initially examining the farms that have higher agricultural income streams, it appears that these farms have similar characteristics. These farms have high family farm income (FFI ha^{-1}), high land values and high dairy stocking rates. All of these characteristics make it unlikely that they will consider a land use change to afforestation as the opportunity cost of agricultural income foregone is high for these farms. These are on average the most intensive farms and are likely to continue in agriculture.

Table 4. Summary Statistics Relative to Might Plant/Never Plant

	Aware of Irreversibility	Average Land Value per ha (ratio)	Farm FFI/ha	Dairy LU ha^{-1}	Labour Units	Av Age	Farm Size	Teagasc client	Has Reps	Has Off-Farm Job	Medium Soil	Best Soil	Worst Soil
Ag>For / Might Plant	0.74	1.26	911	0.9	1.20	54	58.0	0.76	0.28	0.10	0.25	0.73	0.03
Ag>For / Never Plant	0.76	1.14	919	1.2	1.30	53	53.3	0.65	0.33	0.18	0.31	0.66	0.03
For>Ag / Might Plant	0.59	0.93	279	0.0	1.04	55	47.0	0.47	0.16	0.36	0.47	0.48	0.06
For>Ag / Never Plant	0.72	0.96	327	0.1	1.07	59	41.8	0.47	0.23	0.31	0.42	0.45	0.13

Note: Income Components are on a per hectare basis. NPVs are adjusted to annualised definition, dividing by $\sum_{t=0}^{n_j} \frac{1}{(1+r)^t}$, varying with the planting cycle for the relevant yield class and soil type. Assumption: Opportunity Cost based on NPV2 (MGM)

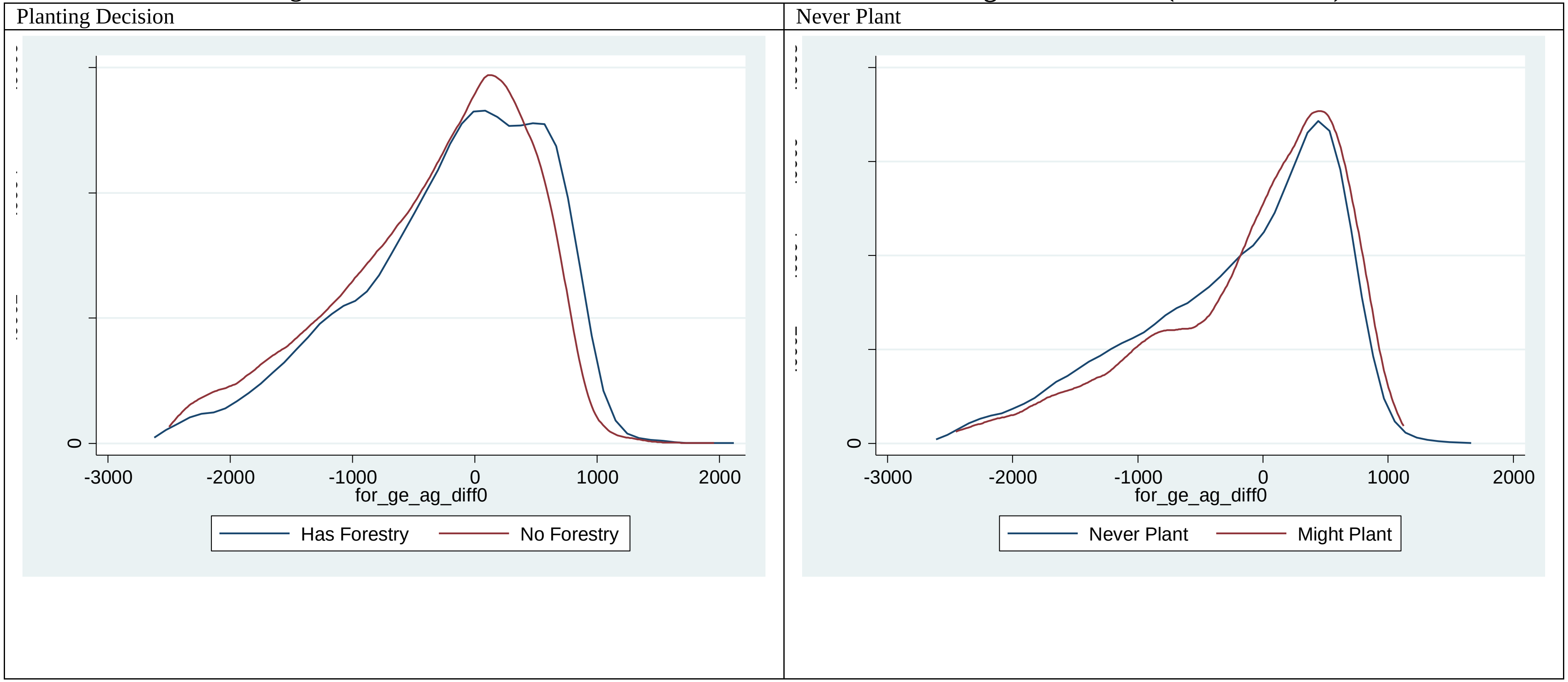
The cohort of farms that will never plant despite having higher forest income streams also presents a definite pattern. These farms have the lowest FFI ha^{-1}, the smallest farm size, the lowest livestock numbers and are the oldest farmers on average. These farms are the least intensive and display a strong negative cultural bias against forestry. From the perspective of the irreversibility of afforestation, farms that will never plant have a high level of awareness of the permanency of afforestation regardless of whether their income streams are higher from forestry or from agriculture. The corollary of this is that farms with higher forest income streams that might plant, are least likely to be aware of the permanent nature of the decision.

The characteristics of the farms and farmers that might plant in the future (depending on the financial incentives offered) are particularly interesting for both policy makers and extension agencies. These farms represent just under 16% of the farm population. Those with higher agricultural income streams are again quite intensive farmers: they have high FFI, dairy stocking rates and large farms, making it unlikely that they would plant unless forest income streams were comparable to or greater than the income from agriculture. On the other hand, of those who might plant and who have higher forest incomes, almost half of these farmers on average have an off-farm job; these farms have the lowest self-reported land value and; on average have the highest proportion of worst soil and a high proportion of medium soil. Their willingness to consider afforestation is possibly a diversification strategy to optimise both their land and their time resources.

Summary statistics 4: kernel density

Next, kernel densities of the “has forest/no forest” and “might plant/never plant” variables are presented in Figure 1. For simplicity purposes, the results presented are calculated using NPV2 (MGM ha^{-1}). The log normal distributions of the incomes are quite similar and overlap slightly, indicating that the distribution of incomes for planters and non-planters is very similar. The same is the case for the distribution of incomes for those who might or would never plant. However the curves for the “has forest” and “might plant” variables are slightly more positive in income.

Figure 1. Kernel Densities of Difference between Forest and Agriculture NPV (NPV2 –MGM)



Note: Income Components are on a per hectare basis. NPVs are adjusted to annualised definition, dividing by $\sum_{t=0}^{n_j} \frac{1}{(1+r)^t}$, varying with the forest rotation for the relevant yield class and soil type. Assumption: Opportunity cost based on NPV2 (MGM).

5. RESULTS

The primary purpose of this analysis is to ascertain whether there is a relationship between the relativity of forest and agriculture income streams and the likelihood of planting. This involves an examination of the relativity of the farm and forest life cycle income streams that would prevail on individual farms, given their environmental conditions. This is presented by generating two income variables as follows:

- Ag > For represents farms where the potential life-cycle income from agriculture is greater than from forestry
- For > Ag represents farms where the potential life-cycle income from forestry is greater than that from forestry.

These variables allow us to characterise farms on the basis of whether they would be better off financially if they planted land or not. Farms are additionally characterised on the basis of whether they have planted in the past or whether they will consider planting in future.

Logistic regressions of farms with forests (has forest) and farms that might plant

Logistic regressions are estimated for the farms with forests (has forest) (as presented in Table 5). The variable forest income greater than agricultural income (For > Ag) which had been hypothesised would be significant, is indeed significant and positive, indicating that those with higher forest incomes are more likely to have forests.

In relation to the sensitivity of calculation of agricultural income, both methods of calculation of the NPV of income streams (with and without subsidies) have a reasonable pseudo $R^2$and are both significant at the 1% level. However the magnitude of the For > Ag coefficient is almost double when subsidies are included indicating that while the inclusion of subsidies may not be a major driver of the financial decision, agricultural subsidies may have had some impact on the likelihood of having a forest. As hypothesised, farm size is significant and positive for both NPV calculation methods. Land value (logged) which is a variable that captures farmers' (self-assessed) perception of land value is also positive and significant, indicating that as self-reported land value increases, the likelihood of having a forest increases. Farms participating in AE schemes and having an extension contract are also more likely to have forests.

Off farm income is also significant and positive, indicating that farms with forests are likely to have an off-farm income source. As expected, FFI is significant and negative for both NPV calculation methods, reflecting that farms with high farm incomes are less likely to have forests. All regions other than Dublin and East are positive and significant, reflecting that over the period examined, all regions are likely to have farms with forests. The interpretation of the soils results is less clear, however the positive coefficients for the best soils (although only significant for the MGM NPV calculation) can be explained by high levels of planting by dairy farmers in the 1980s and 1990s.

Table 5. Models of farms with forests (farm GM with and without subsidies)

has forest	For>Ag NPV2 (MGM)			For>Ag NPV1 (GM incl. subs)		
	Coefficient	SE		Coefficient	SE	
Income: For>Ag	0.2998***	0.0456		0.5885***	0.0491	
Land Value ha^{-1} (logged)	0.6351***	0.0392		0.6795***	0.0396	
Family Farm Income ha^{-1}	-0.0004***	0.0001		-0.0001	0.0001	
Dairy Stocking Rate	0.00002	0.0000		-0.0001**	0.0000	
Labour Units	0.0134	0.0437		0.0597	0.0442	
Age Squared	-0.000001	0.0000		-0.00001	0.0000	
Farm Size	0.9588***	0.0308		0.9526***	0.0311	
Extension contract - Teagasc	0.2587***	0.0379		0.2751***	0.0380	
AE scheme - REPS	0.3669***	0.0434		0.3936***	0.0427	
[5]Region 3 – East	0.3081***	0.0785		0.3431***	0.0785	
Region 4 - Midlands	0.3635***	0.0796		0.3769***	0.0799	
Region_5 - Southwest	0.5394***	0.0750		0.5505***	0.0752	
Region_6 - Southeast	0.3459***	0.0881		0.3123***	0.0882	
Region_7 - South	0.4384***	0.0712		0.4595***	0.0714	
Regions 8 - West	0.618***	0.0740		0.6159***	0.0741	
Off farm income	0.4374***	0.0824		0.4073***	0.0826	
Soil 2-medium soils	-0.0496	0.0480		-0.0576	0.0489	
Soil 1-best soils	0.1071	0.0667		0.1606**	0.0673	
Constant	-0.2331***	0.0687		-0.1753**	0.0694	
No of observations			27970			27970
Pseudo R^2			0.0779			.00824

Note: *** denotes statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Fundamental Choices about Planting

Farms that might consider afforestation in the future are considered in Table 6. This is essentially the corollary of farms that will never plant and represents a much smaller sub-set of the overall population with a corresponding drop in pseudo R^2 value. The results show that the relationship between the relativity of income streams and the likelihood of considering forestry in future is again significant and positive, indicating that those farms with higher forest incomes are more likely to (might) plant (for both methods of NPV calculation). In this model however, there is very little difference in the magnitude of the coefficients on the For > Ag variable (whether subsidies are included or not). This possibly reflects the largely complementary nature of agricultural and forest subsidies in 2012 when the data were collected. Again as hypothesised, farm size is significant and has the expected signs. Land value (logged) is positive (although of less significance than in the "has forest" model). In this model, age (squared) is negative and significant indicating that older farmers are less likely to plant and the likelihood of planting drops as age increases. Participation in AE

[5] NFS Regions:
Region 1 (dropped) Border: Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan.
Region 2 – (not reported) Dublin
Region 3 – Kildare, Meath, Wicklow
Region 4 – Laois, Longford, Offaly, Westmeath
Region 5 – Clare, Limerick, Tipperary NR
Region 6 – Carlow, Kilkenny, Wexford, Tipperary SR, Waterford
Region 7 – Cork, Kerry
Region 8 – Galway, Mayo, Roscommon.

schemes is not significant in this model which is possibly a reflection of the substantial difference between measures and payments in previous AE schemes (REPS) and the later AEOS (Agri-Environment Options Scheme) which was in operation in 2012 when the supplementary survey was undertaken. Off-farm income is not significant in this model, possibly indicating that the farmers who might plant are likely to be full-time farmers. In terms of the location of future planting, soil type is not significant and only the midlands and southwest regions are significant but both are negative, indicating that future planting by farmers is less likely in these regions.

Table 6. Models of the farms that might plant (farm GM with and without subsidies)

Might plant	For>Ag NPV2 (MGM)			For>Ag NPV1 (GM incl. subs)		
	Coefficient	SE		Coefficient	SE	
Income: For>Ag	0.5681***	0.2187		0.6476***	0.2127	
Land Value ha^{-1} (logged)	0.3647**	0.1803		0.3951**	0.1808	
Family Farm Income ha^{-1}	0.0004	0.0003		0.0005*	0.0003	
Dairy Stocking Rate	-0.0001	0.0001		-0.0002**	0.0001	
Labour Units	-0.1117	0.2146		-0.0836	0.2132	
Age Squared	-0.0001**	0.0001		-0.0001**	0.0001	
Farm Size	0.5949***	0.1516		0.5679***	0.1515	
Extension contract - Teagasc	-0.0149	0.1618		-0.0087	0.1619	
AE scheme - REPS	-0.0001	0.1742		0.0413	0.1755	
Region 3 - East	-0.1163	0.2862		-0.0796	0.2863	
Region 4 - Midlands	-0.9003***	0.3021		-0.9018***	0.3015	
Region_5 - Southwest	-2.1875***	0.6175		-2.2371***	0.6184	
Region_6 - Southeast	0.1574	0.2560		0.1676	0.2563	
Region_7 - South	0.2361	0.2720		0.2395	0.2728	
Regions 8 - West	-0.1207	0.2691		-0.1318	0.2700	
Off farm income	0.1824	0.1954		0.1637	0.1964	
Soil 2- medium soils	0.3986	0.3476		0.475	0.3497	
Soil 1-best soils	0.1778	0.3550		0.2728	0.3581	
Constant	-4.0953***	0.7983		-3.9496***	0.7804	
No of observations			1393			1393
Pseudo R^2			0.0575			0.0594

In summary, it is interesting to note that while drivers such as farm size are consistently strong and significant across the "has forest" and "might plant" models, it would appear that the inclusion of agricultural subsidies in the calculation of the opportunity cost is less relevant for future rather than historic afforestation.

The secondary purpose of this analysis is to examine whether the afforestation decision is one that involves a straight land use substitution which is made in isolation, or is alternatively part of a more complex lifestyle decision-making framework. This is achieved by using changes in the level of intensity of farming as a proxy for wider whole farm decisions. Research undertaken by Ryan et al. (2014) suggests that livestock density on cattle and sheep farms in particular, is likely to have had a strong influence on the afforestation decision over the last 30 years. The decision to substitute forestry for an agricultural enterprise also changes the intensity of production on the farm as it reduces the livestock carrying capacity. Farmers who plant can thus choose to intensify, de-intensify or maintain livestock density. The analysis shows that just under one third of farms had no change in livestock density in the year of planting (Table 7). A quarter of farms increase stocking rate while the largest proportion of farms (43%), reduce livestock density in the year of planting.

Table 7. Consequences of planting – change in farming intensity in year of planting

	Percentage
No change	32.0
Decrease Stocking Rate by 5% or greater	42.9
Increase Stocking Rate by 5% or greater	25.1
	100

The farm characteristics are further examined in relation to the three stocking density change categories and are presented in Table 8.

Table 8. Average characteristics of farms with new forests by category of stocking rate change

Stocking rate change	For >Ag	Farm income (€ ha^{-1})	Dairy (LU ha^{-1})	Labour Units	Age	Farm Size (ha)	Teagasc Clients	AE Scheme -REPS	Off Farm Job	Direct payment (€)	Previous LU/ha	Medium soil	Good soil	Good soil
No change	0.32	398	0.87	1.3	49	68	0.53	0.18	0.12	11682	1.6	0.44	0.44	0.12
Increase SR by 5%	0.47	298	0.62	1.2	48	62	0.49	0.14	0.23	12796	1.2	0.48	0.31	0.20
Decrease SR by 5%	0.52	383	0.52	1.2	52	55	0.42	0.33	0.17	16585	1.5	0.40	0.46	0.14

The farms that don't change the livestock density per hectare after planting are the largest and most intensive farms with the highest average livestock density, highest dairy livestock density, highest average hours worked and the highest average farm income. Less than one third of these farms have a higher NPV of income from forest than from agriculture. These farms were already reasonably heavily stocked (average LU ha^{-1} of 1.6), so they had no choice but to reduce stocking density as a result of having less land available for grazing. It is likely that these farmers did not have spare capacity in terms of land and made an economic decision to optimise their land use, by replacing a marginal agricultural enterprise with a more productive forestry enterprise. These farms can be characterised by having "intensive/optimisation" objectives.

For the 25% of farmers who increase intensity as a result of afforestation, forest income is greater than agricultural income on almost half (47%) of these farms They have a slightly smaller average farm size of 62 ha and the lowest farm income, are younger and are more likely to have off-farm income, suggesting that these are part-time farmers who have planted excess land which they did not need as they maintain similar or greater stock numbers on a reduced land area. These are farmers who may be optimising their work hours by planting land to free up time to supplement overall income with off-farm income. These farmers could be characterised as having "diversification" objectives.

However, almost half of the farms (44%) decrease their stocking rate suggesting that these farms may be "winding down". Prior to planting, this group had high average stocking density and just over half of these farms have higher incomes from forestry. The farms are smaller on average (55 ha) and the farmers are older. They are more likely to be in AE schemes; and have considerably higher direct payments than the other groups. These farmers appear to have "de-intensification" objectives.

In summary, it would appear that the decision to afforest land involves consequential decisions in relation to farming intensity. At the very least, this involves decisions in relation to livestock density, but it would also appear that the decision to afforest may be taken as part of wider lifestyle objectives.

6. DISCUSSION AND CONCLUSIONS

To date it would appear that an analysis of this depth into the heterogeneous distribution of livestock farms and their characteristics has not previously been conducted in the afforestation context, therefore it was difficult to know what to expect. However, it is evident that there is an *a priori* relationship between financial drivers and the likelihood of planting. In particular, the relativity of agricultural and forest incomes over the period analysed, has a large impact on the afforestation decision. Farms with higher forest income streams (For > Ag) are significantly more likely to have afforested land and to consider forestry in the future.

Interestingly, 40% of farms have higher forest income streams over the period (which reduces to 25% when agricultural subsidies are specifically taken into account). This represents a substantial area of land and again highlights the competitiveness of forestry on marginal land and for specific farm systems. While the inclusion of agricultural subsidies has an effect historically, the calculation of the opportunity cost is statistically significant whether subsidies are included or not.

An examination of the change in farming intensity as a result of planting reveals three categories of farmers in relation to farm management objectives. The farm and farmer characteristics of these typologies are described and the conclusion is drawn that a "one size fits all" programme based solely on financial incentives may not be the most appropriate means to encourage further farm afforestation. The usefulness of a segmentation approach for agricultural policy is recognised in the UK, and extensive research has been undertaken by Defra (Department for environment, food and rural affairs) in this area (Pike 2008, 2011). The Defra studies explore a range of studies undertaken in England in relation to farming style, in the context of decision making. The studies report that the importance of a segmentation framework lies in using a deeper understanding of "who farmers are, what they do, what they think and feel, and how they respond to policies" in order to help policy makers to design long-lasting solutions (Pike 2008).

This paper shows that there is a high level of awareness of the permanence or irreversibility of the land use change across farms with and without forests. McDonagh et al. (2010) identify this irreversibility as the second largest barrier to afforestation after the desire to stay farming. In a study of farmer participation in woodland conservation schemes, Bell et al. (1994) find that activities that aim to create a more favourable attitude towards the goals of the programme may have a stronger influence on participation than financial incentives and conclude that both direct (financial) and indirect (extension) incentives may be useful.

Bateman (2006) recognises the importance of taking farmers' mind-sets into account and acknowledged the inability to do so as a weakness in estimating the opportunity cost of farm afforestation. The inclusion of attitudinal survey data in this analysis has added greatly to understanding the different motivations of farmers in relation to afforestation.

The percentage of farmers who will not consider afforestation (84%) (regardless of the financial incentives involved), is an important finding of this analysis. This is not surprising as only 3-4% of NFS farmers state their intention to plant within the next three years (Ryan and Kinsella 2008). These are older farmers for whom negative cultural attitudes are stronger than financial drivers. On a more positive note, this paper also identifies a cohort of large, younger farmers who might plant, if the income form forestry is greater than the agricultural income.

The objective of this paper was to better understand the heterogeneity in afforestation decisions. It seems clear that financial incentives are significant but are not strong enough on their own to incentivise planting. This study shows that not all farmers will respond to financial incentives and a more targeted approach may be necessary to improve the uptake of farm afforestation in future.

These findings are important for policy makers who wish to incentivise farm afforestation to increase timber production, maximise carbon sequestration in an effort to mitigate agricultural greenhouse gas production and improve ecosystem service provision. Further research is needed to test these possible typologies, opening up the possibility of future targeting of communication strategies for farmers with very different mind-sets and objectives. This paper also concludes that an examination of the feasibility of structuring afforestation incentives to coincide with actions incentivising farm re-structuring or greenhouse gas mitigation, could overcome some of the barriers that currently hinder the land use change to forestry.

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