# Incorporating agricultural opportunity costs in the returns to farm afforestation

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Teagasc Rural Economy Working Paper Series

## 1.1 INTRODUCTION

Over most of the period examined in this thesis, higher financial incentives were offered to farmers than to other land owners to undertake afforestation. As a result, over 80% of afforestation on privately owned land was undertaken by farmers. In changing land use from agriculture to forestry, these farmers incurred an opportunity cost in relation to the loss of agricultural income on the land. Thus, an examination of the farm afforestation decision must integrate both the financial and physical components of the agricultural enterprise in conjunction with the proposed forest enterprise. According to Herbohn et al. (2009) this approach is considered to be a considerable improvement on models that consider the forestry investment in isolation.

A fundamental criterion for choosing forestry over alternative land uses is that forestry provides the largest land rent i.e. the biggest average return per hectare per year (Helles and Lindaal 1996). Chapter 5 illustrates that the economic return on afforestation is heavily dependent on soil productivity. As afforestation involves a land use change, a major factor affecting the net farm afforestation income is the opportunity cost of the superseded agricultural enterprise. However, to our knowledge, many studies do not explicitly take this holistic whole-farm approach.

In order to understand the consequences of afforestation for these farmers, it is necessary to understand the nature of the different opportunity costs incurred by farmers in different circumstances. Some of the most comprehensive studies in this regard include those undertaken by Herbohn et al. (2009), Bateman et al. (2005), Breen et al. (2010) and Upton et al. (2013), who all report that soil productivity and farm system are likely to affect the magnitude of the opportunity cost.  Thus information on the agricultural incomes foregone for different farm systems is included, taking productivity factors into account.

The focus of this chapter is on the agricultural opportunity costs that would be incurred by farmers considering afforestation in any given year. The decision to plant involves a major land use change from perhaps a potentially flexible pastoral agricultural enterprise to locking the land into an alternative enterprise for the foreseeable future. Although in theory, afforestation is a long-term decision, uncertainty around long term income and a dearth of information on long term returns from forestry, means that farmers often base decisions on available short-term information. Thus the inter-temporal nature of the decision is thus also likely to be a strong driver of afforestation behaviour. Farm afforestation also implies long-term investment in a land resource and disinvestment in other land-use activities. It entails the foregoing of an annual agricultural income and agricultural subsidies and replacing it with forest subsidies and a long-term forest income. Therefore in calculating the agricultural opportunity cost, it is important to consider agricultural income measures that reflect both short and long term issues. The availability of significant quantities of (actual) agricultural income data in the annual NFS and forest income simulated in Chapter 5, allows for the investigation of the relative importance of agricultural opportunity costs and potential forest income in the afforestation decision making process.

This chapter broadens and deepens the analysis in a previous study (Upton et al. 2013) undertaken by the author (amongst others) which looked at the NPV of replacing an agricultural enterprise with forestry form 1995 to 2009, using the agricultural gross margin to calculate the opportunity cost. This chapter builds on earlier analysis in Chapter 3 which highlights the influence of environmental characteristics (particularly soil class) on land use and productivity; on Chapter 4 which describes the relative importance of agricultural and forest subsidies over the period; and on Chapter 5, which describes the simulation of forest incomes and highlights the relative importance of forest market and forest subsidy incomes. Here a similar examination of the relativity of agricultural subsidies and agricultural market incomes is undertaken on a per hectare basis. In Chapter 5 it is clear that soil productivity is a very strong driver of the magnitude of forest market incomes and this is also expected to be the case for agricultural market incomes. The effect of soil productivity in achieving differential outcomes for both agriculture and forestry is also examined.

## 1.2 THEORETICAL FRAMEWORK

*Previous studies*

The vast majority of literature in relation to the economics of forestry, focuses on deforestation or management decisions in pre-existing forests, with a much smaller literature dealing with the afforestation decision. The literature that deals with agricultural opportunity costs in the context of farm afforestation is limited and focuses largely on the calculation of the opportunity cost of carbon sequestration through afforestation at an aggregate level (see Moulton and Richards 1990; Parks and Hardie 1995), while Dudek and LeBlanc (1990) use average opportunity costs. Other studies that specifically deal with farm level agricultural opportunity costs include Plantinga et al. (1999); Adams et al. (1993); Alig et al. (1997). These studies make the assumption that agricultural rents represent the opportunity cost of enrolling in afforestation/sequestration programmes.

In the case of making the decision to plant some of their agricultural land, it is assumed that farmers are unlikely to plant land which gives a higher return in another farm enterprise. In the Irish context, Breen et al. (2010) use average farm management data (Teagasc various years) to calculate the opportunity cost for each of the main agricultural enterprises of planting willow for biomass. Breen et al. (2010) subsequently use a similar methodology to calculate the opportunity cost of the superseded agricultural enterprise. In a study conducted in the Philippines, Zelek and Shively (2008) move beyond average values and take the land value and the costs associated with the existing land use into account.

Some of the most comprehensive agricultural information is provided by Herbohn et al. (2009) who describe the Australian Farm Forestry Financial Model (AFFFM) and compare it to other Australian farm forestry models. Of the models reviewed, the Farmula model (Kubicki et al. 1991) and the Agroforestry Estate Model (Middlemiss and Knowles 1996) are whole farm models. However the AFFFM gives greatest attention to the calculation of the agricultural opportunity cost. The AFFFM is essentially a farm forest extension tool that builds on a forest extension tool (Australian Cabinet Timbers Financial Model) developed by Herbohn et al. 1999) to incorporate proposed forests into the farm financial context. The AFFFM aims to improve the ability of farmers to estimate the returns to afforestation on an individual farm and allows farmers to download forest growth data scenarios and to input cost and income data for their specific farm. In relation to livestock systems animal numbers, livestock carrying capacity and gross margin per hectare are recorded, while crop type, area and gross margin per hectare are recorded for tillage systems. This necessitates the inclusion of the biophysical context of the farm in relation to soil type. In relation to its treatment of the impact of farm afforestation on the overall farm financial situation, the AFFFM appears to be the most comprehensive available in the (grey and published) literature and as a consequence, this chapter builds on the AFFFM inputs and outputs in the calculation of agricultural opportunity costs. However, the primary limitation of the AFFM for our purposes is that it does not allow for the drawing of inferences in relation to the impact of agricultural opportunity costs on the afforestation decision across the population of farmers.

In contrast, Bateman et al. (2005) sets out to specifically model changing patterns of land use from agriculture to forestry in Wales, taking the environmental context of individual farms into account. The GIS analysis undertaken by Bateman et al. (ibid) includes agricultural opportunity costs based on the Farm Business Survey in Wales and is thus statistically representative. To achieve this, farm economic and biophysical datasets are linked. Farms are clustered into systems on the basis of economic output and estimates are generated for farm gate income (FGI) to model the land use change from agriculture to forestry on the basis of the biophysical factors affecting individual farms. The study is based on farm level data for just one year 1989/90 and acknowledges the complexity surrounding the choice of appropriate farm income measure in relation to whether to use income measures that are net of overhead costs and/or subsidies and the impact that the use of different measures could potentially have on the opportunity cost and subsequent net gain from engaging in farm forestry.

This chapter aims to deepen the analysis previously undertaken by the author and colleagues in Upton et al. (2013) which utilised average farm incomes by system and soil type and Upton et al. (2014) which utilised simulated micro-data at electoral district level to approximate the agricultural opportunity cost of afforestation.

*Unit of measurement of opportunity costs*

Of the limited studies that include agricultural opportunity costs in the economic return to farm afforestation, the majority of calculations are undertaken on a per hectare basis (see Plantinga 1999; Herbohn et al. 2009; Bateman et al. 2005; Breen et al. 2010; Upton et al. 2013). In Ireland, the average afforestation plot in Ireland is 9 ha (DAFM 2014b), whereas the average farm size is 35 ha (Hennessy & Moran 2015). Therefore for the purpose of this analysis, it is presumed that afforested areas comprise a relatively minor component of the overall farm operation. Thus in order to reduce complexity, the analysis in this and subsequent chapters is undertaken on the basis of the afforestation of one hectare and the consequent loss of agricultural income on that hectare. This choice also allows for ease of comparison between agricultural and forest incomes, as was evidenced in comparing agricultural and forest subsidies on a per hectare basis in Chapter 4.

The fact that farmers generally plant only a portion of their land also means that the reduction in utilisable agricultural area UAA may have little or no impact on overhead costs in the short term. For example, in the short term, machinery repayments still need to be met whether a portion of the land is afforested or not. However if in future machinery does not need to be replaced due to de-intensification, or needs to be upgraded due to intensification, then overhead costs can influence  long term decisions.

*Soil type and productivity*

One of the fundamental factors in any land-use decision is soil type. This factor dictates the feasibility and the productivity of both forest and agricultural land uses (Upton et al. 2014). Forestry is recognised as a robust land-use option that is less restricted than agriculture by poor site conditions (Farrelly et al. 2011). Although the specific agricultural enterprise can be a reflection of soil quality, more detailed examination of how agricultural productivity and agricultural income vary with soil class is warranted. Different farm systems have different opportunity costs therefore the variability of both agricultural and forest incomes on different soil classes should be tested.

An examination of the resultant financial and physical farm changes is necessary in order to unpick the complexity of the consequences of Irish farm afforestation. Chapter 5 shows clearly that the returns from afforestation depend largely on the species and the yield class of the planted land, however the reduction in UAA may affect agricultural subsidy and market income in addition to livestock carrying capacity.

*Relative impact of agricultural and forest subsidies*

In determining the relative importance of the market and subsidy components of income, the percentage share of subsidies in forest incomes is examined to test whether the share of subsidies increases or decreases for different soil classes. Forest subsidies are allocated on the basis of species, which is indirectly related to soil productivity. However for a given species, it is not expected that forest subsidies will vary by agricultural soil class or forest yield class.

The share of subsidies in agricultural income over time is also of interest. Historically, the relationship between agricultural subsidies and soil productivity varies with changing policy instruments over the period examined. In some of these periods, agricultural subsidies were directly related to farm livestock densities. It is expected that there will be a difference in the share of subsidies (per hectare), between the periods when subsidies were coupled to production and the post-decoupling period would also like to test if there is a relationship between agricultural subsidies and soil class.

Prior to the 1992 MacSharry Reform of the Common Agricultural Policy (CAP), market policy instruments were in place. These policies included intervention pricing, export subsidies and import levies and boosted agricultural incomes by enabling farmers to sell their produce at prices above world prices (Swinbank 1980). In the "post MacSharry" period, farmers continued to receive direct payments coupled to production. A number of production based subsidies (premium payments) were introduced but a maximum stocking rate limit, measured as livestock unit per hectare, was applicable to all (Cardwell 2002). In theory, a reduction in livestock density during this period results in a reduction in "headage" subsidy payments. Yet O'Connor and Kearney (1993) report that many farmers were lightly stocked and thus had the flexibility to afforest land and still increase livestock density. These farmers benefited financially on both the market and the subsidy front as a result of planting and incurred very little in terms of opportunity cost in the short term. However the long term opportunity costs need to take account of the overhead costs incurred at overall farm level.

In 2005, the Single Farm Payment (SFP) was introduced to fully decouple agricultural payments from production and was based on the average historic livestock payments and the average land area farmed in the years 2000, 2001 and 2002. From this period onwards, subsidies were no longer coupled with production and are likely to be less important in the calculation of opportunity costs. Not all subsidies were coupled with production during this period however. The Rural Environmental Protection Scheme (REPS) provided a per hectare payment based on total farm area. Farmers in REPS who planted some of their land would have lost REPS payments on that land. The potential loss of REPS was considered to be a factor in the reluctance of many farmers to plant (Breen et al. 2010) but accounting for this would add significantly to the complexity of this analysis and would possibly not provide much additional information. In reality, larger REPS farmers were more likely to plant as

REPS payments decreased as agricultural area increased, so larger farms stood to lose a smaller proportion of the subsidy.

The Less Favoured Areas (LFA) scheme was based on the area of land farmed up to a maximum threshold. Once farmers didn't drop below the area threshold, planting some land would not have negatively affected their payment. In the case of this particular subsidy, LFA payments were in fact negatively related to production as the highest payments were available for the most "disadvantaged" land. These payments were available on both agricultural and afforested land during the 1990s. (See Chapter 2 for greater detail on forest subsidies and Chapter 4 and Ryan et al. (2014) for greater detail on agricultural subsidies). Since then the afforestation of land designated under the LFA scheme incurred a loss in LFA payments except for large farms that could plant hectares in excess of the area ceiling without losing payments.

Thus it is likely that subsidies will play a large role in the opportunity cost in post MacSharry years, necessitating the use of an agricultural income measure which takes agricultural subsidies into account in calculating the opportunity cost for this period. On the other hand, it is likely that subsidies will be of lesser importance in the post SFP years. In this case an agricultural income measure that ignores subsidies in calculating the post SFP agricultural opportunity cost can be used.

*Measures of agricultural income*

While standardised approaches to the measurement of forest incomes are based on simulated timber revenues and prices (as discussed in Chapter 5), the reporting of agricultural incomes is more localised and different measures are used in different countries and for different reporting purposes. The reporting of European agricultural incomes is generally based on EU Farm Data Accountancy Network (FADN) data. FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy which consists of an annual survey carried out by the Member States of the European Union. The agricultural income measures commonly reported vary with reporting objectives. For instance, two different measures, "Farm Net Value Added" (FNVA) and "Income" are used to examine EU agricultural income evolution over time (EC 2006) where:

$$FNVA = Output + Subsidies - Intermediate\ consumption - Depreciation$$

$$Income = Output\ + subsidies - (\ depreciation + \ specific\ costs + overheads)$$

The essential difference between these measures is the treatment of overhead costs such as wages, rent and interest which are not deducted for the FNVA measure. This is a useful measure for short term assessments. However, it is likely that the “Income” measure (which is adjusted for overhead costs) would be smaller in magnitude and would be a more useful measure for making long term decisions. In their study on the opportunity cost of carbon sequestration through afforestation, Plantinga et al. (1999) assume that overhead costs for agricultural production (e.g. machinery) are constant across crops. This illustrates how different measures can be useful depending on the perspective. The challenge here is to select the appropriate measure/s which best reflect both the market and subsidy components of agricultural opportunity cost in different periods, given different policy environments and subsidy scenarios.

We hypothesise that the decisions farmers make in relation to livestock density as a consequence of afforestation are an important component of the opportunity cost of afforestation and that they are also directly related to intensity of production and thus to soil productivity. It is also hypothesised that agricultural systems in themselves are related to productivity. In the case of livestock farms, livestock carrying capacity is dictated by soil productivity and soil trafficability (within EU regulatory limits). All measures are reported at the farm level as opposed to the enterprise level. The assumption therefore is that a farmer who afforests a portion of the farm reduces average land use equally across all enterprises, rather than reducing the lowest gross margin enterprise.

In the case of high cost enterprises such as dairy and tillage, these enterprises need to be sited on highly productive soils in order to make a sufficiently high return to cover large overhead costs. It is assumed in this study that planting on a portion of the farm will not affect farm overhead costs (such as machinery repayments, electricity) which remain unchanged in the short term. The inclusion (or not) of overhead costs in agricultural income calculations is also relevant to whether long term or short term agricultural income measures are needed. In general, overhead costs may not be relevant in the short term, but should be included for longer term decisions.

In addition to determining the relative importance of subsidy and market income for both forest and agricultural incomes, an examination of the influence of soil productivity market and subsidy incomes will reveal useful information. The net farm afforestation income (NFAI) is essentially the net gain to a farmer for planting one hectare of a particular species and yield class less the agricultural income foregone on that hectare. However, forest incomes are generated using 2015 prices, while the opportunity cost of planting in a given year in the dataset is of interest here. Therefore the forest incomes need to be adjusted to make them comparable to agricultural incomes in terms of purchasing power in a given year.

### 1.3 METHODOLOGY AND DATA

*Soil productivity*

In estimating net farm afforestation income (NFAI) (taking the agricultural opportunity cost into account), it is necessary to utilise methodologies that take the biophysical, financial and temporal components of the land use change decision into account. Soil productivity as represented by agricultural soil classes and forest yield classes is an important driver of overall income for both land uses. A comparable measure of productivity needs to be derived to compare agricultural and forest productivity and the associated incomes.

Sitka spruce (*Picea sitchensis (Bong.) Carr.*) is recognised as a robust tree species with huge potential productivity under Irish climatic conditions (Farrelly 2010). Early forest soil-site-yield studies focussed on quantifying the productivity of conifers such as Sitka spruce in relation to marginal agricultural land (Bulfin et al 1973). Using the General Soil Map (Gardiner and Radford 1980) classification, Farrelly et al. (2009) generate forest productivity (yield class) estimates for Sitka spruce in Ireland across a range of soil types. A spatial model was then used to map the potential productivity of Sitka spruce throughout Ireland in a Geographical Information System (GIS) (Farrelly et al. 2011). The model predicts that 73% or 5.103 million ha of the total land area in Ireland is capable of producing Sitka spruce with a low to medium timber productivity potential (yield class 14 or greater). Furthermore, 62% of the total land area could potentially result in medium to high timber productivity (YC 20 or greater).

Agricultural soil class data are derived from the National Farm Survey (NFS), which collects detailed information from a representative sample of farms in Ireland, and include the range of use or limitations of each of six soil types. These soil classes are originally derived from the General Soil Map of Ireland which classifies soils into the 41 soil associations described by Gardiner and Radford (1980). Using the productivity values generated by Farrelly et al.

(2011), Sitka spruce yield class estimates are assigned to the NFS agricultural soil classifications as detailed in Table 6.1. These estimates allow for the categorisation of NFS farm data in relation to the relevant forest yield class for Sitka spruce, which in turn allows for the comparison of agricultural and forest productivity on the basis of agricultural soil class/Sitka spruce yield class.[1]

**Table 1.1 Sitka spruce (SS) yield class estimates for NFS agricultural soil classes**

| Soil class | Agricultural use | Soil type | SS yield class |
|---|---|---|---|
| 1 | Wide | No limitations | 24 |
| 2 | Moderately wide | Minor limitations | 24 |
| 3 | Somewhat limited | Higher elevations, heavier, poorer structure | 20 |
| 4 | Limited | Poor drainage | 20 |
| 5 | Very limited | Agricultural potential greatly restricted | 18 |
| 6 | Extremely limited | Mountainous, steep slopes, shallow soil | 14 |

Source: Farrelly et al. (2011)

*Simulation of Forest incomes using the Forest Bio-Economic System (ForBES) model*

The Teagasc ForBES model grew out of the Teagasc FIVE (Forest Investment and Valuation Estimator) which is an Excel based knowledge transfer tool that that was developed by the author (among others) as a forestry extension tool.[2] FIVE employs the UK Forestry Commission (FC) yield models (Edwards and Christie 1981) to predict future timber outputs based on species, yield class, rotation and thinning regime on a per hectare basis. For the purpose of this analysis, the ForBes model simulates forest incomes for Sitka spruce for a range of yield (forest productivity) classes from 14 to 24 (also based on the Edwards and Christie (1981) models as discussed in Chapter 5. The forest subsidy inputs for individual years are provided by the ForSubs model (see Chapter 2 for more detail).

Over the period analysed, there were a number of changes to forest subsidies (forest grant and annual premium payment) categories. In order to facilitate comparison over time, the subsidy for the most commonly planted subsidy category is used i.e. either "non-diverse[3] Sitka spruce" (in the early years) or "Sitka spruce 10% diverse" or "Sitka spruce 20% diverse" in later years as these categories most closely approximate to the composition of forests planted over the period of analysis. Before 2000, Less Favoured Area (LFA) subsidy payments were specific to the agriculturally disadvantaged status of an area and the payment associated with

[1] This methodology can also be used for other tree species once the relativity of growth rates with Sitka spruce is available.
[2] For a description of FIVE, see Ryan et al. (2013).
[3] SS Non-diverse: 100% SS; SS 10% diverse: 90% SS + 10 % other conifer/broadleaf; 20% diverse: 80% SS with 20% other conifer/broadleaf (see Chapter 2 for further detail).

the most severely disadvantaged areas which covered the largest proportion of land area is included for this period. The ForSubs model allocates afforestation costs on the basis of the proportion of afforestation costs covered by the afforestation grant which ranged from 80% to 100% over the period. Thus the relevant subsidy payment for each year of the analysis is taken from the ForSubs model to become an input in the ForBES model.

ForBES generates timber volume outputs from thinnings and clearfell, assuming marginal thinning intensity. A percentage of revenue from thinnings and clearfell is subtracted to cover the costs of harvesting and timber sales to produce net realisable harvested timber volumes. Financially optimum rotations were used for each yield class which varied between 38 and 46 years. A revenue value for the net realisable volume (NRV) is then calculated by applying Coillte (State Forestry Board) 10 year average conifer roundwood price series (ITGA 2014), by adjusted to the relevant year using the consumer price index (CPI). It is assumed that timber prices do not change over the period of analysis in real terms. Costs of inspection paths, insurance and reforestation are included in the calculation.

*Agricultural income measures*

Since 1972, Teagasc has conducted a National Farm Survey (NFS) on an annual basis to fulfil Ireland's statutory obligation to provide data on farm output, costs and income to the Farm Accountancy Data Network (FADN) of the European Commission. A random, nationally representative sample is selected annually in conjunction with the Central Statistics Office (CSO). Farm systems are classified on enterprises defined in Commission Decision 78/463 and its subsequent amendments. These categories have changed over time but Table 6.2 provides examples of enterprises that would generally be included in the systems.

**Table 1.2 System Enterprise examples**

| System | Enterprise examples |
|---|---|
| Dairy | Specialist milk production |
| Dairy other | Specialist milk production with cattle rearing, dairying with rearing and fattening cattle, mixed livestock -mainly dairying, field crops combined with dairying, dairying combined with field crops |
| Tillage | Specialist cereals, oilseeds and protein crops, Field crops combined with non-dairying grazing livestock, Specialist root crops, Various field crops combined |
| Cattle | Specialist cattle - mainly rearing |
| Cattle other | Specialist cattle - mainly fattening, mixed livestock |
| Sheep | Specialist sheep, sheep and cattle combined |

Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms. In addition to economic factors, characteristics of farms are collected in the survey, including a six level measure of soil quality defined primarily by the diversity of uses for which land can be used. The most recent (preliminary) report for the 2014 accounting year is based on a sub sample of 798 farms which represents 78,641 farms nationally (Hennessy and Moran 2015).

There are four commonly used agricultural income reporting measures which are derived using NFS data. Family Farm Income (FFI) is the principal measure used in the Teagasc NFS to reflect overall agricultural farm income. Family Farm Income represents the return from farming for the farm family to their labour, land and capital. It does not include non-agricultural income. FFI includes subsidies and is net of overhead costs.

$$FFI = \ (Gross\ output\ (+subsidies) - (Total\ costs\ (direct\ costs\ (DC) + overhead\ costs\ (OC)))$$

Farm Net Margin (NM) is essentially gross output (GO) with all direct costs (feed, fertiliser etc.) and overhead costs (electricity, machinery, maintenance, etc) stripped away and without subsidies (direct payments) and reflects just the enterprise returns without overhead costs:

$$NM = (GO - Subsidies) - ((Total\ costs\ (direct\ costs\ (DC) + \ overhead\ costs\ (OC))$$

Both FFI and NM are good indicators of long term income, however in reality, many farmers make many decisions on the basis of gross margin which does not take overheads into account.

Farm Gross Margin (GM) is a broader measure of output as only direct costs such as fertilisers and feed stuffs are deducted. Gross margin measures are a common measure of agricultural profitability and are short term rather than the long term measures as overhead costs are not deducted.

$$(Farm)GM = (GO\ \ +\ Subsidies) -\ DC$$

The broadest measure, Market Gross Margin (MGM) looks at the market output less subsidies and thus reflects only the gross margin from the market:

$$MGM = (\ GO - Subsidies) - DC$$

While all four measures generate valid measures of income, there is likely to be considerable variation in the level of income depending on the objective of a given analysis and the measure chosen. In relation to the treatment of overhead costs, both FFI and NM measures are net of overheads and are useful for long term decision making. FFI includes subsidies but NM is net of subsidies. Similarly, for the short term gross margin measures, GM includes subsidies but MGM excludes subsidies.

For the purpose of this analysis it is assumed that although a farmer planting land during the post MacSharry period when subsidies were coupled with production, could have lost agricultural subsidies as a consequence of afforestation. In reality, those farmers considering afforestation were likely to have been farming extensively and to have had additional grazing capacity to carry the existing livestock numbers on less land, thereby not suffering a significant loss of animal subsidies. On the other hand, farmers planting since 2000 were able to "consolidate" their SFP entitlements and could thus avail of both agricultural and forest subsidies on planted land. Since 2008, afforested land has been eligible for SFP, thus farmers who plant eligible land receive both afforestation and single farm payment subsidies.

*Generation of Agricultural Opportunity Costs using farm survey data*

The Teagasc National Farm Survey (NFS) assigns farms to one of six farm systems on the basis of farm gross output of the dominant enterprise[4], as calculated on a standard output basis[5] i.e. specialised dairy; dairy other; tillage; cattle rearing; cattle other and sheep[6]. A panel dataset from 1985 to 2013 is utilised to calculate agricultural incomes for each farm system and each of the 6 NFS soil classes for each year of the dataset on a per hectare basis. This essentially gives us the agricultural opportunity cost of afforestation in that year, taking into account the farm system and soil productivity.

In order to capture the inter-temporal nature of the decision to change from an agricultural system with annual returns to a 40 year forestry crop, the agricultural income values must be inputted as an annual (opportunity) cost in ForBES for each year of the relevant forest rotation. It is assumed here that agricultural incomes are time invariant and subsidies are held

[4] Note that farms may have multiple enterprises but are categorised on the basis of the dominant enterprise.
[5] Standard output measures are applied to each animal and crop output on the farm and only farms with a standard output of €8,000 or more, the equivalent of 6 dairy cows, 6 hectares of wheat or 14 suckler cows, are included in the sample (Hennessy and Moran 2015).
[6] Some changes have been made to system classifications over time which can make longitudinal comparisons difficult.

constant for the period of the forest rotation. The discounted cash flow (DCF) methodology is used to calculate the net present value (NPV) of each of the agricultural incomes. This is similar to the methodology used by Plantinga et al. (1999) who calculate agricultural rents (to represent the opportunity cost) as the present discounted value of the stream of real annual income per acre net revenues from crop and pasture land.

A number of temporal issues arise in relation to the compatability of the forest and agricultural income datasets. Firstly, ForBes generates annual equivalised (AE) NPVs for the forest incomes. As there are different rotation lengths for different yield classes, the AE formula also needs to be applied to convert the nominal agricultural opportunity costs to annual equivalised NPVs. Secondly, the forest incomes are generated using 2015 data but this needs to be comparable to the agricultural opportunity cost in any given year in the dataset (take for example 1988), that afforestation might have been considered. As the farm dataset has a much greater number of inputs and outputs, it makes sense to adjust the forestry inputs and outputs. Therefore the relevant consumer price index is applied to bring the (2015) forest income back to the relevant year (1988). The general consumer price index (CPI) (for the household basket of goods) is used, which enables the expression of the forest income in terms of the purchasing power it would have given the farmer, if s/he had undertaken afforestation in 1988.

*Net Farm Afforestation Income (NFAI)*

In incorporating the annual agricultural opportunity cost in the return to farm afforestation, values are generated for net farm afforestation income (NFAI) for planting a hectare of new forestry on land which was previously in a livestock grazing system. NFAI is essentially the forest income (expressed as annual equivalised value of NPV) less the agricultural income/opportunity cost (also expressed as annual equivalised NPV). All NFAI values are CPI adjusted (base year 2013) to make forest and agricultural incomes directly comparable relative to 2013 prices.

The agricultural opportunity costs are calculated using each of the four agricultural income measures discussed. However, to simplify presentation, the focus of the analysis is limited to: (a) FFI as a long term measure which includes subsidies and is exclusive of overheads and (b) MGM as a short term measure which doesn’t account for overheads or subsidies. The MGM per ha measure is selected to reflect the post MacSharry era when overheads and subsidies are less likely to be important in determining the opportunity cost; and the FFI per ha measure should be more relevant in relation to longer term financial decisions in the post SFP era, when overheads and subsidies should be taken into account. Again for the purpose of simplicity, the year closest to the average for the two periods following the largest policy changes is reported i.e. 1998 for the post MacSharry period and 2007 for the post SFP period.

In summary, the analysis in this chapter

- builds on previous relevant studies, particularly Herbohn et al. (2009) and Bateman et al. (2005)
- uncovers the complexity inherent in the market and subsidy components of the opportunity cost
- investigates the sensitivity of using long term and short term focused methods of calculating the opportunity cost
- examines changes and trends in opportunity costs over a significant time horizon.

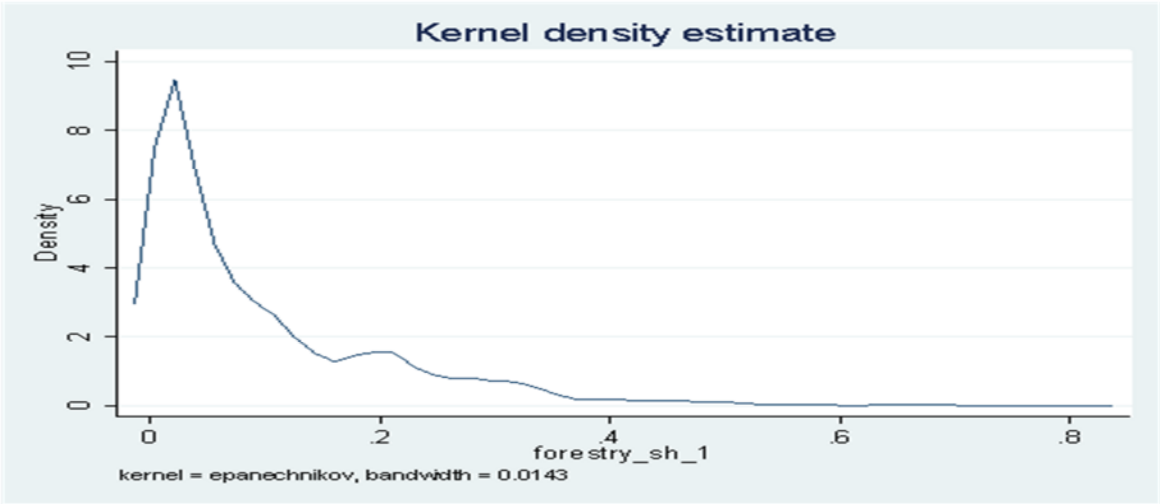
To do this, forest productivity values are assigned to agricultural soil classes. The analysis then uses a longitudinal farm dataset to generate agricultural incomes for each year from 1984 to 2014. Forest and agricultural incomes are decomposed into their market and non-market components to assess the temporal effects of productivity, costs, prices and inflation changes. The relative importance of market and subsidy income for both forest and farm returns is also analysed.

As forest market income is a multi-period income, much more so than agriculture, a temporally comparable metric is necessary. The ForBES model (Ryan et al. 2016) generates forest income for a given year, whereas there are multiple years of farm data in the NFS. Additionally, agricultural and forest inputs and outputs change in value over time. Therefore in order to compare different years, it is necessary to apply relevant price indices to the relevant incomes. NPVs are generated for agricultural incomes and converted to equivalised (AE) NPVs, in order to incorporate the annual agricultural opportunity cost in the net economic return resulting from the conversion of one hectare of land from agriculture to forestry for each system.

*Summary statistics*

Across the Irish and international literature, farm size is a consistently significant determinant of the likelihood of planting, suggesting that it is less likely that afforested areas comprise a large proportion of the overall farm and that the comparison of agricultural and forest returns on a per hectare basis may be justified. An examination of the proportion of the total farm area afforested on the "farms with forests" in the NFS longitudinal dataset shows that the choice is indeed justified.

**Figure 1.1 Kernel density of the distribution of farms with forests over time**

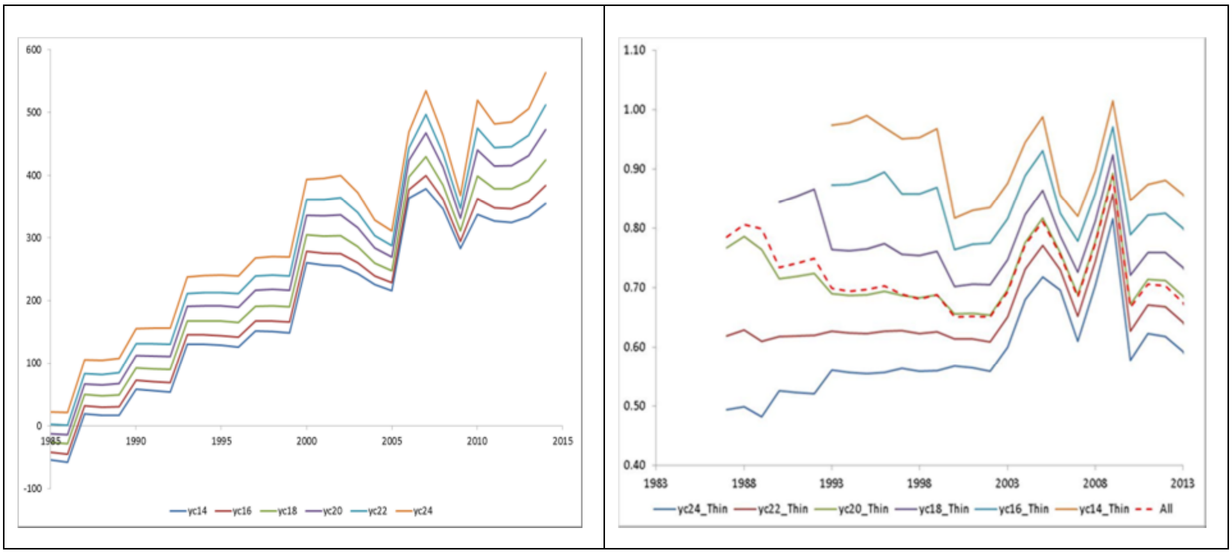



The results are presented in Figure 6.1 which shows that from 1984 to 2014, over 90% of farms with forests planted less than 10% of the total farm area. On the basis of this finding, all other analyses in this thesis are also presented on a per hectare basis.

Additionally, trends over time are presented for both forest and agricultural incomes in Figure 6.2 to establish the relative importance of subsidies and whether the share of subsidies in income streams varies with soil class.

**Figure 1.2 Annual Equivalised NPVs (€/ha) and Share of Subsidies in Forest Income over time**

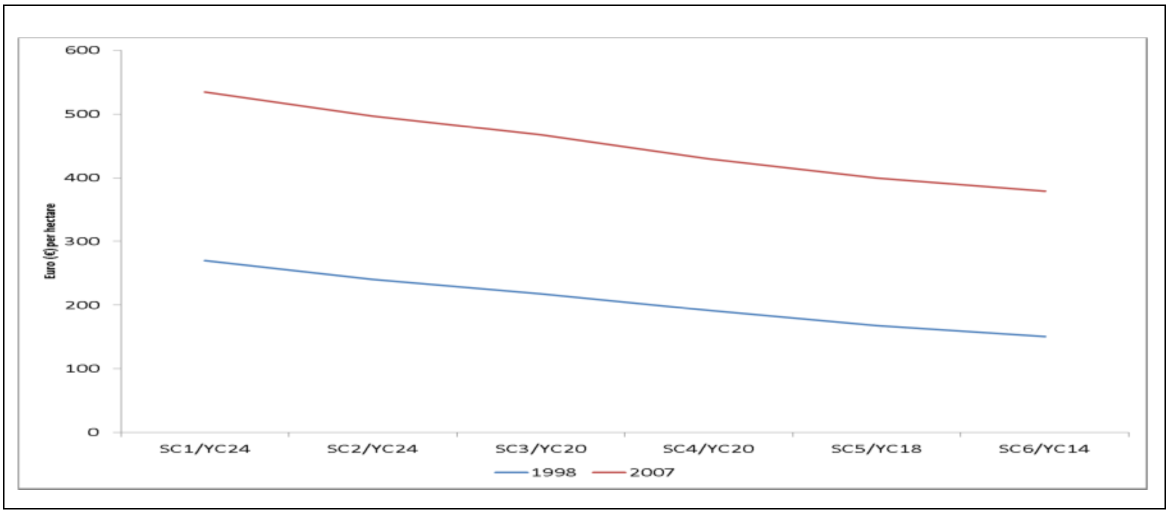
| Forest AE NPVs for Sitka spruce (Thin) | Share of subsidies in forest income over time |
|---|---|




In initially examining trends in forest incomes, the annual equivalised NPVs and subsidy share for the thin option for Sitka spruce by yield class over time are presented in Figure 6.2. In relation to the effect of soil productivity on forest return, there is a strong upward trend in forest (subsidy plus market) incomes over time, regardless of soil class. The downward spikes occur as a result of a decrease in both demand and price of sawn timber at the end of the construction boom and a reduction in forest subsidies as a result of government budgetary constraints. This longitudinal trend mirrors rising trends in forest subsidies and timber prices over this period (Ryan et al. 2013). However as expected, the returns are greater for higher forest yield classes. It would appear that soil class also affects the share of forest subsidies in overall forest income as there is a consistent trend over time.

For higher yield classes, subsidies form a relatively small proportion of income, however for the lowest yield class examined (14), this rises to 100% of income at a number of points in the period examined. The weighted average annual equivalised forest NPVs across all soil types in the post MacSharry and post SFP eras also show similar trends in Figure 6.3.

**Figure 1.3 Weighted Average Annual Equivalised Forest NPVs (€/ha) (1998 & 2007)**




In relation to the effect of soil productivity, the pattern for both years is identical, confirming the strong relationship between forest productivity and soil class. However, the forest incomes are considerably higher in 2007 than in 1998, reflecting large increases in forest subsidies between 1998 and 2007 (Ryan et al. 2014) and the high timber prices achieved towards the end of the construction boom (Ryan et al. 2013).

In examining agricultural incomes, the share of subsidies in overall income is first analysed. Figure 6.4 presents the share of subsidies in the agricultural income measures that include subsidies, namely FFI and GM from 1995 to 2013. The share of subsidies is higher in FFI than in GM as overheads are deducted from FFI, resulting in a lower income. The share of subsidies in both measures of agricultural income rises steadily over time reflecting a number of increases in agricultural subsidies (McCormack et al. 2013). The share of subsidies peaks for both measures in the poor market income year of 2009 and declines as a component of income following a period of strong market income increases in recent years (Hennessy and Moran 2015).

**Figure 1.4 Share of agricultural subsidies in agricultural incomes measured using FFI/ha and GM/ha over time**

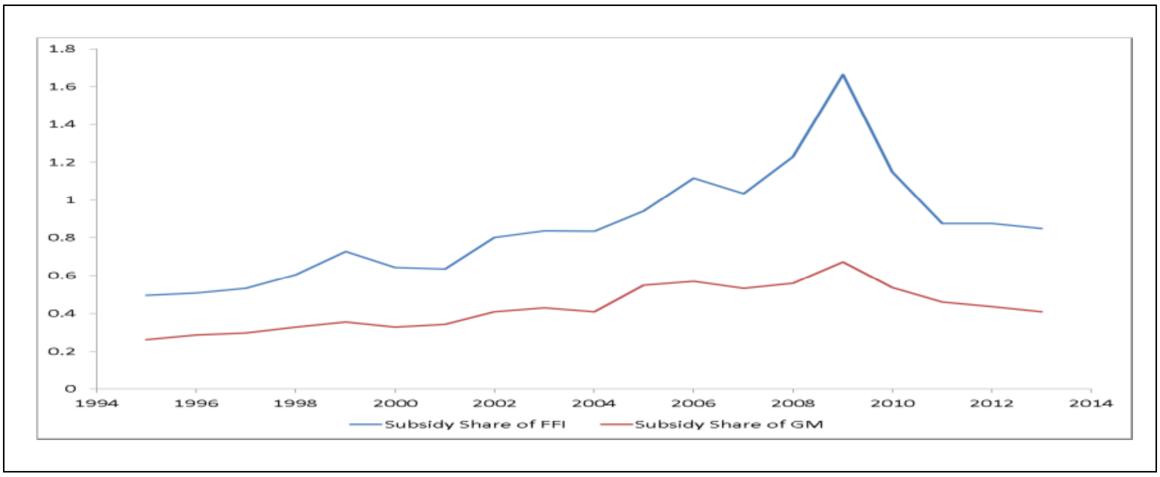


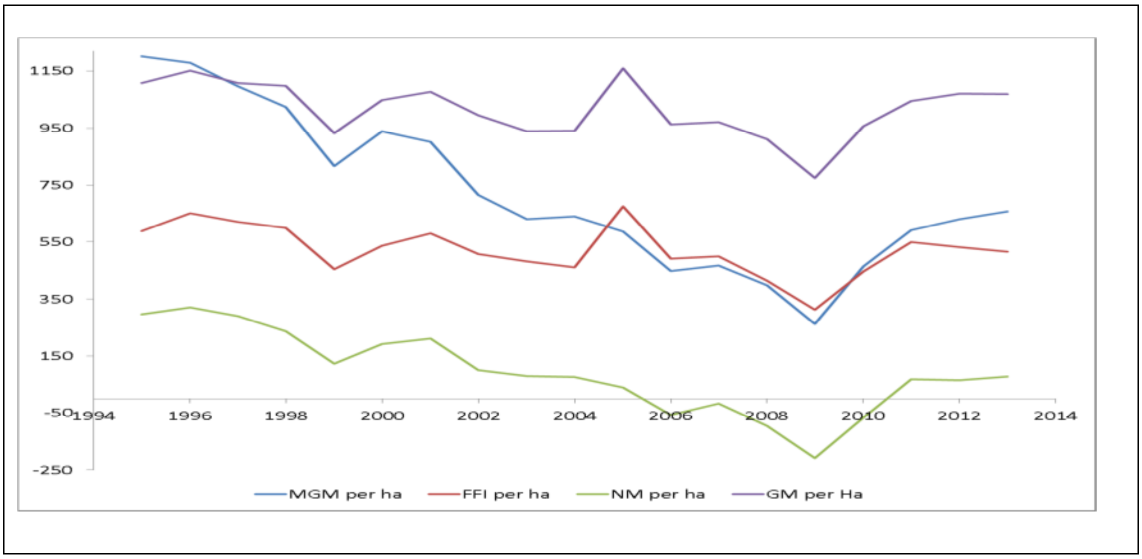

Table 6.3 presents the average livestock density across all years and all livestock systems. As expected, this confirms the strong and almost linear effect of soil code on livestock density. The best soils have a much higher stock carrying capacity than poorer soils may be steep or have impeded drainage.

**Table 1.3 Average livestock density for each soil code over time** (**LU ha$^{-1}$**)

| Soil code | SC6 | SC5 | SC4 | SC3 | SC2 | SC1 | All |
|---|---|---|---|---|---|---|---|
| Livestock density | 0.99 | 1.07 | 1.33 | 1.35 | 1.63 | 1.62 | 1.45 |

Next the average annual equivalised NPVs are calculated and weighted by the number of farms across all years for each system and for all farms (across systems). These are presented in Figure 6.4 for each of the four agricultural income measures under discussion, namely Family Farm Income (FFI), Net margin (NM), Gross Margin (GM) and Market Gross Margin (MGM), in Figure 6.5. All values are CPI adjusted (base year: 2013). As the focus here is on the post MacSharry and post SFP policy periods, temporal reporting is restricted to the period 1995 to 2013. Although the measures follow a general temporal trend, it is evident that there is a wide variation in agricultural income from strongly positive to marginally negative, depending on the measurement perspective. As expected, the gross margin (GM) measure is the highest in terms of magnitude of income as it includes subsidies and overheads are not deducted. Family Farm Income (FFI) and Market Gross Margin (MGM) report intermediate income values while the lowest income is reported by net margin (NM) measure which is net of subsidies and overheads. All measures show the effect of high and low income years. In 2005, farmers received carryover SFP scheme payments from the previous year, leading to a substantial increase in reported incomes for 2005, whereas 2009 was one of the worst financial years for farmers across all systems, due largely to poor weather conditions. All measures show a slightly downward trend over the period and the gap between GM and NM is substantial and consistent.

**Figure 1.5 Weighted Average AE of NPV (€/ha) of agricultural income (1985 to 2013) using four agricultural income measures (CPI adjusted)**

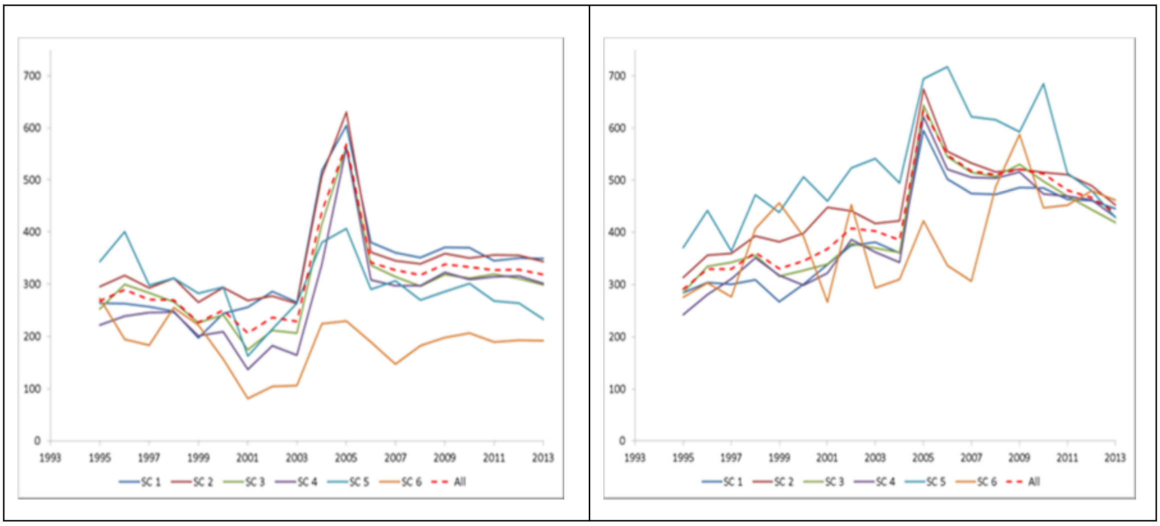



Until the late 1990s, the GM (including subsidies) and MGM (excluding subsidies) measures report similar incomes, indicating that agricultural income was comprised largely of market income during this period. However, the increasing impact of subsidies is evident for the post MacSharry period as GM (incl. subsidies) increases and MGM (excl. subsidies) decreases. From 2005 onwards, the MGM (no subsidies and not accounting for overhead costs) and FFI (incl. subsidies and accounts for overhead costs) measures report similar income trends. It is possible that subsidies and costs cancel each other out until 2011, when strong market incomes lead to a rise in MGM. This is examined further at system level later to see if any additional information can be uncovered.

In further examining the impact of agricultural subsidies on income, Figure 6.6 illustrates the trends in agricultural subsidies by soil class over time.

**Figure 1.6 Agricultural subsidies and Direct payments per hectare by Soil Code (1985 to 2013)**

| Pillar I Agricultural subsidies | Agricultural subsidies (all) |
|---|---|



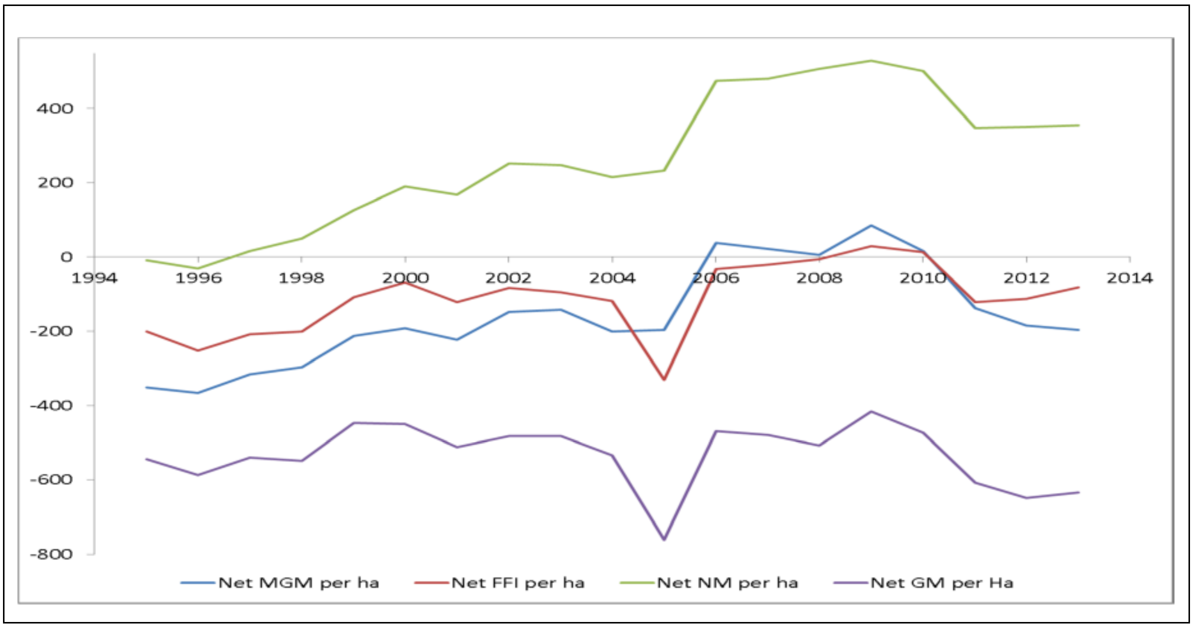

Pillar I payments of the Common Agricultural Policy (CAP) are examined separately as these are production-related prior to 2005 and are based on historical production post 2005. In general, farms on better soil classes receive higher Pillar I subsidy payments over the period[7]. This confirms *a priori* expectations as these subsidies are dependent on soil productivity which in turn affects livestock carrying capacity on dairy, cattle and sheep farms. However, the trend is quite different when all subsidies (including non-productivity related subsidies such as LFA (Less Favoured Area) and REPS (Rural Environment Protection Scheme) payments are examined in the second graphic. Here, the trend is less consistent and indicates the importance of these non-productivity related subsidies. Large farms received higher (area-based) REPS payments, regardless of soil productivity. In addition, farms with low livestock densities were eligible for extensification payments and were also likely to be designated as More Severely Handicapped (MSH) thus receiving the highest rate of LFA payment (McCormack and O' Donoghue 2014). As a result and in aggregate, farms on soil code (SC) 6 (extremely limited use) have higher payments in many years than farms with better soil classes. However, conclusions should be tempered by the limitation presented by the smaller number of NFS observations in (SC) 6.

[7] The spike in 2005 is again reflective of carry-over payments

## 1.4 RESULTS

The primary objective of this chapter is to examine the agricultural opportunity cost incurred as a result of farm afforestation of one additional hectare of land in each year of the dataset. This is calculated as the annual forest income stream less the agricultural income foregone for each year of the forest life-cycle and is described as Net Farm Afforestation Income (NFAI) per hectare. The effect of soil productivity class on the net farm afforestation income is evaluated in addition to the suitability of using different agricultural income measures to reflect both short and long term decisions in different policy environments.

**Figure 1.7 Average Net Farm Afforestation Income (NFAI) (€/ha) calculated using four agricultural income measures (CPI adjusted) over time**




Note: CPI Base Year: 2013

Figure 6.7 presents weighted average annual equivalised NPVs for NFAI are presented across all years for each system and for all farms (across systems). CPI adjusted NFAI is reported for all four agricultural income measures. The results show that the net income resulting from farm afforestation is hugely influenced by the agricultural income measure used to calculate the opportunity cost. The direction of the temporal trends is again similar to the agricultural incomes reported earlier. However, this is almost the inverse as it is evident that when higher agricultural incomes (such as those represented by GM) are deducted from the forest income stream, the net benefit of afforestation is likely to be negative. The converse is also true. As NM is the income measure which generates the lowest agricultural income, it has the highest NFAI per ha as the NFAI incorporates a smaller opportunity cost. However, the high system net margins for an enterprise such as dairying (relative to dairy other, cattle and sheep) results in a high opportunity cost and a consequently low net farm afforestation income. In addition, it is likely that the higher opportunity cost associated with better soil classes could also result in lower net income.

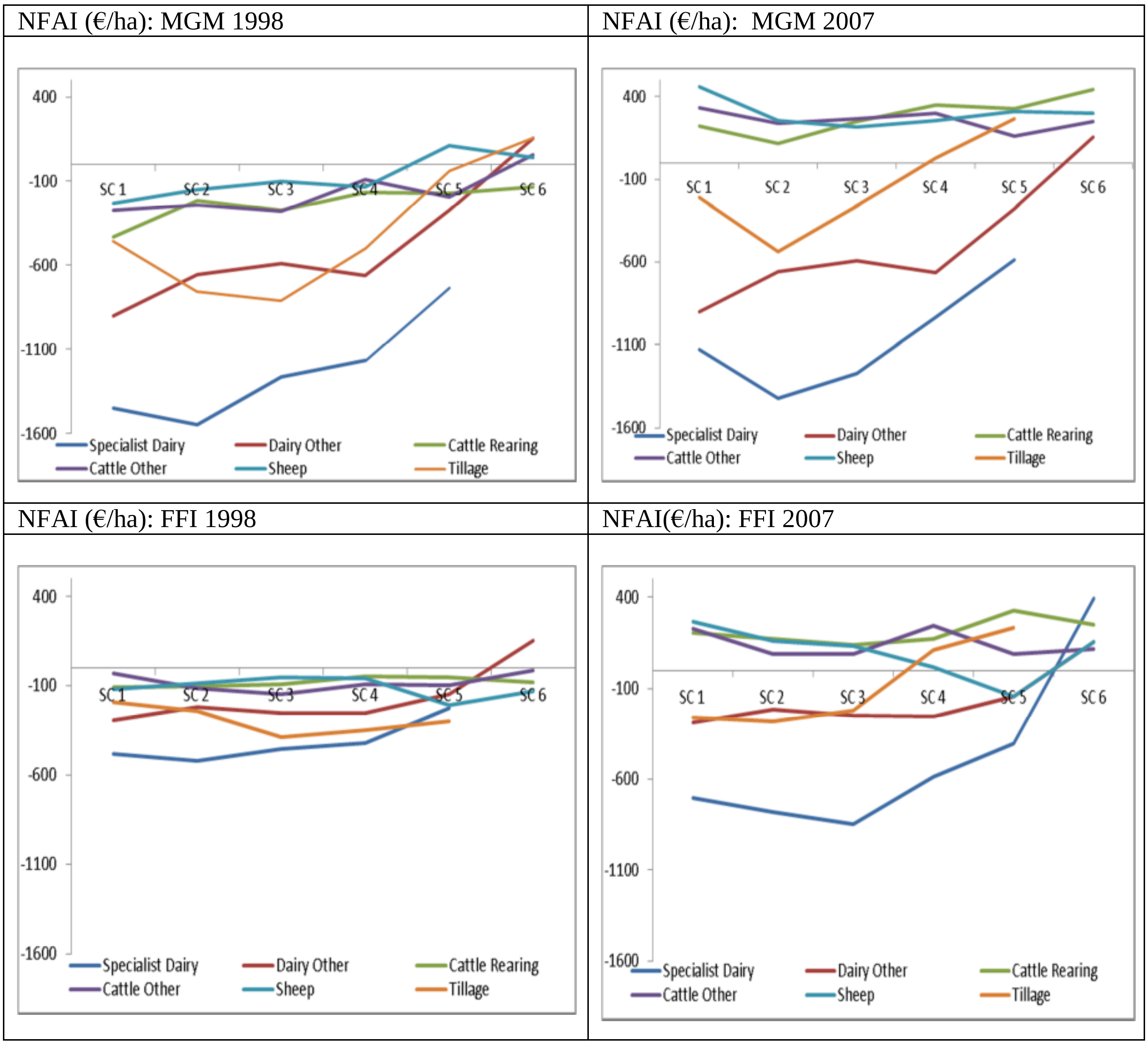
In analysing the differences between policy eras, the NFAI per ha of converting one hectare of land from agriculture to forestry for each farm system and soil class for both MGM and FFI is presented in Figure 6.8 for 1998 and 2007. While the NFS is nationally representative by farm system, the sample is not representative in terms of soil type. The values are also limited by smaller NFS sample sizes on the poorest soil (SC) 6, therefore the AE values for this soil class are not as robust as the remainder of the soil classes. A cursory glance shows that there is indeed huge variability in net farm afforestation incomes across farm systems and also in relation to soil productivity. Initially NFAI over time is assessed for each agricultural income measure, before comparing NFAI across soil codes and income measures.

*Temporal effects on NFAI*

It is difficult to disentangle the effect of forest and agricultural incomes in the net farm afforestation as forest and agricultural incomes are largely moving in opposite directions. Re-capping on what has already been observed, it is evident in Figure 6.1, that average forest income is higher in 2007 than in 1998. In addition, Figure 6.5 shows that 1998 MGM is considerably higher than FFI, whereas there is little difference between the measures in 2007. This is reflected in the different patterns and magnitudes of net income between NFAI (MGM 1998) and NFAI (FFI 1998) and the similarity in pattern between the two income measures in 2007. Thus the higher net incomes arising from afforestation are likely to be influenced by higher forest incomes in 2007.

In initially examining the MGM net afforestation income per ha, by farm system, across the two years represented by the post MacSharry and post SFP periods. Dairy incomes are high in both periods, resulting in a strongly negative net farm afforestation income, particularly for productive soil classes. Dairy other and tillage systems follow a similar pattern with a considerable negative NFAI for productive soil classes. The general pattern is that they are consistently higher than net incomes for the dairy, dairy other and tillage systems which require more productive soils.

**Figure 1.8 Average NFAI (€/ha) (CPI adjusted) expressed as average Market Gross Margin (MGM) and average Family Farm Income (FFI) (1998 & 2007)**




The difference in the magnitude of the net income between the time periods arises as average MGM across all systems (Figure 6.8) is considerably higher in 1998 than in 2007, highlighting the volatility of agricultural incomes. Net forest income calculated using FFI is largely negative and more tightly bunched in 1998 than in 2007. In 2007 however, the NFAI is positive and higher for livestock systems and lower for the dairy system. All the livestock (cattle rearing, cattle other and sheep) MGM net income averages are positive with cattle rearing and sheep systems peaking at around €450 $ha^{-1}$. Similar to the MGM measure, dairy, dairy other and tillage systems have negative NFAI but the livestock systems are again positive with the cattle rearing system having the highest FFI value at just under €200 $ha^{-1}$.

*Soil effects on NFAI*

In relation to the effect of soil code on NFAI per ha, all systems are negative in 1998, it is evident that across all soil codes for both measures (except for the sheep, tillage and dairy other systems) which become positive at SC5. The dairy system shows the most strongly negative net income across all soil classes regardless of the subsidy period or the income measure used (SC 6 is not reported as there are less than 10 observations). The income patterns for dairy other and tillage are similar to dairy although not as strongly negative. As these three systems require good soil quality it is not surprising that the net benefit of afforestation is negative on good soils and the benefit only becomes positive on intermediate (SC4 and SC5) soil classes, which are however productive (YC 20 and YC 18 respectively) in forestry.

There is less variation between soil codes for livestock systems in 1998 for both income measures as NFAI only becomes marginally positive at SC5 or SC6. The highest MGM value for the sheep system occurs at SC5, with a slight upward trend in FFI across soil classes for cattle systems.

Overall, the strongly negative trend in NFAI for the dairy system is self-evident and remains negative in both years, due to the high opportunity cost associated with replacing a dairy enterprise with a forest enterprise. It is thus highly unlikely that dairy farmers would consider afforestation in either period. On the other hand, in 1998, sheep farms have the highest net income at €100/ha on SC5 for the MGM measure. In 2007 cattle farmers have the highest net forest incomes (€400 $ha^{-1}$ at SC5 for the MGM measure and €350 $ha^{-1}$ for the FFI measure).

*Measurement effects on NFAI*

FFI differs from MGM in relation to the addition of subsidies and the deduction of overhead costs. Subsidies are likely to be of greater importance on cattle and sheep farms which had historically high coupled subsidies, whereas dairy, dairy other and tillage systems are likely to be more influenced by overhead costs as they are high cost systems relative to the livestock systems. Thus it is plausible to assume that the inclusion of subsidies in the FFI measure impacts largely on livestock farms and on cattle farms in particular. This appears to be the case and is borne out by the fact that the rise in NFA is greater for cattle systems than for sheep.

In examining the relativity of NFAI in both periods, particularly for cattle farmers, there is another plausible explanation for the higher NFAI in 2007 than in 1998. The results seem to indicate that farmers considering afforestation in the post MacSharry period could have lost agricultural subsidies resulting in a lower NFAI, whereas farm afforestation in the post SFP era returns a higher NFAI as there is little or no loss of agricultural subsidies – a win-win situation. If as had been previously hypothesised, farmers in the post MacSharry period had sufficient land to accommodate forestry without losing out on subsidies, then they too would have been in a win-win situation.

In relation to overhead costs, the effect of deduction of overhead costs in high cost systems (for the FFI measure), reduces the agricultural income or opportunity cost which in turn increases the NFAI per hectare. Therefore the most appropriate measure of income is dictated by the characteristics of the system, i.e. short term measures are suitable for low cost/high subsidy systems whereas long term measures are more appropriate to high cost/high production systems with lower dependency on subsidies.

### 1.5 DISCUSSION

The financial consequences of converting agricultural land to forestry are of primary concern to forest policy in Ireland and to the achievement of afforestation goals in particular. Historically, afforestation has always been associated with lower quality soils in Ireland. This study confirms the competitiveness of afforestation with other pastoral land uses and the importance of planting year, soil quality and agricultural income measure in understanding the potential financial impacts of land conversion. The results show that afforestation does not compete financially with the dairy system under any conditions for the average farm values examined here. This is the case regardless of whether a gross or a net measure of agricultural income is used to calculate the agricultural opportunity cost.

In addition, the results confirm that afforestation is generally not competitive with either the dairy other or tillage systems, at least on soils of reasonable quality, in either time period. Again, this is the case, regardless of how the opportunity cost is calculated. While these findings go further than previous studies, they are consistent with an earlier analysis conducted by Upton et al. (2013) and echo other Irish studies. While dairy farmers were responsible for a large proportion of the land planted in the earlier part of the period examined,[8] farmers engaged in livestock enterprises are the most likely to benefit financially from converting land to forestry in the latter part of the time period (Breen et al. 2010; Ryan et al. 2008; Howley et al. 2012).

The significance of these results for potential future afforestation lies in the relative size of the livestock sector in Ireland. Livestock systems (cattle rearing, cattle other and sheep) account for over 68% of farms, and the cattle systems alone make up more than half the farms in Ireland (Hennessy and Moran 2015). Although an exact breakdown of the area of land under different agricultural systems is not available, approximately 80% (3.4 million ha) of all agricultural land in Ireland is used for grass, including pasture, silage and hay, 11% (0.5 million ha) for rough grazing and only 9% (0.4 million ha) for crop production (Hynes and Hennessy 2012).

In addition, this study shows that in general, the NFAI of afforestation is higher in 2007 (in other words the opportunity cost is lower). The higher NFAI is due to market variation rather than subsidies, as the market income in 2007 is considerably higher. This finding is also consistent with Upton et al. (2013) who find that over time, average forest incomes become more competitive with agricultural incomes. Additionally, this study builds further on the relativity of the agricultural and forest subsidy components of income (Chapter 4) by examining the effect of soil class on the components over time, individually and in aggregate.

As expected, soil is a stronger driver for market income than for subsidy income for both forestry and agriculture, in that there is a direct and linear relationship between forest productivity and soil class. Forest subsidy payments are not directly related to productivity (other than during the period when the level of payment depended on LFA status) however, the share of subsidies in forest income increases dramatically on poorer soil classes. This means that in effect, forests on poorer soils are proportionally more highly subsidised relative to the market income from forestry.

The relativity of agricultural subsidies and market income is complicated by the interaction of the subsidy schemes and the measures used to calculate market income. As with forest incomes, there is an upward trend in agricultural market income as soil class improves, regardless of the income measure used. However, the trend is much stronger for dairy, dairy other and tillage systems as these systems require the higher productivity and livestock

[8]Many dairy farmers bought additional land to expand dairy quotas and subsequently planted this land

carrying capacity of the better quality soil classes (SC1, SC2, SC3). Agricultural incomes are much more volatile on an annual basis than forest incomes thus the share of subsidies is greatest (and most important) in years when market income is low.

There is an obvious relationship between agricultural subsidy payments and soil class, which is stronger for productivity-related subsidies. This relationship is indirect, as subsidies are related to productivity which in turn is related to soil type. Farms on better soils have higher productivity related (Pillar I) subsidy payments. When non-productivity related subsidies (Pillar II) are included, farms on medium to poor soils benefit the most. In this regard, farms on poorer soils (SC5 and in particular SC6) are proportionally more highly subsidised. On these soils, the share of subsidies has a much greater role in the opportunity cost than market income. This possibly helps to explain the reluctance of some farmers in the past to plant land that is at best marginal for agriculture, as they stood to lose more subsidies (premiums and REPS) than in the post SFP period.

The components of agricultural income that have the greatest influence on opportunity costs are agricultural subsidies and overhead costs. In the past, the subsidy component was of greater importance in calculating the opportunity cost on livestock (particularly cattle) farms, while measures that deduct overhead costs are more important to give a true reflection of the opportunity cost for high cost systems (dairy, dairy other and tillage).

The calculation of the opportunity cost is very sensitive to the income measure used as the different measures generate very different opportunity costs, particularly in relation to the treatment of subsidies in the post MacSharry and post SFP periods. In addition, net and gross measures that treat overhead costs differently, have a large effect on the magnitude of the opportunity costs. This component is likely to be of even greater importance in the calculation of opportunity costs in the future, as many dairy farms undertake investment to facilitate expansion. The next Chapter will test if the difference between measures is significant.

Since the introduction of area-based direct payments, there is less potential to lose agricultural subsidies as afforestation is an eligible land use for SFP. This means that the subsidy component of the opportunity cost is likely to be less of an issue in future. REPS is now closed and subsequent agri-environment schemes are not mutually exclusive of afforestation. Farmers could still lose LFA payments if they are below the maximum area threshold but areas of natural constraint (ANC) will be reviewed in 2018 and the LFA scheme will be replaced.

*Summary of findings*

The financial components of the opportunity cost examined here indicate that on average, livestock farmers on marginal soils stand to gain financially by converting land from agriculture to forestry. It would appear that since the SFP era in particular, the potential loss of subsidies has been decreasing, as previously conflicting schemes end.

This finding further develops and confirms the earlier less complex economic analysis undertaken by Upton et al. (2013) and the spatial analysis undertaken by Upton et al. (2014) and is an important finding in relation to future targeting of afforestation on soils and farm systems where it is most likely to lead to an increase in farm income. To the best of our knowledge, an inter-temporal analysis of both the market and subsidy components of agricultural opportunity costs and their methods of calculation has not previously been undertaken in the literature. This may be largely due to the comprehensive nature of the data required to undertake this type of analysis. While the findings in this chapter relate specifically to the soil classes, market and subsidy parameters that apply in the Irish context, there are commonalities across many EU countries in which subsidy regimes applied.

The analysis in this chapter indicates that the financial reward for converting agricultural land to forestry is unlikely to be the sole driver of the decline in planting rates. Farmer motivations also play an important part in their land-use decisions, with the perceived lifestyle benefits of farming and the productivist mentality of some farmers limiting their interest in adopting what amounts to a major change in enterprise away from traditional farming (McDonagh et al. 2010). Farming and the production of food may thus provide a satisfaction that forestry and the production of timber lacks even where the latter is the financially optimum land use. A negative attitude amongst farmers towards forestry has been identified as a barrier to planting in previous surveys, although regional variances may exist (Ní Dhubháin and Gardiner 1994; O'Leary et al. 2000). Restrictions on afforestation in environmentally sensitive areas may also have a negative impact on afforestation rates locally (Collier et al. 2002) and it is likely that "thresholds" of forest cover may be reached in some parts of the country where land availability is restricting expansion ( Upton et al. 2012).

The inclusion of the agricultural opportunity cost is important to improve the understanding of the farm afforestation decision (Herbohn et al. 2009). This study reveals a much greater level of complexity than was previously envisaged, in determining the inter-temporal impacts of subsidies, market income and soil type on the agricultural opportunity cost. The results clearly show that the opportunity cost is not a flat rate per hectare but is very much a system opportunity cost. It is also evident that soil type is reflected in both the opportunity cost of the agricultural income foregone and the productivity of the forest. Thus the results of this study demonstrate the importance of soil class, farm system and opportunity cost in understanding the financial outcome of land conversion. These results are potentially relevant for other countries that wish to incentivise farm afforestation. They are also relevant to policy makers in countries that wish to pursue goals in relation to carbon neutral agriculture.

*Limitations*

The NFS sample is representative of farms at the level of system and size but due to changes in the NFS sample, small farms may be under-represented since 2010 (Ryan et al. 2016b), however it is evident from the analysis in this thesis that small farms are less likely to plant. In addition, the NFS is not representative by soil class and SC6 is under-represented. Thus, although the agricultural income measures (MGM and FFI) are valid for the farms included in the sample, they are not representative of all farms in Ireland, therefore it is not possible to identify the proportion of the farming population, or the land area of land in Ireland that would financially benefit from converting to forestry from these results.

The results presented here are based on average values across farm systems and soil codes. While the study provides significant new information, there are limitations to using averages i.e. it is necessary to be able to examine within system variation in order to be able to understand individual farmer preferences While this chapter adds to the understanding of the relative importance of the subsidy and market components of the opportunity cost presented in Chapter 4, the disentangling of the complexity calls for going beyond the averages to look at the situation across the distribution of farms.

### 1.6 CONCLUSIONS

This chapter set out to decompose agricultural and forest incomes into their market and subsidy components to assess the relativity of market income and subsidies. The role of soil class as a driver in both market and subsidy income was examined, before calculating the annual agricultural opportunity cost associated with the afforestation of one hectare in each year of the dataset for each farm system. In addition, the sensitivity of the calculation of the opportunity cost to the use of both short term (gross) and long term (net) agricultural income measures was assessed.

Significant variability between systems, years and soil classes is observed. The annual equivalised NPVs associated with forestry replacing cattle rearing, cattle other and sheep enterprises confirm that forestry is a highly competitive alternative land use option for these systems, regardless of whether a gross or a net measure of agricultural income is used to calculate the agricultural opportunity cost. The importance of being able to calculate the opportunity cost for a given year is clearly evident, as over the period examined, as a result of policy changes and price volatility, there are large variations in relation to system, subsidies, soil type and overhead costs. The results highlight the complexity of the decision confronting farmers who must weigh up agricultural market prices and the potential loss of agricultural subsidies when considering afforestation. Essentially farmers are confronted by a trade-off in which the parameters change from year to year.

This chapter draws together the spatial environmental analysis in Chapter 3, subsidy analysis in Chapter 4, and the forest market incomes generated in Chapter 5. To date, such a comprehensive study of the opportunity cost of land conversion from agriculture to forestry has not previously been published in the international literature. This study contributes to the literature (a) by analysing in detail the annual farm level agricultural opportunity cost over a 20 year period; (b) by examining the relativity of the market and subsidy components of the opportunity cost; (c) by assessing the effect of soil productivity on market and subsidy income; and (d) by examining the sensitivity of calculation of the opportunity cost to the treatment of subsidies and overhead costs in a range of farm income measures.

The results of this study pose a conundrum: why is the afforestation rate declining if forestry is a more financially attractive option for many farmers? Ideally, further studies are needed to analyse the motivation to plant from the perspective of the financial and environmental characteristics of the individual farm interacted with the behavioural characteristics of the farm owner. According to Beach et al. (2005), forest related land use decisions are driven by a combination of market drivers, policy variables, owner characteristics and land conditions. Thus future investigations of afforestation patterns may benefit from examining additional factors that may be discouraging farmers to convert to forestry. One such factor which is important to landowners in Ireland is land value. Land prices can have a significant effect on farmer's decisions to enter forestry (Kula and McKillop 1998), which may offer some explanation of the reduction in planting during years of high economic growth. In addition, the permanency of the afforestation decision imposes restrictions on the flexibility of land use, thereby potentially reducing land value and de-incentivising planting.

In theory, farmers are expected to behave rationally by maximising their profits, however, if this were the case, more livestock farmers would plant. There is also a significant literature that suggests that many farmers are not profit-maximisers but are motivated by maximising the utility that they derive from farming and the faming lifestyle (Key 2005; Key and Roberts 2009: Vanclay 1992 & 2004; Duesberg 2013; Howley et al. 2015).Using a behavioural approach to further examine the afforestation "conundrum", could add to this work by broadening the analysis to incorporate that elusive behavioural element – what motivates farmers.

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