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Economics of Farm Afforestation in Ireland

A thesis submitted in fulfilment of the degree of
Doctor of Philosophy

by
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DESCRIPTION OF THESIS

In recent years, afforestation in Ireland as in many European countries has fallen well short of policy targets. Previous studies which address the decline in farm afforestation focus on either the economic or the behavioural reasons in isolation. This thesis takes a holistic view of the inter-temporal land use change decision necessitated by the consideration of afforestation on farms, by analysing the physical, economic and behavioural drivers of afforestation, using a longitudinal (30 year) NFS dataset.

The spatial distribution of non-industrial private forests (NIPF) in Ireland is examined from the perspective of the influence of soil quality. In examining the relative returns to agriculture and forestry, the market and subsidy components of the economic return are examined individually. The complexity of the relationship between agricultural and forestry subsidies is disentangled using a hypothetical farm framework and reveals that agricultural and forest incentives were conflicting for much of the period examined.

The market return to forestry is investigated using a bio-economic model which generates optimal rotations, incorporating agricultural (market and subsidy) income as the opportunity cost of afforestation. This reveals a wide variation in income when different soil quality, opportunity costs and rotation optimisation criteria are taken into account.

Insights into the behavioural aspects of the afforestation decision are gained by building a structural model based on revealed preferences which considers the utility maximising choices made by a representative sample population of farmers within a life-cycle theoretical framework. The findings show that on balance, farmers act rationally in preferring to farm than to afforest land, even if the income from forestry is higher. There is solid evidence that the gain in (forest) income is not sufficient to off-set the decrease in agricultural income, perceived decline in wealth and loss of utility derived from farming.

In examining the underlying heterogeneity in relation to farm and farmer characteristics, it is evident that farms with higher forest income streams are

significantly more likely to have afforested land and to consider forestry in the future, but 84% of farmers will not consider afforestation, regardless of the financial incentives. Farmers who have planted are categorised according to the level of farming intensity after planting and three typologies are presented i.e. older “de-intensifying” farmers who are maximising subsidies, younger “intensifying” farmers who are optimising their land resource and “diversifying” part-time farmers who are optimising their time.

This thesis confirms that while financial incentives are significant, they are not strong enough on their own to incentivise increased planting. Given the increasing pressure for sustainable intensification of agricultural production, potential incentive schemes to mitigate agricultural GHG production through further afforestation must recognise that a more targeted approaches which incorporates farming and lifestyle objectives may be necessary to improve the uptake of farm afforestation in future.

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1.2 GLOSSARY

Abbreviation	Explanation
AE	Annual Equivalised (Net Present Value)
AES	Agri- environment (Scheme)
AEOS	Agri-Environment Options Scheme
BEF	Biomass Expansion Factor
CAP	Cost Benefit Analysis
CBA	Common Agricultural Policy
CL	Conditional Logit
COFORD	Council for Forest Research and Development Programme for Competitive Forestry Research for Development
Con	Conifer
CPI	Consumer Price Index
DAFF	Department of Agriculture, Food and Forestry
DAFM	Department of Agriculture, Food and Marine
DAS	Disadvantaged Area Scheme
DBH	Diameter (tree) at Breast Height
DCF	Discounted Cash Flow
Defra	Department of environment, food and rural affairs
ERS	Early Retirement from farming Scheme
ForSubs	Forest Subsidies model
ForBES	Forest Bio-economic System model
FEPS	Forest Environment Protection Scheme
GHG	Greenhouse gases
GLAS	Green Low-Carbon Agri-Environment Scheme
HWP	Harvested Wood Products
IFCN	International Farm Comparison Network
IPCC	Intergovernmental Panel for Climate Change
IRR	Internal Rate of Return
ITGA	Irish Timber Growers Association
LEV	Land Expectation Value
LFA	Less Favoured Areas (includes MSH and LSH)
LSH	Less Severely Handicapped area
LU	Livestock units
LULUCF	Land Use Land Use Change and Forestry
MSH	More Severely Handicapped area
n/d	non diverse conifer planting category (e.g. Sitka spruce)
NFS	National Farm Survey
NPV	Net Present Value
OPF	Operational Programme for Forestry
REPS	Rural Environment Protection Scheme (REPS-4)
RUM	Random Utility Maximisation
SC	Soil Code
SFP	Single Farm Payment
SCW	Suckler Cow Welfare scheme
SPH	Stems per hectare
SS	Sitka spruce
TFSM	(Teagasc) Typical Farm (Subsidies) Model
UAA	Utilisable Agricultural Area
YC	Yield Class

1.3 STATEMENT

I declare that the research presented in this thesis is my own work.

Signed

.....

Mary Ryan

1.4 ACKNOWLEDGEMENTS

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Firstly, I owe a huge debt of gratitude to my Teagasc supervisor Prof. Cathal O' Donoghue. Without his vision and support, this thesis would never have been undertaken. More importantly, without his insight, energy, enthusiasm, understanding and belief in me, this thesis would not have been completed within the four year time-frame. I also wish to acknowledge the help and support of my NUI Galway supervisor Dr. Stephen Hynes and the helpful advice of my Graduate Research Committee (Trevor Donnellan, Natasha Evers and Stephen McNena).

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Economists, Milan (2015), in addition to the comments of anonymous journal reviewers. I am grateful for the helpful comments and insights of staff and students in relation to student presentations in both Teagasc and NUI Galway. All of these contributions helped to refine my research.

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Chapter 1. INTRODUCTION

The afforestation (or establishment of a forest on previously un-forested land) of agricultural land involves a complex decision-making process and the influencing factors can be difficult to isolate. Nevertheless it is an important policy objective across many EU countries (EU Commission 2013). Yet in recent years, the rate of afforestation in many European countries has been declining (Eurostat 2013). Despite having soils and climatic conditions which are particularly suited to timber and fibre production, Ireland has one of the lowest forest covers in Europe at 11% (Eurostat 2013). In addition, despite the availability of strong financial incentives, afforestation has fallen well short of policy targets over the last 20 years.

The decline in afforestation comes at a time when the importance of the ecosystem services provided by forests is increasingly recognised and valued (EU Commission 2013). In Ireland, the most recent review of forest policy reaffirms the benefits of afforestation and sets even higher targets for future afforestation in order to optimise benefits from forest ecosystems such as the provision of timber for processing, fibre for renewable energy production, carbon sequestration and biodiversity conservation. This decline in afforestation has consequences for downstream timber processing; for the increasing demand for wood fibre; and for the potential of forests to sequester carbon and mitigate greenhouse gases generated by other sectors such as agriculture.

While there are large volumes of literature that deal with either agriculture or forestry as a land use, there is a dearth of literature that examines the factors involved in the land use change from agriculture to forestry, within the same framework. Thus the primary objective of this thesis is to take a holistic view of the interaction of biophysical, economic and behavioural components of the choices faced by farmers when considering afforestation. Given the need to incentivise further afforestation as an element of broader land use and sustainability policies, this research is timely in that it aims to provide valuable insights for policy makers in the design of future afforestation incentive schemes.

1.1 CONTEXTUAL FRAMEWORK

International forest policy context

Afforestation is increasingly valued for its potential to enhance ecosystem services and is being actively promoted in many countries through state policy and support (Kanowski 2010). For example, the Scottish Government's rationale for woodland expansion includes the tackling of greenhouse gas emissions, restoring lost habitats and adapting to climate change (Forestry Commission 2009). Forest cover expansion is included as a source of carbon dioxide emission reduction under the Kyoto Protocol, which is a significant factor in the promotion of forest expansion policies (Nijnk and Bizikova 2008). Similar to many countries, Ireland has sought to increase forest cover for some time with rural employment and economic diversification benefits being important drivers in the 20th Century, while ecosystem services are increasingly recognised in modern forest policy (DAFF 1996; OCarroll 2004; DAFM 2014a).

In the context of overall forest cover, the conversion of land from agriculture to forest is unusual in the European and even in the global context. Many countries with high levels of forest cover either have a long tradition in the management of plantation forests or have large areas of natural forest. Countries with well-developed forest cultures are generally more interested in management and reforestation decisions, rather than the afforestation of additional land. However a number of countries with low levels of forest cover have been actively promoting afforestation of agricultural land in order to increase forest cover (Eurostat FAO). Globally, this includes Australia, New Zealand and Chile. In Europe, the United Kingdom, the Netherlands, Belgium, Greece and Ireland all have incentive programmes to increase afforestation (in most cases of agricultural land) with varied success.

In the EU 28, forests and other wooded land cover a slightly higher proportion of total area (42.4%) than agricultural land. The drivers of incentive schemes in western European countries, which have had extensive policy supports to incentivise farmers to afforest agricultural land, are based generally on the multifunctional timber and ecosystem benefits provided by forests, with increasing prominence on the potential for afforestation to mitigate agricultural greenhouse gases. 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). However, UK forest expansion has dropped back from a high of 40,000 ha yr⁻¹ per year in the early 1970s to an average of about 10,000 ha yr⁻¹ (Forestry Commission 2013).

The Flemish region of Belgium which is characterised by low forest cover has a target to expand forest area by 10,000 ha to 12%. However afforestation in Flanders has actually declined and expectations are that it will be difficult to realize an increase in the forest area (Van Gossum et al. 2012). It is likely that the Dutch policy goal to increase forest cover by 66,000 ha by 2020 will also not be realised (Van Gossum et al. 2010).

Despite having soils and climatic conditions which are particularly suited to timber and fibre production, Ireland has one of the lowest forest covers in Europe at 11% (Eurostat 2013). Successive policy interventions have implemented incentives to increase forest cover. Ireland's most recent forest policy review (DAFM 2014a) calls for an afforestation rate of 15,000 ha yr⁻¹ to avoid a significant supply slump in future wood supply. However, despite the strong financial incentives, annual afforestation has fallen well short of target afforestation rates.

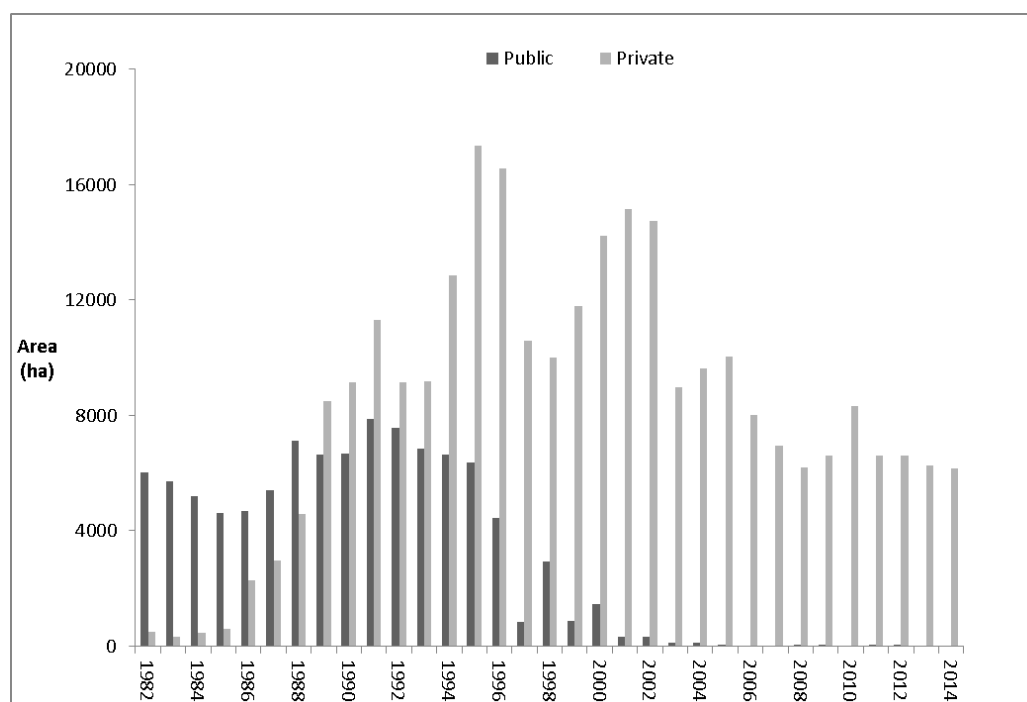
Irish Afforestation policy context

The expansion of non-industrial private forests (NIPF) in Ireland is unique in the European context in that the almost doubling of forest cover within the last thirty years has taken place largely on farmland. Until the mid-1980s, virtually all afforestation in Ireland was undertaken by the State as only limited financial incentives were available to the private sector. However by 1989, as a result of the introduction of EU funded afforestation subsidies, the level of afforestation carried out by the rapidly expanding private sector exceeded public sector (State) planting for the first time. By 1993, an early government target of one million acres (404,700 ha) of new forest cover was reached. From 5,242 hectares in 1985, annual afforestation reached a high of 23,710 ha in 1995 (Forest Service 2014).

However, as financial incentives for private afforestation increased, public afforestation declined rapidly due to the unavailability of EU forest subsidies for public afforestation. From 2006 onwards, public planting virtually ceased and all afforestation was carried out by the private sector; the vast majority of which was

undertaken by farmers (Forest Service 2014). Figure 1.1 presents the private and public annual afforestation over a 30 year period.

Figure 1.1 Annual afforestation in Ireland (hectares) from 1984 to 2014



Source: ITGA (2015)

From a bio-physical perspective, the increase in farm afforestation is not surprising as Ireland has some of the highest growth rates for conifers in Europe and also has a large proportion of land which is marginal for agriculture but highly productive under forests (Farrelly et al. 2011). From an economic perspective, the expansion was facilitated by a series of Irish and EU subsidies which increased in magnitude over time and which were largely focused on incentivising the afforestation of agricultural land. However, from a behavioural or attitudinal perspective, the rate of expansion is surprising, given the dis-incentive presented by the permanency of the land use change decision from agriculture to forestry. Under the 2014 Forestry Act (and previously under the 1946 Forestry Act), a felling licence is necessary to thin forests and to fell or remove trees. The Act also allows the Minister to set conditions which include re-planting of harvested forests (re-forestation) (Irish Statute Book 2014). Thus the decision to plant is not taken lightly by farmers. The rapid increase in forest cover is also surprising given the lack of forestry tradition among Irish farmers and the consequent low level of knowledge of the economic returns from forestry (Ní Dhubháin and Greene 2009).

Ireland's forest policy has undergone a number of significant changes in emphasis since the founding of the State when forest cover represented just one % of the land area, to the current forest cover of 11%. While the primary aim of Irish forest policy has remained the achievement of self-sufficiency in timber supplies, broader policy objectives were also pursued. The social dimension around rural employment particularly in the western half of the country was an important policy objective. Successive forest policy strategies have set policy objectives and annual targets for private sector afforestation and have made recommendations as to the achievement of these targets, largely through financial incentives. In the 1996 Strategic Plan for the Development of the Forestry Sector in Ireland, ambitious targets of 20,000 and 25,000 hectares ha yr^{-1} were outlined (DAFF 1996). Achieving this target would deliver an annual timber output of 10 million m^3 and a total forest cover of 17% by 2030.

These targets were set in order to achieve a critical mass of timber production which would allow the developing timber processing sector to grow. An additional driver for the consumption of wood products emerged with the EU Renewable Directive (2009/28/EC) which set targets for increased consumption of renewable energy. Across the EU, the demand for biomass for renewable energy for heat and power had historically been a significant driver of afforestation and forest management interventions, however it was only with the introduction of sizeable grants for the introduction of biomass boilers in the late 1990s and early 2000s, that the demand for fibre for biomass began to grow in Ireland. The 2010 National Renewable Energy Action Plan for Ireland sets a target of 16% renewable energy by 2020 (DCCAE 2016). These targets are challenging. In a drive to achieve these targets, policy makers are focusing initially on the biomass sector, for which a new framework of incentives is currently being finalised.

Projects such as the Clare Wood Energy Project (CCWEP 2016) had significant success in developing the local supply and demand elements of wood energy as a product. Unfortunately, in recent years there has been a sharp decline in the demand for timber for wood energy due to a combination of the suspension of grants during the recent economic recession and low oil prices.

Due to a decline in afforestation in the 2000s, the afforestation targets were revised downwards in the 2011 Programme for Government to 14,700 ha yr⁻¹ (DPER 2011). This was further reduced in 2009 when an interim target of 10,000 ha yr⁻¹ was set for the remainder of the 2007-2013 Rural Development Programme (Government of Ireland 2009). In recent years, even these reduced targets have not been met as since 2005, afforestation has only exceeded 8,000 ha yr⁻¹ in 2006 and in 2010 (Forest Service 2014). Despite these recent low afforestation rates, the most recent revision of forest policy (“Forests, Products and People”), re-affirms the importance of forestry as a national land use policy and increases the target to 15,0000 ha yr⁻¹ (DAFM 2014a).

Agricultural policy context

This most recent expansionist forest policy coincides with the expansion of Irish agricultural production in the form of the *Food Harvest 2020* and the *Food Wise 2025* (DAFF 2010; DAFM 2015a) government strategy documents. The strategies present opportunities for many farmers who have the infrastructure and scope to increase productivity while maintaining efficient cost structures. However, it is likely that these farmers will be constrained by the level of greenhouse gas (GHG) emissions produced.

The drive to produce more food to feed the rapidly expanding global population has meant that agricultural food production is expanding rapidly in many countries with consequent impacts on the environment in relation to air, soil and water quality. This has brought about a greater focus on more efficient use of our natural resources (land, water, air) to allow for the sustainable intensification of food production systems while minimising environmental impacts. The Irish agri-food sector has targets to significantly expand dairy and beef production (DAFM 2015a).

EU Climate and Energy policies impose limits on the level of carbon that can be released to the atmosphere in the form of greenhouse gases¹. Policy makers worldwide are now looking at ways to mitigate greenhouse gas production as agricultural production is intensified in response to increasing global demands for food. Due to the large role played by the agri-food sector in the Irish economy, agriculture already accounts for 33% of total national greenhouse gas (GHG)

¹ Ireland’s 2020 target is to reduce its emissions by 20% compared to 2005. The European Council has already agreed to an overall target reduction of 30% in emissions by 2030 but recognises (in the Effort Sharing Decisions) that national targets can vary according to circumstances.

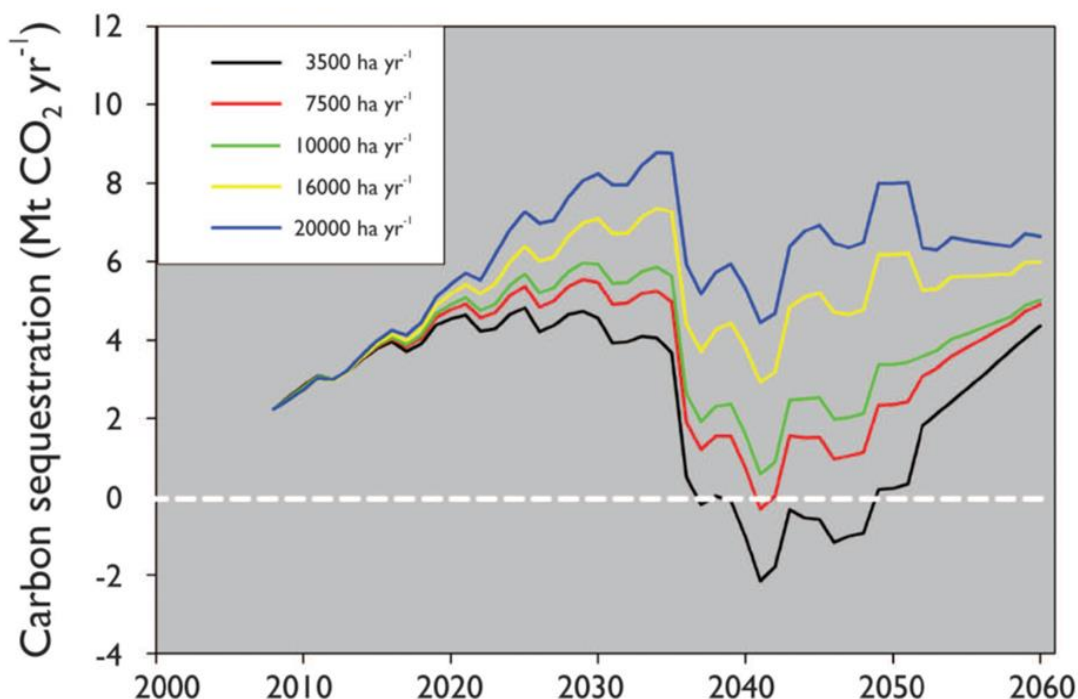
production in 2014 (EPA 2015). As a result, mechanisms to reduce or mitigate agricultural GHG production are being investigated. These include efficiency measures such as the reduction of “per kilo of product” emissions from the production of food products; identifying technologies to reduce emissions directly; and integrated land management options (Hennessy et al. 2013; Ryan et al. 2016b).

The primary land management mechanism is the ability of forests to sequester carbon from the atmosphere, thereby reducing GHG levels. The decision of the EU Council of Ministers in 2014, to allow for the inclusion of Land Use, Land Use Change and Forestry (LULUCF) into the 2030 greenhouse gas mitigation framework (EUCO 2014), opens up the possibility of using afforestation as a means of agricultural GHG mitigation. The COP 21 commitments to reduce GHG emissions (UNFCCC 2016) further highlight the potential for afforestation to facilitate the sustainable intensification of agricultural production and long term carbon neutrality.

However, if the decline in afforestation continues, not only will it be difficult for Ireland to meet its GHG reduction commitments from 2020 onwards, but it may also be forced to buy carbon credits. Between 2007 and 2012, Ireland spent €100 million purchasing carbon credits, however, the reduction in emissions as a result of the economic downturn has meant that there has been no further requirement to buy credits to date (Matthews 2015).

There are also other consequences of the reduction in afforestation rates. Ireland’s recent forest policy review (DAFM 2014a) calls for increased annual afforestation of 15,000 ha yr⁻¹ to avoid a significant supply slump in future wood supply. In addition, 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. Experts predict that Ireland’s forests are in danger of becoming carbon sources as the large areas planted in the 1990’s are harvested from 2035 onwards, releasing previously sequestered carbon. This is illustrated in Figure 1.2 which shows that 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).

Figure 1.2 Projected sequestration of carbon dioxide by Kyoto forests to 2060, based on afforestation (COFORD 2010)



Source: Hendrick and Black (2008)

This situation can be alleviated by the inclusion of the treatment of forest-based carbon to include the harvested wood products (HWP) pool², which was agreed at the 2011 Land Use, Land-Use Change and Forestry (LULUCF) climate change meeting in Durban. However, the challenges posed by future “emissions gaps” will be compounded if there is a carbon shortfall between carbon sequestered in new forests and carbon released from mature forests over time.

Policy Challenges

Despite significant and prolonged financial incentive programmes aimed primarily at farmers, annual afforestation in Ireland has consistently been below 7,000 ha yr⁻¹ in recent years (DAFM 2013a), bringing the threat of a “carbon cliff” ever closer. In an attempt to increase afforestation rates, the most recent programme of afforestation incentives which is implemented under the Rural Development Programme 2015-2020, provides for the first time since the late 1980s, the same level of forest subsidies for farmers and non-farmers (DAFM 2015b). This opens up opportunities for investors to buy land suitable for afforestation from farmers or to buy the timber

² <http://unfccc.int/resource/docs/2011/cmp7/eng/10a01.pdf>

rights from farm forests. However, while Irish farmers may be slow to afforest land, they are even more reluctant to sell land as evidenced by the low annual land sales: an average of less than 1% of the agricultural land bank in Ireland changes hands in any given year (Ganly 2009).

In considering either planting their land or selling the land for afforestation, farmers need to have sufficient information to be in a position to measure the economic trade-off between future forestry income streams and the agricultural income foregone against the prices offered for forestry land for sale. Recent changes to Common Agricultural Policy (CAP) payments and the on-going volatility in the prices of agricultural outputs and inputs, suggest that Irish farmers are heading into a period of greater uncertainty and possibly more fluctuating farm incomes. These external factors may prompt greater consideration of land use and enterprise change (Breen et al. 2010), again highlighting the need for farmers to have access to sufficient economic information to make informed decisions on the economic returns to forestry based on the bio-physical conditions pertaining to their farms.

Land conversion to forestry is a complex issue that is influenced by social, economic and environmental factors that policy-makers should account for in the development of forest policy and the setting of targets (Beach et al. 2005). The decision to plant also has an inter-temporal dimension in that it involves a major land use change from a relatively flexible pastoral agricultural enterprise to locking the land into an alternative enterprise for the foreseeable future. This entails the foregoing of an annual agricultural income and agricultural subsidies and replacing it with forest subsidies and a long-term forest income. The magnitude of the agricultural income foregone and the potential forest income are also dependent of the biophysical context of individual farms. In addition, the farm afforestation decision is also complicated by changing and uncertain prices over the forest life-cycle.

It is clear that the afforestation programmes implemented over the last 20 years have failed to incentivise sufficient afforestation to meet policy targets. This poses challenges to policy makers to understand the reasons for the lack of further afforestation and to understand how to incentivise further planting. This thesis undertakes an applied policy analysis to address these very relevant and immediate challenges. In order to do this, it is necessary to holistically examine all the factors

that influence the farm afforestation decision in order to better understand the motivations of farmers to either plant or not plant in order to inform policy makers.

1.2 THEORETICAL CONTEXT

On many levels, farming and forestry differ hugely as land uses. Factors such as inherent preferences in relation to either forestry or farming, the externalities generated by forests, the risks associated with long-term investments, the length and permanent nature of the forest rotation are specific to the afforestation decision and must be taken into account in an analysis of the land use change.

Theory of Land Use Change

Profit-maximisation has long been considered to be the main economic driver in relation to decision-making at the level of the firm. However, there is a growing literature that suggests that this represents an over-simplified view of the inherent factors and that individuals make decisions based on the expected change in their level of ‘well-being’, where the term used for well-being or welfare is “utility” (Edwards-Jones 2006). Thus economists use utility maximisation frameworks, rather than profit maximisation frameworks in determining the drivers of behaviour.

In understanding the economic drivers of land use change, the first step is to understand the differential preferences and returns to farming (F) and forestry (trees) (T). The utility or happiness that derives from alternative land uses i.e. farming and forestry (L_F and L_T), can be described in terms of returns to land use (p_F and p_T) and farmer preferences for either farming or forestry, respectively α and β in Equations 1.1 and 1.2:

$$U = \alpha \cdot L_F \cdot p_F + \beta \cdot L_T \cdot p_T \quad (1.1)$$

where

$$\alpha > \beta \quad (1.2)$$

as it is evident from the literature that farmers generally prefer to farm rather than to afforest land (Ní Dhubháin and Gardiner 1994; Duesberg et al. 2013; Howley et al. 2015).

In economic terms, the marginal rate of substitution (MRS) is the rate at which a consumer is ready to give up one good in exchange for another good, while maintaining the same level of utility. The ratio of marginal utility is modelled to develop an understanding of the MRS between Farming (F) and Forestry (T) planting.

Equation 1.3 illustrates the marginal Rate of Substitution between Farming and Forestry:

$$\begin{aligned}
 MRS_{FT} &= \frac{MU_F}{MU_T} = \frac{\delta U}{\delta L_F} \cdot \frac{\delta L_T}{\delta U} & (1.3) \\
 &= \alpha p_F + \frac{1}{\beta p_T} \\
 &= \frac{\alpha p_F}{\beta p_T}
 \end{aligned}$$

If the return to land use from farming is the same as planting a forest (if $p_F = p_T$) then:

$$MRS_{FT} = \frac{MU_F}{MU_T} = \frac{\alpha}{\beta} > 1 \quad (1.4)$$

This implies that farmers prefer to farm rather than plant forests and tells us that in order to counter-balance these preferences, the return to land use needs to be higher from forestry than from farming. This also applies, due to inertia, to any move from the *status quo* to an alternative land use.

Ecosystem services (ES)

Forests provide a range of ecosystem services, which generate ecological, economic, social and cultural values. These services emerge from the biophysical structure or ecosystem process generating a function that provides a service, having a benefit and thereby a value to humans (Potschin and Haines-Young 2011). Forestry contributes directly to the rural economy through the transformation of biological and other inputs into a range of outputs. However, there are also many indirect benefits to rural areas and to society which are described by Slee and Roberts (2004) as: linkages with upstream suppliers and downstream processing sectors, the re-spending of income derived from forestry (and related industries) in rural areas, in addition to the

provision of non-market benefits (public goods) or to use the popular term, ecosystem services.

Societal demands of forest ecosystem services are likely to increase in the coming decades, because of the increased need for timber, pulp, bioenergy and other forestry products, in combination with increasing needs to use forest land for recreation and preservation of biodiversity among other purposes. At the same time, mitigation of and adaptation to climate change call for forest management practices that promote carbon sequestration and resilience.

This inevitably leads to trade-offs which are an inherent part of ecosystem service management. Ideally, management practices which improve the provision of one service should synergise with other ecosystem services, although this may not always be possible. In these cases, the relative benefit of one service, from both an ecological and an economic standpoint should be weighed against each other. The only way in which this can be carried out in an efficient manner, is through a better understanding of the relationship between multiple ecosystem services and their drivers.

This thesis aims to provide new information on the economic trade-offs implicit in the land use change from agriculture to forestry. This in turn will inform future work regarding trade-offs between the economic and environmental elements of ecosystem service provision in the wider land use context.

Marginal Private Benefit and Marginal Social Benefit

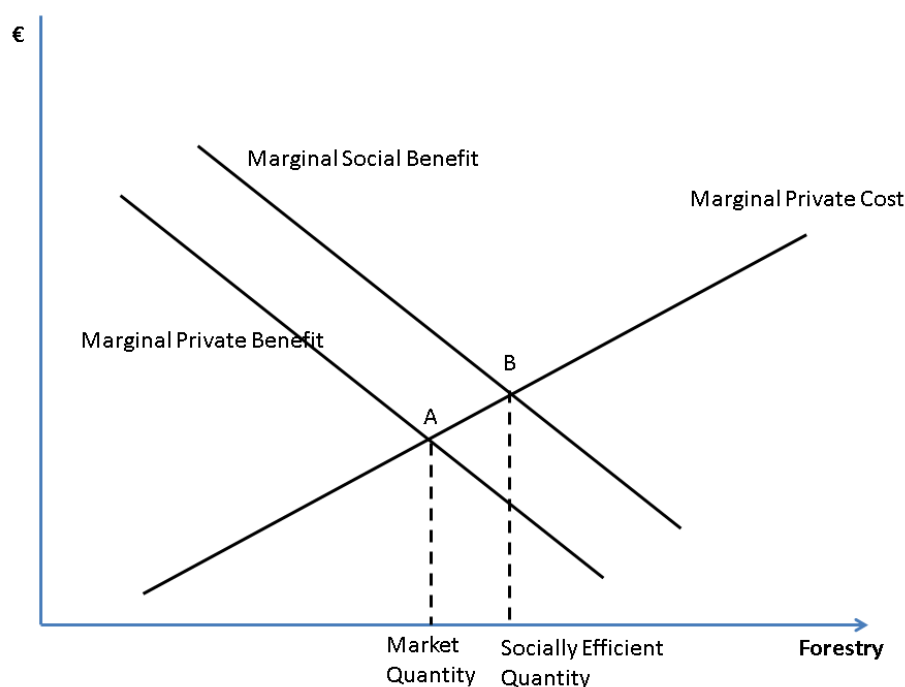
The provision of these “public goods” such as carbon sequestration (among others), means that the benefits from planting forestry extend beyond those that apply to the farmer. Such public benefits arising from private land are known as externalities which can be positive in the case of public goods such as carbon sequestration, or negative in the case of atmospheric emissions or pollution (public bads). The rationale for the state to “step in” to control pollution arises from the existence of these externalities, which are costs (or benefits) imposed by the polluter on others.

According to van Rensburg et al. (2002), individuals express different preferences when adopting a personal or a social perspective. In theory, farmers will plant when the marginal private benefit equals the marginal private cost. In other words, the extra income and costs respectively, associated with an incremental land use change to

forestry, at least balance each other out. However as the benefits to society are larger due to the presence of externalities, the socially optimal intersecting point is located at a higher level of forestry than is privately optimal (see Figure 1.3). This difference motivates the concept of Pigouvian³ subsidies, or payments to the provider of the public good, to equalise the marginal social benefit and the marginal private benefit. If this happens, then in theory, the level of planting would be expected to coincide with the socially optimal level.

Economists usually concentrate on the relative cost-efficiency of policy instruments. However, in the context of examining the respective benefits of regulation and taxes in limiting nitrogen emissions in agriculture, Lally et al. (2007) recognise the importance of other criteria including the uncertainty regarding policy outcomes, the equitable distribution of costs, the political acceptability of proposed policies and co-ordination with existing policy in the wider land use sphere. As it is unlikely that any policy option is preferred simultaneously on all of these grounds, policy choices in reality are made in the context of competing criteria (Hanley 1997).

Figure 1.3 Marginal Social Benefit and Marginal Private Benefit of Afforestation



³ In the presence of positive externalities, those who receive the benefit do not pay for it and the market may under-supply the product. Similar logic suggests the payment of a Pigouvian subsidy to make the users pay for the extra benefit would spur more production.

Forestry is also associated with other risks such as fire and storms (wind blow) which can cause extensive damage, as in the case of Storm Darwin in 2014. Natural disasters have a low probability of occurrence in any particular stand of timber but research suggests that forest damage caused by disturbance is increasing (Schelhaas 2008). Without the support of a well-developed insurance market, farmers or potential investors may be reluctant to consider forestry as an option (Zhang and Stengler 2014).

While the broad theoretical context of afforestation as a land use encompasses the provision of a broad range of ecosystem services, this thesis focuses on the economics of afforestation in a land use context with the aim of examining the effectiveness of policies aimed at incentivising further afforestation. The timing differential of agricultural and forest income streams was the motivation for the historic structure of policy payments that provide upfront forest establishment subsidies (grants) and annual forest premium payments until revenues are realised from timber harvesting. The higher preference for income now, relative to future income, (known as the discount rate), means that there is less incentive for a land use change that substitutes current income from farming for future income from forestry. The questions that arise here are:

- (a) whether the structure of current policy incentives in the form of subsidy schemes, sufficiently mitigates this preference?
- (b) whether other forms of incentive which are additionally focused on the provision of environmental and social ecosystem services, could assist policy makers in designing new afforestation schemes?

1.3 LITERATURE REVIEW

While there is a dearth of literature that deals with the factors motivating the land-use change from agriculture to forestry, there is a considerable literature that deals with forestry as a land use. In a meta-analysis of many of the econometric studies of non-industrial private forest owners, Beach et al. (2005), assessed the factors driving decision-making among forest owners and categorised them as follows: owner characteristics (and preferences), plot/resource conditions (soil type and plot size), policy variables (factors that affect the forest investment decision) and market drivers

(costs and returns from forestry and alternative enterprises). Country specific studies differ in relation to policy drivers and the relative importance of these factors but there is strong commonality around the biophysical, economic and attitudinal factors driving decision-making.

Biophysical literature

The economic return from forest crops is primarily dictated by biophysical factors such as soil quality, elevation, slope and rainfall. However, by manipulating tree growth through management practices, economic returns can be optimised for a range of timber production, economic or environmental objectives. The vast majority of the literature dealing with tree growth and the biophysical environment relates to forest management decisions and the optimisation of timber and revenue returns (see for example Halbritter & Deegen 2015; Standiford & Howitt 1991; Tahvonen et al. 2013; West et al. 2012). A large proportion of the literature from developing countries deals with the problem of de-forestation (Namaalwa et al. 2007; Sankhayan et al. 2003).

Increasingly in recent years, there is a considerable volume of literature which examines some of the wider non-timber value of forests such as biodiversity management (Tikkanen et al. 2012), biomass production for renewable energy (Lecoq et al. 2011), continuous cover forestry (Assmuth & Tahvonen 2015) agroforestry (Graves et al. 2007) and climate change mitigation (Pihlainen et al. 2015). However, the non-timber benefit that has received most attention in recent years is the potential of forests to sequester carbon. While there is a considerable literature that deals with the loss of sequestered carbon as a result of deforestation, many studies also deal with the management of carbon in forests (Diaz-Balteiro & Romero 2003; McKenney et al. 2006; Upadhyay et al. 2006; van Kooten et al. 1995).

However, most of the literature deals with forest management or optimisation questions in relation to forests that already exist. The literature in relation to afforestation, particularly in an agricultural context i.e. the conversion of previously unplanted land to forestry, is in comparison, quite limited. Such studies include work by Vanclay (1998) and Verburgh (2004) who describe decision support tools to aid in the conversion decision. Various cost benefit analyses (CBA) which consider biophysical factors in the conversion of agricultural land to forestry have been undertaken which include a Welsh study by Bateman et al. (2006), an Irish study by

Clinch (1999), an input-output study on the effects of forestry in rural Scotland by Thomson and Psaltopoulos (2005), an Australian study by Loane (1994) and a CBA undertaken in new Zealand by Middlemiss & Knowles (1996).

The aforementioned studies were undertaken at national or regional level – few studies have been undertaken at the farm level. In Australia however, where most afforestation is undertaken on previously agricultural land, studies undertaken by Kubicki et al. (1991) and Herbohn et al. (2009) examine both the economic returns to forestry and the farm level agricultural opportunity cost of land conversion to forestry.

Economic literature

The most comprehensive economic analysis of forestry in Ireland was undertaken by Clinch (1999) who carried out a comprehensive Cost Benefit Analysis (CBA) to assess the magnitude of both timber and non-timber costs and benefits of afforestation in Ireland. Using the 1996 forest strategy (DAFF 1996) as a case study, Clinch employed the Total Economic Value (TEV) framework to assess the Net Social Benefit (NSB) by bringing together the costs and benefits of timber and non-timber elements of forest production and adjusting for time using five test discount rates. The non-timber costs and benefits assessed included landscape, wildlife, recreation, carbon and water. The 1996 strategy shows a return of 4% which is below the Government test discount rate of 5%. At a 5% discount rate, a best case NSB of £343 million results from historically high timber prices and a high carbon price, while a worst case scenario results in a NSB of minus £565 million (Clinch 1999). Clinch questions whether the social benefits of the strategy justify the level of subvention. While Clinch did not take into account the opportunity cost involved in converting land from agricultural enterprises to forestry, he did state the need to address the question of whether forestry is a more viable prospect for farmers than an alternative land use.

In 2004, the Irish government commissioned a comprehensive policy review for Irish forestry. Among other issues, the ensuing report addressed the question of how best to incentivise farmers to undertake afforestation (Bacon 2004). The report cited an analysis undertaken by Behan and McQuinn (2005) which utilises Teagasc National Farm Survey (NFS) data to examine the relative returns from forestry and other agricultural enterprises. This analysis found that forestry returns would not be

competitive with dairy enterprises and would only be marginally greater than tillage. However, forest returns would be competitive with cattle and suckler enterprises in all regions of the country except in the south east, where they were similar. While the study did not consider the opportunity cost faced by farmers in foregoing income from existing farm enterprises when considering the decision to plant, it did however, include an estimate for the opportunity cost of labour that would have been necessary for agricultural production but is freed up as a result of planting.

In the most recent CBA of forestry in Ireland, Barwise (2009) considered an assessment of government support for afforestation. This study focused on the timber, carbon and recreation values of forests but did not address the land use change and opportunity cost issues.

As part of a wider economic analysis of forestry, a study conducted in Wales by Bateman et al. (2005) was one of the first to examine a case study concerning woodland, agriculture and a CBA of the land use change. Firstly, the recreational value of woodland was estimated by appraising methods for the monetary evaluation of woodland recreation and a review of Geographic Information System (GIS) based analyses which transferred results to the case study area. Secondly, newly estimated timber yield models were extended to include the net benefits of carbon sequestration provided by forests. Thirdly, the opportunity cost of converting land from agriculture to woodland was examined.

This was undertaken by collecting individual farm-level cost and revenue data during 1989/90 on a representative sample of 571 farms as part of the Farm Business Survey of Wales (FBSW). Biophysical characteristics such as agro-climatic variables were extracted from the LandIS database and supplemented with elevation datasets. The matching of the farm and biophysical databases was difficult as the resolution of the databases was different; however it allowed for a generalised characterisation of the biophysical environment faced by each farm. Models of both farm-gate and social values of production were presented for the dominant farming types and finally, the preceding analyses were synthesised through cost-benefit analysis of potential conversion of land from agricultural production to forest. Bateman's GIS approach was novel in that it allowed for the incorporation of biophysical data within the economic modelling of output values. This work added considerably to the

understanding of the role of economic factors within the biophysical constraints imposed by the environmental conditions and geographical location of individual farms.

In examining economic returns from farm afforestation, McKillop and Kula (1988) and McCarthy et al. (2003) find that the profitability of agriculture and forestry are significant factors in determining afforestation rates. Collier et al. (2002) find that the main reasons to plant are the attractiveness of afforestation premiums payable on land not suitable for agriculture. In an analysis of farm forestry versus other farm enterprises, Behan (2002) finds that the uptake of afforestation lagged behind what would be expected on the basis of the relative economic returns between agriculture and forestry but noted that “the long term and irreversible nature of the afforestation decision make it difficult to compare forestry returns with annual agricultural returns”.

In an attempt to compare like-with-like, Breen et al. (2010) address the opportunity cost of a superseded agricultural enterprise by including the agricultural income foregone as an opportunity cost for each year of the forestry rotation in estimating the returns to forestry in Ireland. This study uses a Discounted Cash Flow (DCF) methodology to calculate the net returns from three afforestation options - Sitka spruce (*Picea sitchensis* (Bong.) Carr), ash (*Fraxinus excelsior*) and a mixture of Sitka spruce and ash. The forest income streams are generated using average farm management data (Teagasc various years). The income foregone from grazing rental, spring barley, winter wheat, lowland sheep and store to finished beef enterprises were estimated using the authors' farm model. The analysis shows that the greatest net present value (NPV) arises when a farmer converts from store to finished beef to a Sitka spruce forest.

This is consistent with NFS survey data from 2007 which shows that almost half of the farmers who state an intention to plant within the next three years are livestock farmers (cattle rearing and cattle other) on relatively large farms (Ryan et al. 2008). These findings are also consistent with the results of an economic analysis conducted by Upton et al. (2012), who find that a change in land use from agriculture to forestry is most financially beneficial for cattle systems.

Although standard economic measures examine profitability over a full rotation, the role of subsidies has also been recognised as central to understanding afforestation rates. While reporting on a drop in annual planting in 1992, duQuesne Ltd. (1993) concludes that the gains from increased forestry subsidies were eroded by the availability of animal subsidies, which encouraged farmers to increase their stock numbers

Collier et al. (2002) report that particularly since the reform of the Common Agricultural Policy (CAP) in 1992, the majority of farmers retained their land in agriculture to avail of agricultural subsidies. They further note that the main reasons that farmers had not planted were that (a) they might need to maintain agricultural production to be eligible for extensification payments⁴; (b) they were waiting to see if grants and premiums will be improved; and (c) they were waiting to see what (policy) changes would emerge in the future. Collier et al. (2002) conclude that uncertainty around EU (Fischler) proposals and conflicts between agricultural and forest policies were forcing farmers to adopt a wait and see approach rather than committing to long term afforestation.

McCarthy et al. (2003) examine factors influencing the afforestation decision such as planting grants and forest premiums as well as the returns available from harvesting. They find that the rate of afforestation is sensitive to both forestry and agricultural subsidies, particularly to the Rural Environment Protection Scheme (REPS) which was introduced in 1994. The study further finds that that increasing the up-front payments i.e. the planting grant, is a more cost-effective measure for increasing the rate of private planting than increasing the level of the longer term forest premium. These findings were similar to those reported by Barrett and Trace (1999) who used aggregate national data in a time series regression and found that agricultural and forest subsidies had an impact on both land prices and land use in Ireland.

In comparison to the effect of subsidies on the planting decision, McCarthy et al. (20013) also note that the effect of the financial returns from timber sales, while statistically significant, is relatively low and conclude that this is perhaps because it could take 40 years or more to realise these revenues. Other factors not considered by

⁴ Payments for farming extensively (at a low livestock density) – reduction of the agricultural land area due to afforestation could have increased the livestock density above the threshold. See Chapter 4 for more detail.

the authors are the lack of knowledge of the value of timber and the economic returns to forestry already highlighted in the literature (Greene 2009; Ni Dhubhain 2010; Upton 2015).

Behavioural literature

Traditional economic theory suggests that individuals make decisions based on the expected change in their level of “well-being”, where the technical term used for well-being or welfare is utility (Edwards-Jones 2006). Given that utility is a difficult concept to measure, economists have often made the simplifying assumption that money can act as a substitute for utility. This has led to the situation observed in many agricultural economic models where farmers will act in all circumstances to maximise profitability (Edwards-Jones 2006). However, the Random Utility Maximisation (RUM) and Discrete Choice methodologies employed by McFadden (1973) and Ben-Akiva and Lerman (1985), incorporate the value of leisure time as a component of utility. While these methodologies have been used in other land-use and farming contexts (Becker 1993; Kimhi 2004; Ahearn et al. 2006), there appears to be a dearth of RUM/ Discrete Choice studies that deal with afforestation.

The role of wellbeing in public policy is evidenced by the relevance of objective wellbeing measures in setting government targets and monitoring change (Gilbert et al. 2016). However, according to Shucksmith 2009), the incorporation of subjective measures can assist in understanding societal wellbeing. In the context of rural wellbeing, subjective wellbeing evaluations are increasingly being utilised to assess wellbeing (Shucksmith et al. 2009; Gilbert et al. 2016).

While utility maximisation accounts for more than just the economic dimension, there is a growing literature that suggests that the heterogeneous nature of the farming population makes for even more complex behaviour which is influenced by a broad range of socio-economic and psychological variables (see Willock et al. 1999a, 1999b, for a review of this literature).

The reality and the uniqueness of the Irish afforestation context is complex. Malone (2008) outlines this complexity in listing common themes that impact levels of afforestation which are peculiar to the Irish context. These include the value of land; the need for land for farming purposes; historical negative attitudes to forestry;

environmental conditions attached to afforestation; the requirement to re-afforest and a lack of forest culture. The complexity of the Irish context relates also in part to an absence of a farm forestry tradition within agriculture. This translates into a lack of economic knowledge in relation to the returns to afforestation and a lack of management expertise in relation to appropriate management (silviculture) of forests. These barriers are further compounded by evidence to indicate that where opportunities afforded by forestry development exist, these are very often overlooked or dismissed by farmers due to attitudinal factors such as emotional attachment to the land and/or negative attitudes around the perception of failure in farming (Malone 2008).

Attitudinal literature

Attitudes have been described by Willock et al. (1999a) as “a positive or negative response towards an attitude object (where an attitude object may be a person, idea, concept or expressed by evaluating a particular entity with some degree of favour or disfavour”. Forestry has traditionally not been seen as an integral part of traditional agriculture and most farmers consider forestry only as an alternative land-use for their worst land (Ní Dhubháin and Gardiner 1994). Negative cultural attitudes towards forestry have also been widely reported in other countries. In a study conducted in Finland, Selby and Petajisto (1995) find that there is a perception that converting land to forestry can sever the dynamic historical process involved in the creation of agricultural landscapes and thereby have a negative effect on local communities. Similarly in the UK, Watkins et al. (1996) find that most farmers do not want woodland on their farmland, as they see their land as being exclusively a preserve for agricultural production.

Early attitudinal surveys conducted by Ni Dhubhain and Gardiner (1994) find that Irish farmers are largely unwilling to plant land. Of the 10% of farmers surveyed who stated an intention to plant, 58% said that their land was “good for nothing else” while 39% of those who would not plant said they did not have suitable land (i.e. they felt their land was “too good for forestry”). Similarly O Leary et al. (2000) found that the main reason behind farmers’ negative attitudes towards forestry was not dissatisfaction with the low financial rewards, but rather a negative cultural bias towards forestry.

Frawley and Leavy's (2001) study of farmers' primary motivations for not planting indicates that 88% of the farmers surveyed were not considering afforestation. Of those who stated they would not plant, 51% perceive the main difficulty with farm forestry as being due to the small size of their land and/or needing their land for other forms of production. Elands and Wiersum (2001) and Elands et al. (2004) suggest that the notion of 'failure' or needing the land for other uses often relates to the "historic conviction of farmers that the removal of forests enabled the creation of productive lands".

Malone (2008) attributes the Irish reluctance to afforest land to the fact that forestry was seen as a land use for poor or marginal land and "a departure from traditional agriculture". However Malone also suggests that it is important to highlight the fact that a "decision to convert a parcel of land or a farm to a forest is not a decision taken in isolation but is based on a variety of factors, family and personal circumstances as well as the relative attraction of premiums available (as well as being) a major long term decision which is irreversible and removes other options for land use has implications for (this) generation and ... the next generation (and) impacts neighbours and or a locality".

In Ireland farmers are encouraged by financial incentives to consider a land use change from a pasture or arable enterprise to forestry. Studies that examine farmers' attitudes towards afforestation in Ireland (Frawley and Leavy 2001; O'Leary et al. 2000; McDonagh et al. 2010; Ní Dhubháin and Gardiner 1994; Duesberg et al. 2013) cite reluctance to plant land that is "good" for farming. McDonagh et al. (2010) and Duesberg et al. (2014) find that the most important barriers to planting were the desire to farm and the reluctance to limit the future potential of land by locking themselves into a permanent land use choice such as forestry. Farmers interviewed by Duesberg et al. (2014) presented the most simplistic view, ascribing their reluctance to engage in forestry as "simply because it is not farming".

In summary, while much has been written about the diversity of landowners' motivations in relation to forestry decisions, there is a heavy focus in the international literature on decision-making in terms of the management of existing forests in relation to timber yield optimisation, or in relation to the impacts of deforestation. This literature largely relates to countries that have older natural forests. There is a

much smaller volume of literature that deals with the land use change from agriculture to forestry as this is only relevant in countries with predominantly plantation forests such as the British Isles, Australia, New Zealand, Chile, Argentina and Ireland. These are the studies which are most relevant to the Irish case as they largely represent the planting of fast-growing plantation forests on previously agricultural land.

In studies where the land use change to forestry has been explicitly considered, the focus tends to be on either the economic or socio-cultural aspects of the decision and few studies include the spatial and bio-physical characteristics of farms. A holistic examination of the decision-making process inherent in the consideration of planting agricultural land, data are required on farm incomes and soil types in order to incorporate an agricultural opportunity cost. It would appear from the literature that there are few forestry studies that have access to these agricultural data. Even those studies that incorporate opportunity costs do so at an aggregate level (Herbohn et al. 2009) or generate average values across farm systems (Upton et al. 20143).

To the best of our knowledge, only the Bateman (2005) study incorporates farm income data but the main focus of this study relates to spatial modelling of the biophysical characteristics of farm clusters and the farm level data utilised relate to one year only. However, the complex role of agricultural subsidies in farm incomes over time has to date precluded comparative analyses with forest subsidies. The inclusion of a spatial dimension which would allow for an assessment of the effect of soil type and forest location on afforestation patterns in Ireland over time has also not been studied in the literature.

In relation to economic behavioural analyses, the focus in the international literature is largely on profit-maximising behaviour however, it would appear from the qualitative studies conducted to date in Ireland, the UK and Europe, that there are many factors which affect the decision to plant, other than financial factors. To our knowledge, an examination of the afforestation decision in the context of a wider framework, which looks at both financial and non-financial determinants of the happiness or “utility” derived from a land use change from agriculture to forestry, has not previously been undertaken in the international literature.

While there are commonalities in relation to farmers attitudes around the adoption or non-adoption of afforestation in the UK and Northern Europe in particular, due to our

history in relation to land tenure and also in relation to the heterogeneous nature of the Irish farming population, it is likely that attitudes towards forestry in Ireland may be different to those in other countries. There is little information on (a) whether Irish farmers are likely to plant in future and (b) the level of financial incentives necessary to overcome the cultural and attitudinal barriers that exist around the land use change to forestry. In addition, there is little information available to policy makers in relation to the characteristics and motivations of the farmers who have overcome these barriers to plant some of their land.

1.4 THESIS OBJECTIVES

The objective of this thesis is to fill existing gaps in the literature. At a high level, there is an information gap in relation to understanding how the biophysical and policy environments affect the relative returns to both agriculture and forestry. There is also a gap in relation to how heterogeneous farm and farmer characteristics and attitudes can affect farmers' motivations in relation to afforestation, given their specific farm and environmental characteristics. In relation to the behavioural literature, it appears that there are not any utility maximising behavioural studies that deal specifically with the land use context. In addition to investigating these gaps, an exploration of whether the afforestation decision may actually involve a more complex interaction of economic, bio-physical and socio-cultural/behavioural factors than has been previously considered, could add significantly to the literature.

Using Ireland as a case study, this thesis sets out to investigate the interaction of the economic, bio-physical and socio-cultural/behavioural components of the afforestation decision using farm level data, over almost 30 years from 1984 onwards. Focusing primarily on the complexity of the afforestation decision at individual farm level and the relative importance of the economic, bio-physical and socio-cultural/behavioural factors, the following questions will be addressed:

Q: Does the soil type and/or spatial location of proposed afforestation areas have an impact on trends in planting and the likelihood of future planting?

Q: Has the relativity between agricultural and forest subsidies over time contributed to declining afforestation rates?

Q: Do different optimisation outcomes arise in relation to forest income streams depending on underlying agronomic management practices or economic afforestation objectives?

Q: How does the agricultural opportunity cost impact on the net revenue from farm afforestation on different farm systems, with different biophysical conditions?

Q: Q: Is Irish farmer behaviour in relation to the afforestation decision consistent with the economic theory?

Q: Is there a difference between the farm and farmer characteristics of those who have and those who haven't planted and between those who and wouldn't consider planting?

Q: Would an analysis of the change in intensity of farming after planting reveal information on the motivation for afforestation?

Ultimately, these research questions require the development of an infrastructure that allows us to develop a discrete choice model and to analyse the distribution of farms with/without forests over a long time period. Many of the data elements required to answer these questions relate largely to the changes that happen on farms when land is planted. These are represented graphically in Figure 1.4.

An analysis of the planting decision requires the generation of inter-temporal forest and agricultural income streams that include both market and subsidy components. Forest subsidy income streams are generated using a forest subsidy model while forest market income streams are generated using forest growth curves as part of a bio-economic model. Agricultural income streams are generated using time series farm level data from the National Farm Survey (NFS). Land and hours worked models are also derived using NFS data. The various models generate income streams for farms with and without forests as illustrated in Figure 1.5. An NFS longitudinal dataset provides observations on farm and farmer characteristics for farms with and without forests. Additional attitudinal data are provided by an NFS supplementary survey conducted in 2012, which included questions on farmers' attitudes in relation to afforestation.

Figure 1.4 Expected change in components of income, land value and hours worked: No Plant vs Plant

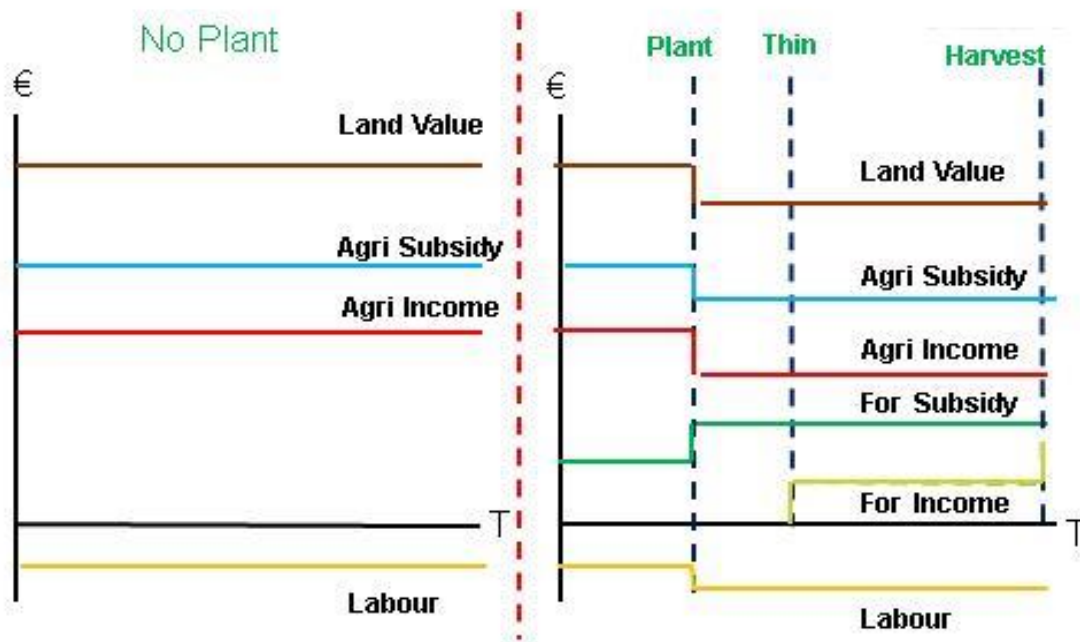
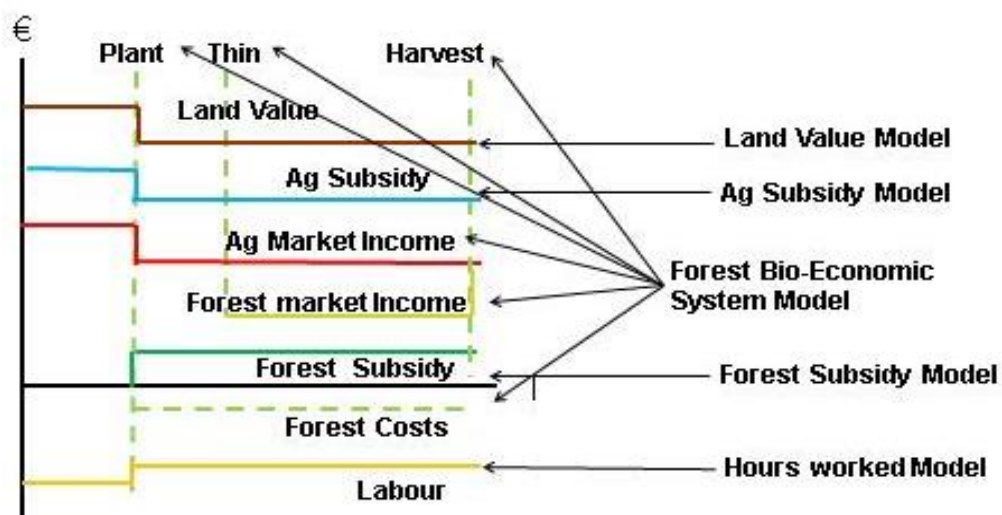


Figure 1.5 Model infrastructure



1.5 STRUCTURE OF THESIS

Chapter 1

This chapter presents the rationale, background literature and structure and contribution of the thesis. Each individual component of the data infrastructure required for this thesis is built up in individual chapters. These components are then amalgamated to facilitate more comprehensive analysis in later analytical chapters. Chapter 1 also presents the contribution of the thesis and the research already disseminated from this thesis.

Chapter 2

Chapter 2 begins with a historical overview of the policy context of afforestation in Ireland. This chapter serves three purposes. Firstly, it chronicles the increasing importance of forestry in government policy from the foundation of the Irish State to the present day, as represented by the increasing magnitude of incentive payments over the period. Secondly, this chapter chronicles changes in eligibility, conditions and payments that allow us to parameterise historical forest subsidies over the period 1984 to 2014. In addition, this chapter also details the agricultural subsidies available to farmers during the period. This information forms the basis of a subsidies model (developed in Chapter 4) with the capacity to model historic and future forest subsidies. Thirdly, this chapter presents a policy narrative of the qualitative and quantitative studies which have specifically influenced the uptake of afforestation in Ireland and puts forward areas for further consideration in this thesis.

This chapter pulls together the policy information in relation to both agricultural and forest subsidies which forms the basis of the journal article which is further developed in Chapter 4.

Chapter 3

This chapter examines the importance of physical site characteristics in understanding land conversion to forestry and investigates whether the proportion of poorer quality soils in an area has an effect on afforestation rates. Overall the analysis in this chapter highlights the potential for economic and physical spatial data to be combined in a meaningful way to understand spatial variations in annual land conversion to forestry.

This analysis also highlights the importance of land availability in policy development and of potential conflicts between policies with similar goals. The spatial analysis for this chapter was undertaken by the contract researcher working on the FIRMEC project, (who is thus first author on the papers relating to this chapter), in conjunction with the primary thesis supervisor. The background analysis, coordination and writing of this chapter were undertaken by the thesis author (FIRMEC project PI). A published journal article and a conference paper arise directly from this chapter:

Upton, V., O'Donoghue, C. and Ryan, M. 2012. A spatial model of afforestation in Ireland. Presented at the Agricultural Economics Society of Ireland Annual Conference 2012, Dublin.

Upton, V., O'Donoghue, C. and Ryan, M. 2014. The Physical, Economic and Policy Drivers of Afforestation in Ireland. *Journal of Environmental Management* 132. pp 79-86.

Chapter 4

Chapter 4 examines the reported policy conflicts between agricultural and forest policies over the period 1984 to 2012. Here the focus is on just one component of the farm afforestation decision i.e. the relativity of forest and agricultural subsidy payments. Based on the parameters developed in Chapter 2, a forest subsidy model is built which feeds into a “typical farm” subsidy model. Using hypothetical micro-simulation, the agricultural and forest subsidies that would have been available to cattle farmers in each year over the period are generated, allowing us have a greater insight into the choices (in relation specifically to the subsidy trade-off) confronting farmers contemplating afforestation. The following journal article relates to the work undertaken in Chapters 2 and 4:

Ryan, M., McCormack, M. O'Donoghue, C. and Upton, V. 2014. The role of subsidy payments in the uptake of forestry by the typical cattle farmer in Ireland from 1984 to 2012. *Irish Forestry* Vol. 71 Nos 1&2, 92-112.

Chapter 5

The objective of this chapter is to develop a forest bio-economic model with the capacity to model different afforestation and forest management choices with

consequentially different optimal financial rotations to inform an increasingly important sector in which prices and policies are changing over time. The biophysical theory underpinning forest growth is reviewed, in order to understand how output can be manipulated. Next the scientific literature on forest bio-economic models is reviewed in order to inform the assumptions necessary to model the relevant choices. The assumptions and data needed to develop such a model are justified and illustrated with descriptive statistics. Growth, cost and income curves are generated by species, yield and management scenarios for different optimisations and expressed in terms of Net Present Value (NPV). Finally, sensitivity analysis is conducted on the results and discussed in relation to afforestation targets and evolving forest policy. This chapter is synthesised in the following journal article:

Ryan, M., O'Donoghue, C. and Phillips, H. 2016. Modelling financially optimal afforestation and forest management scenarios using a bio-economic model. *Open Journal of Forestry*. Vol 6. No. 1.

Chapter 6

This chapter focuses on the calculation of the opportunity cost incurred by farmers considering afforestation in any given year of the time period under examination (1985-2013). The relative return to one hectare of either agriculture or forestry is examined by disaggregating the market and subsidy components of income. Both short and long term average agricultural income measures are calculated. To compare long-term forestry and annual agricultural incomes, a temporally comparable metric is necessary. Using the forest bio-economic model described in Chapter 5, Annual Equivalised (AE) NPV's are generated for both the forest and agricultural average incomes.

Excerpts from this chapter have been included in a Forest Service DAFM promotional campaign and in a popular article in the Irish Farmers Journal Autumn Forestry Supplement: "Take a long term view when considering farm forestry."

Chapter 7

Chapter 7 focuses on the economic theory surrounding the behavioural aspects motivating the afforestation decision. The life-cycle, random utility maximisation, discrete choice model described in this chapter brings together the infrastructure

described in previous chapters. Using the time-series dataset of farms with and without forests, the parameters of a discrete choice model of the decision to afforest part of a farm are estimated. Counterfactual forest income streams for farms that didn't plant forests are generated and counterfactual agricultural income streams are generated for farms with forests. This information is used to estimate the parameters of a choice model which examines the impact of NPV of income, land value and hours worked on farmers' utility (for a range of afforestation choices ranging from 0% to 50% of the farm area). Peer-reviewed conference papers from this chapter were presented as follows:

Ryan, M., O'Donoghue, C. and Upton, V. 2014. Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers. Paper presented at European Association of Agricultural Economists. Ljubljana, Slovenia. 25-28th August 2014.

Ryan, M., O'Donoghue, C. Upton, V. 2015. Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers. International Association of Agricultural Economists. 2015 Conference, August 9-14, 2015, Milan, Italy. <http://purl.umn.edu/212285>.

A journal article based on these conference papers is currently in preparation.

Chapter 8

The final analytical chapter goes beyond the average analysis conducted in Chapter 6, to examine the distribution of farms in the time-series dataset, in order to capture more of the heterogeneity of farm and farmer characteristics in the farming population. This allows for an examination of the relativity of forest and agricultural income streams in relation to a range of characteristics which include soil class, farm system and farm size. In addition, the effect of farmer characteristics such as age, hours worked on-farm and off-farm income are assessed. A binary logit model is estimated for the characteristics of the farms/farmers whose life-cycle forest income streams are greater than the agricultural income streams, in relation to whether they have forests or not. In addition, the characteristics of farms/farmers who might or who will never consider afforestation are examined. Finally, the wider decision-making context of the afforestation decision on farms with forests is examined by analysing

livestock density changes in the year of planting. Conference papers based on this chapter were presented as follows:

Ryan, M. and O'Donoghue, C. 2016. Heterogeneous Economic and Behavioural Drivers of the Farm Afforestation Decision. Conference paper presented at 18th BIOECON conference. Kings College, Cambridge. September 14-16. http://www.bioecon-network.org/pages/18th_2016/Ryan.pdf.

Ryan, M., O'Donoghue, C., Upton, V., Phillips, H. and Farrelly, N. 2013 Modelling Inter-temporal Differential Returns to Agricultural and Forestry Land Use. Paper presented at 87th Conference of the Agricultural Economics Society, University of Warwick, UK. 8-10 April.

Chapter 9

The final chapter draws together the overall conclusions of the thesis. The concluding chapter also presents a suite of potential options that could be considered by policy makers in seeking to incentivise further afforestation in:

Ryan, M. and O'Donoghue, C. 2016. Socio-economic drivers of farm afforestation decision-making. Irish Forestry. In print.

1.6 CONTRIBUTION OF THESIS

This thesis was undertaken as part of a Teagasc funded research project on Forestry Economics in conjunction with a DAFM funded COFORD (Programme for Competitive Forestry Research for Development) project: "Forestry in Ireland – Modelling its Economics (FIRMEC)". While the research examines discrete biophysical, economic and attitudinal/behavioural factors, it is the interaction of these factors in the whole farm context that reveals the heretofore unrealised extent of the barriers to farm afforestation. The individual components of the thesis either address issues that have not previously been addressed in the literature, or deepen the analysis to examine previously identified issues at individual farm level. However, it is also the holistic whole farm view adopted in this thesis that reveals barriers and potential solutions for policy makers aiming to incentivise increased afforestation levels. Many of the findings of this thesis have already influenced policy in relation to farm

afforestation in Ireland. Journal publications, conference presentations and other dissemination activities arising from this thesis are also listed in this section.

The collation of detailed information on forest policy instruments over the period examined allowed for the parameterisation of these policies in the (ForSubs) model which feeds into the Teagasc Typical Farm Subsidy Model to examine the relativity of forest and agricultural subsidies. This is a complex area which has not previously been addressed.(see Ryan et al 2014a).

The issue of the impact of soil quality and the spatial location of forests on the uptake of afforestation was addressed by the FIRMEC project team which included a contract researcher, the thesis author and the primary thesis supervisor. The combination of spatial and temporal methodologies employed in this study has not previously been used in an Irish afforestation context (Upton et al. 2014)

The early FIVE model was originally designed as a forest extension tool to provide more information on the economic returns to farm afforestation. The development of the static ForBES model is described in sufficient detail to allow for replication and/or adaption in future. The ForBES model is unusual in that it is designed to be useful for both research and extension purposes (Ryan et al. 2013; Ryan et al. 2016a);

The discrete choice analysis is a novel contribution to the literature which progresses the field of study by estimating the parameters of a utility function for farm afforestation for the first time. There are limitations to the methodology and it could be improved in the future by extracting more information on the levels of utility, but the qualitative conclusions are unambiguous: farmers derive utility from agricultural income, land value and time spent farming – they like to farm. Feedback from conferences has been very useful in refining analysis (Ryan et al. 2014b; Ryan et al. (2015);

It would appear from the literature that an in-depth analysis of the heterogeneous distribution of livestock farms and their characteristics across the farming population, has not previously been conducted in the afforestation context. The large proportion of farmers who will not consider afforestation regardless of the financial incentives involved, is an important finding of this analysis. This analysis suggests possible typologies of farmers who might plant on the basis of their long-term motivations, as

revealed by the changes they make in relation to their level of agricultural intensity in the year of planting. An early version of this analysis was presented at the AES conference in 2015. Feedback received at the conference has been incorporated into the thesis (Ryan et al. 2015b).

Contribution of thesis to policy formation

Over the course of the research, the author has been invited to present thesis outputs to a number of policy makers:

- Invited presentation to COFORD Land Availability Working Group. Afforestation Barriers – Economics and Behaviour. Ryan, M., Upton, V., O'Donoghue, C., 2012. September 13 2012.
- Ryan, M., Kinsella, A. & Upton, V. 2014c. An examination of studies of the financial and attitudinal factors affecting the farm afforestation decision. A report prepared for the Forest Service, Department of Agriculture, Food and the Marine. Unpublished confidential report.
- Connolly et al. 2015. Input to Teagasc submission to Government in relation to a potential “Carbon Link” scheme re tax relief/ghg offsetting. Ryan, M. October 2015.
- Invited Presentation to RDS IIEA Leadership Forum on Climate Smart Agriculture on issues surrounding the use of afforestation as a greenhouse gas mitigation tool. Ryan, M., April 16 2015.
- Presentation of thesis summary to Senior Management in Forest Service, DAFM. Ryan, M. and O, Donoghue, C. Agriculture House. March, 2016
- Invited presentations to COFORD Council Land Availability Working Group. Ryan, M. and O'Donoghue, C. April 2016 and June 2016.
- Invited presentation to National Treasury Management Agency. Ryan, M. and O'Donoghue, C. May 2016.

Contribution of thesis to literature: Articles and Conference Papers

- Ryan, M., O'Donoghue, C. Upton, V., Phillips, H., Farrelly, N. 2013. Modelling Inter-temporal Differential Returns to Agricultural and Forestry Land Use using the Forest Investment and Valuation Estimator (FIVE). 2013. Agricultural Economics Society 87th Annual Conference, April 8-10, 2013, Warwick University, Coventry, UK. <http://purl.umh.edu/158854>.

- Ryan, M., McCormack, M. O'Donoghue, C. and Upton, V. 2014a. The role of subsidy payments in the uptake of forestry by the typical cattle farmer in Ireland from 1984 to 2012. *Irish Forestry* Vol. 71: 1&2, pp. 92-112.
- Ryan, M., O'Donoghue, C. Upton, V. 2014b. Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers. 2014 International Congress, August 26-29, 2014, Ljubljana, Slovenia. <http://purl.umn.edu/182753>.
- Ryan, M., O'Donoghue, C. Upton, V. 2015b. Heterogeneous Economic and Behavioural Drivers of the Farm Afforestation Decision. *Agricultural Economics Society. 89th Annual Conference. University of Warwick, Coventry, UK. 13 - 15 April 2015.* <http://purl.umn.edu/204237>.
- Ryan, M., O'Donoghue, C. Upton, V. 2015a. Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers. *International Association of Agricultural Economists. 2015 Conference, August 9-14, 2015, Milan, Italy.* <http://purl.umn.edu/212285>.
- Ryan, M., O'Donoghue, C. and Phillips, H. 2016. Modelling financially optimal afforestation and forest management scenarios using a bio-economic model. *Open Journal of Forestry. Vol 6. No. 1.*
- Ryan, M. and O'Donoghue, C. 2016. Heterogeneous Economic and Behavioural Drivers of the Farm Afforestation Decision. Conference paper presented at 18th BIOECON conference. Kings College, Cambridge. September 14-16 2016. http://www.bioecon-network.org/pages/18th_2016/Ryan.pdf
- Upton, V. O'Donoghue, C and Ryan, M. 2014. The physical, economic and policy drivers of land conversion to forestry in Ireland. *Journal of Environmental Management* 132. Pp. 79-86.
- Ryan, M. and O'Donoghue, C. 2016. Socio-economic drivers of farm afforestation decision-making. *Irish Forestry. In print.*

Additional publications associated with thesis

An early version of the opportunity cost of superseded agricultural opportunity costs analysis was published by the FIRMEC team in *Irish Forestry*:

- Breen, J., Clancy, D., Ryan, M. and Wallace, M. 2010. Irish land use change and the decision to afforest: an economic analysis. *Irish Forestry* 67: 6–20.

Comprehensive analysis of the attitudinal barriers to farm afforestation was published by the FIRMEC team in *Irish Forestry and Ecological Economics*:

- Howley, P., Hynes, S., O'Donoghue, C., Farrelly, N. and Ryan, M. 2012. Farm and farmer characteristics affecting the decision to plant. *Irish Forestry* 69 (1&2): 33-43.
- Howley, P., Buckley, C., O'Donoghue, C. and Ryan, M. 2015. Explaining the economic "irrationality" of farmers' land use behaviour: The role of productivist attitudes and non-pecuniary benefits. *Ecological Economics* (2015) pp186-193.

An average analysis of the returns to agricultural land conversion to forestry was published in 2013:

- Upton, V., Ryan, M., Farrelly, N. and O'Donoghue, C. 2013. The potential economic returns of converting agricultural land to forestry: an analysis of system and soil effects from 1995 to 2009. *Irish Forestry* 70 (1&2): 61-74.

Chapter 2. AFFORESTATION IN IRELAND – THE POLICY CONTEXT

2.1 INTRODUCTION

Historical context - State afforestation

Trees originally dominated the Irish landscape but the tree clearances initiated by Neolithic man continued until the late 19th century. By the time the Irish State was founded in 1921, the dominant land used was agriculture with just under 1% of forest cover. Since the founding of the State, Ireland's forest policy has undergone a number of significant changes in emphasis. Between 1921 and 1980, virtually all afforestation was carried out by the State with private planting accounting for just 3% of the total planting during that period. In the early years, the focus was on developing a strategic supply of home-grown timber. However, there was a stipulation that State afforestation could not compete with agriculture for land, which was reflected in a cap on the amount that the State could pay for land for afforestation. The Programmes for Economic Recovery in 1959 and 1964 confirmed the State planting of 25,000 acres (10,000 hectares) per year with a target of one million acres (400,000 hectares) (DAFM 2014a).

While the primary aim of Irish forest policy remained the achievement of self-sufficiency in timber supplies, broader policy objectives were also pursued. The social dimension around rural employment particularly in the western half of the country was gaining in importance. In relation to environmental conservation, both the European Conservation Year (1970) a Wildlife Act (1977) saw the introduction of policy initiatives to encourage public recreation in forests and the creation of the first woodland nature reserves in the country.

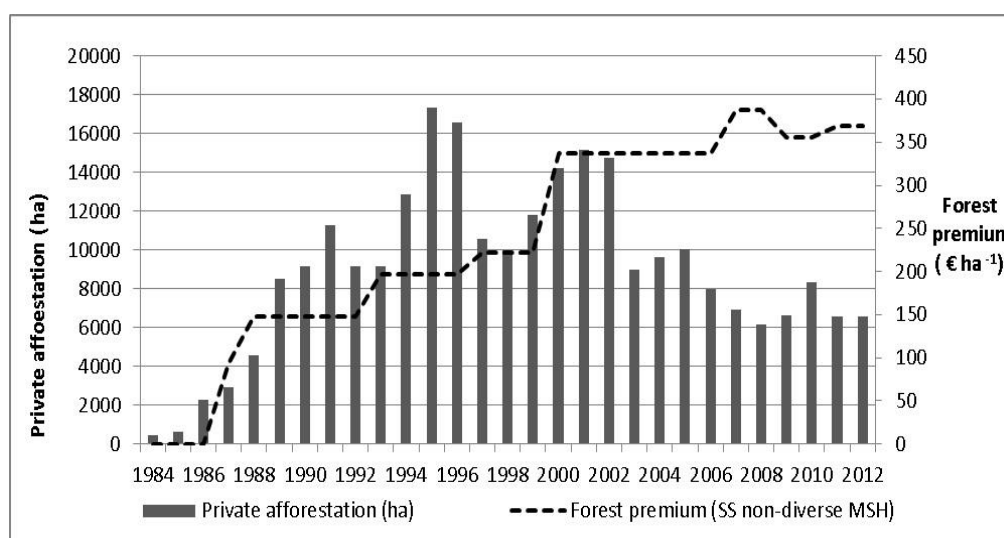
However, successive governments implemented a policy of non-competition with agriculture, reflected in a cap on the price payable by the State for land. This restricted the quality of the land that could be bought for afforestation and consequently restricting the timber productivity of these sites. Therefore, a large proportion of early State afforestation was carried out on peats and on mineral soils at high elevations with low timber yields. Ireland's entry to the EU in 1973 was marked by a downturn in afforestation as land prices soared and agriculture experienced a boom period. State afforestation continued albeit at a lower rate until 2006 when an

EU court decision ruled that Coillte (the State forestry board) was no longer entitled to EU subsidy payments to establish forests.

The afforestation conundrum

On the private afforestation front, after the almost exponential growth in afforestation levels of the mid 1990s, annual afforestation rates have been declining on a steady basis. This decline has generated much interest as it occurs against the back-drop of a series of increases in forest subsidies⁵ as illustrated in Figure 2.1. This seemingly contradictory trend has prompted a number of Irish studies that have examined the factors that led to the decline in annual private afforestation. These studies have focused largely on examining the behavioural and economic factors that could account for the fall-off in private afforestation.

Figure 2.1 Annual private afforestation (ha) and forest premium payments (€ ha⁻¹) for Sitka spruce non-diverse conifer plantations from 1984 to 2012.



Source: Forest Service (2014)

Attitudinal studies such as Kelleher (1986) and Ní Dhubháin and Gardiner (1994) find that the vast majority of farmers will only consider planting land that is “good for nothing else”. Frawley (1998) reasons that although farmers have economic goals when considering forestry, strong beliefs about the appropriate use of farmland can act as a barrier to afforestation. Duesberg et al. (2013) suggest that this is still the

⁵ Establishment grant and annual forest premium payments

case: while farmers in the study would plant marginal land, they would be opposed to planting “good” land that could be used for food production.

From an economic perspective, studies relating to afforestation of agricultural land in Ireland find that the profitability of agriculture and forestry are significant factors in determining afforestation rates (see McKillop and Kula 1988; Behan 2002; McCarthy et al. 2003; Breen et al. 2010; Upton et al. 2012). The duQuesne (1993) report on the uptake of afforestation notes that the value of the final timber crop was not often taken into account in the afforestation decision-making process and that “changes (or even anticipated changes) in subsidies have an immediate and demonstrable effect on the uptake of the forestry support measures”.

2.2 FOREST AND AGRICULTURAL POLICY IN IRELAND

The purpose of this section is to describe the changing policy context in relation to both forestry and agriculture over time. The information on forest and agricultural subsidies in this chapter was compiled as a result of an extensive trawl of official (Forest Service) documents, personal documents and old documents bequeathed by former colleagues. Where not otherwise referenced, information on subsidies is derived from these “grey literature” and unofficial sources. Initially the focus is on State funded incentives for private planting. This is followed by a discussion of the broader range of EU funded agricultural and forest policies. This information contributes to the development of a forestry subsidies model (ForSubs) which is detailed in Chapter 4. In relation to agricultural subsidies, this chapter focuses particularly on eligibility restrictions for cattle subsidies in relation to animal stocking rates and Less Favoured Areas (LFA). These are the parameters most likely to have an impact on the relativity of forestry and agricultural payments. The forestry and relevant cattle subsidy payments are summarised and presented in Table 2.2.

State funded private afforestation incentives

The first private afforestation incentives were introduced by the Irish government in 1922 but private forestry was not high on the agenda and was considered to be secondary to the State afforestation programme (Neeson 1991). Prior to the 1928 Forestry Act, which provided for the introduction of the State Scheme to encourage land owners to plant, by providing a grant of £4/acre (€9.89)/hectare (ha^{-1}), annual

private planting was as low as 200 acres (81 hectares) (Farrelly 2008). Changes to the State Scheme saw regular increases in the grant (from £10/ac in 1944, £20/ac in 1958, £50/ac in 1972, £90 in 1977 and £125 in 1979). However these increases led to only limited increases in the area planted. The mean annual planting over the period 1930-1979 was 193 ha (Gillmor 1998).

According to (Gillmor 1992) the low levels of planting prior to the 1980s were indicative of the existence of strong barriers to planting land. (Gillmor *ibid*) cites a long list of factors including the lack of familiarity with forestry, the association of forests with landlords, the competition for the scarce land resource, small farm size and the uncertainty around the long-term nature of forestry. An additional barrier was added to this list with Ireland's entry to the European Economic Community (EEC) in 1973. A series of EEC funded agricultural incentive schemes ensued under the Common Agricultural Policy (CAP), making it less likely that farmers would consider afforestation. While incentives for private sector were already in existence, the decline in State afforestation led policy makers to increase the incentives available for private sector afforestation, in order to achieve a target of one million acres.

From the 1980s onwards, developments in both national and EU forest policy led to the encouragement of farmer planting through a series of financial incentives, which led to an increase from 100,774 hectares in 1981 to 360,834 hectares of privately owned forests by 2012 (Forest Service 2013). Over this period, the nature of the incentives offered to farmers changed the afforestation programme in Ireland from being almost exclusively carried out by professional foresters in the State sector, to being almost exclusively carried out by a new forest owner type: farm foresters. Initially planting on private land was undertaken largely by forest contracting companies and investment institutions, however farm afforestation grew quickly and the majority of private planting is now undertaken by farmers (Forest Service 2014).

European Agricultural and Forest Policy

The origin of Ireland's current agricultural schemes dates back to accession to the EEC in 1973. The EEC introduced headage payments for livestock in 1975 under the first direct payment scheme. The main objective was to provide farm income support in disadvantaged areas. It was also the first EEC scheme with the objective of preserving the countryside, but this was to be achieved passively through maintenance

of the rural population. The Headage Payments Scheme was the first EEC direct grant aid to farmers in disadvantaged areas, and is still considered an important socio-economic support.

The Western Drainage Scheme was introduced in 1979 (EEC 1978). It had a target of 250,000 acres and an estimated cost over the 5 year period of over £40 million, half of which was financed by the CAP Guidance Fund. It was extended to operate until 1986 (EEC 1981). The Cross-Border Drainage Scheme was introduced in 1979 (EEC 1979). In 1980, the Ewe Premium Scheme, operating under the EEC Sheep Meat Regime, was introduced (EEC 1980a). The Suckler Cow Premium (EEC 1980b) was introduced in 1981. Land prices soared and agriculture experienced a boom period. Marginal land that had previously been available for afforestation was now subject to land reclamation and drainage works. The combined result of these schemes was a downturn in afforestation.

Western Package Scheme for Forestry

The introduction of the Western Package Scheme supported by EU Funding in 1981 saw the first of many initiatives to support afforestation by the private sector and in particular by farmers.

The ten year Programme for Western Development was introduced in April 1981 (EEC 1980c) with the aim of promoting development in the 12 western counties. The programme which became known as the “western package” was available to land-owners in all disadvantaged areas in the country as listed in EEC Directive 35/350. The grant was 50% funded by the EEC but this was increased to 70% EEC funding in 1988 and was subject to a maximum payment of £800 ha⁻¹. The grant was paid in two instalments, 75% on completion of planting and 25% after four years. The minimum area eligible for grant was two hectares for conifers and 0.25 ha for broadleaves. Provision was also made for the payment of forest road grants, subject to a limit of £12/linear metre. The grant was designed to cover 85% of establishment costs for farmers and 70% for non-farmers. The costs incurred in excess of the grant amount had to be carried by the landowner and were a disincentive to many farmers.

However, the increase in the level of grant led to a new phenomenon in Irish afforestation. Co-operatives, pension funds and private investors who were not

deterred by having to pay the balance of the afforestation cost, began to buy and afforest land in areas where agricultural productivity was marginal but forest productivity was high. According to Forest Service records and reports, in the first six years of the western package scheme, almost 6,500 ha were grant-aided, with the largest areas planted in counties Clare, Kerry, Roscommon, Leitrim and West Cork, respectively.

Concurrent with the western package scheme, the State Scheme initiated in 1931 was still available to both farmers and non-farmers, however the lower rate of £500 ha⁻¹ for conifers (and £800 ha⁻¹ for broadleaves) led to little uptake in comparison with the more lucrative western package payments.

On the agricultural front, the milk super-levy and milk quotas were introduced in 1984 (EEC, 1984) - the first major changes to the CAP since Ireland's entry to the EEC. Sheep and suckler cow numbers increased as a result, both supported by EEC direct payment schemes. In 1985, the EEC passed the Agricultural Structures Regulation (EEC 1985), under which the Farm Improvement Programme was introduced in 1986, which subsidised land improvement and on-farm development generally.

While there had been a marked increase in afforestation, take-up of the Western Package scheme was falling well short of the targeted 2,500 ha yr⁻¹ and a promotional campaign was launched in 1985 to increase awareness of the scheme. However, the records for 1986 show that of the 2,280 hectares planted, only 18% of the area was planted by farmers. Bulfin (1994) attributes this to the fact that the lack of short-term income was a disincentive to farmer planting. The Western Drainage Scheme, the Programme for Western Development ("Western Package"), the Cross-Border Drainage Scheme and the Farm Modernisation Scheme were the most significant CAP funded development measures during the late 1970s and early 1980s, and an EEC and a national interest subsidy. The milk super-levy and milk quotas were introduced in 1984 and sheep and suckler cow numbers increased as a result, supported by EEC direct payment schemes.

In 1985, the EEC passed the Agricultural Structures Regulation (EEC, 1985), under which the Farm Improvement Programme was introduced in 1986, which subsidised land improvement and on-farm development generally. While there had been a

marked increase in afforestation since the introduction of the Western Package, take-up of the scheme was falling well short of the targeted 2,500 ha yr⁻¹.

Forest Headage Scheme

A promotional campaign was launched in 1985 to increase awareness of the benefits of afforestation and this was followed by the introduction of the Farm Compensatory Allowances (Headage) Scheme which allowed farmers and farmer Co-ops who were in receipt of livestock headage payments in disadvantaged areas, to retain these payments after planting, for a period of 15 years. The compensatory allowance payable for forestry was £74.13 (€177) ha⁻¹ but was conditional on a reduction of livestock numbers from the last year preceding afforestation, for which livestock headage was paid. While the continuation of headage payments made afforestation more appealing to many farmers, the restriction on stock numbers acted as a disincentive for others. This scheme also limited the total livestock and forestry headage payments to £3,762 yr.⁻¹

The reform of the EC Structural Funds was completed in 1988, which included the CAP Guidance Fund. The reform resulted in Ireland being designated as an “Objective 1” region (highest priority for structural aid), thereby qualifying for a larger share of EC co-funding for agricultural programmes.

Operational Programme for Forestry

In 1988, family farm income was less than £5,000 on two-thirds of farms reflecting government concerns around the preservation of the family farm (Government of Ireland 1991). In the Less Favoured Areas in the Western part of the country, less than 25% of farms had an income of more than £5,000. One of the central Government policy objectives of this period was the preservation of the family farm (Government of Ireland 1990). The primary objectives of the OPF were to provide raw material,; diversify the rural economy, stimulate rural development, provide employment and promote the reform of agriculture (Department of Energy 1991). In line with these policy objectives, grants payable under the OPF continued to favour planting by farmers, who could claim 80% of costs, while non-farmers could only claim 70% (up to a maximum of £800 ha⁻¹ for unenclosed land, £900 for enclosed

land and £1,200 for broadleaves). However, the remaining up-front cost may still have been a disincentive.

The OPF further incentivised farmer afforestation by introducing a Forest Premium Scheme to compensate farmers for loss of agricultural income with annual payments ranging from £50 (€102) ha⁻¹ for conifers up to £116 (€261) ha⁻¹ for broadleaves (although the first premium was not paid until the first anniversary of planting). This scheme included a stipulation that off-farm income could not exceed £11,000 yr⁻¹ (average industrial wage as published by CSO), precluding households from availing of premiums if the spouse's income was above this threshold. Nevertheless, a major shift in planting from the public to the private sector occurred in response to the introduction of this scheme. Planting increased year on year (Table 2.1) and by 1989, the level of private planting exceeded State planting for the first time (DAFM 2013a).

Table 2.1 OPF Afforestation

Year	Hectares
89	3340
90	4000
91	8000
92	9134
93	9170

Source: duQuesne Ltd. (1993)

In 1989 the State's ownership role in relation to forests was transferred from the then Forest and Wildlife Service to Coillte Teoranta (Irish State Forestry Board), which was established under the 1988 amendment to the Forestry Act, with a mandate to carry on the business of forestry and related activities, on a commercial basis and in accordance with efficient silvicultural practices (Irish Statute Book 2014).

In 1990, the Department of Agriculture published its policy review (Government of Ireland 1990c). It anticipated further CAP reforms and a greater EC emphasis on direct payments and environmental sustainability. In July 1991, the Agricultural Structures Regulation and its amendments and the Less Favoured Areas Directive were consolidated by a new Regulation (EEC 1991b). This was a precursor to the 1992 CAP reforms: it included extensification, agri-environmental, forestry and set-aside measures as well as headage payments.

In July 1991, the Agricultural Structures Regulation and the Less Favoured Areas Directive were consolidated by a new regulation which was a precursor to the 1992

CAP reforms: it included extensification, agri-environment, forestry and set-aside measures as well as headage payments and led to speculation in the press that forestry payments would be increased and eligibility relaxed. This led to a decline in the number of applications for grant approval until a revised scheme was announced in early 1992 and back-dated to October 1991.

Revised Forestry Scheme

Under the revised scheme, maximum grant payments were increased to £900 ha⁻¹ for conifers on unenclosed land, £1100 for conifers on enclosed land and £2,000 ha⁻¹ for broadleaves. The off-farm income limit was increased to £13,900 in line with the average industrial wage as published by the Central Statistics Office (CSO 1992). In cases where the annual off-farm income was above this threshold, a payment of £50 (€102) ha⁻¹ for 15 years was introduced for both conifers and broadleaves. This was the first time that part-time farmers or farmers with off-farm income (above the threshold) could avail of annual premium payments. In the previous decade, agriculture had undergone major change but the reform of the CAP promised even more change ahead for Irish farmers and speculation continued concerning the impacts of CAP reform on the afforestation programme.

Policy issues pre CAP Reform

Since the CAP was founded in 1962, it had been the cornerstone of the Community, and absorbed about two-thirds of its budget by the early 1970s. Up until the CAP reforms of 1992, many Irish agriculture schemes and payments were supported through the CAP Guidance Fund. Under the Common Agricultural Policy (CAP) Reform Accompanying Measure, (MacSharry CAP reform) which was agreed in May 1992, prices and market supports for cereals and beef were significantly reduced, however increased compensatory payments were made available to cereal farmers and increased direct payments were made available to beef farmers on the basis of stocking rate reductions. An Extensification Scheme was made available for less intensive farmers. Sheep and suckler cow quotas were introduced. The MacSharry CAP reform also included an Agri-Environmental Scheme, an Early Retirement Scheme for farmers and an Afforestation Scheme for agricultural land.

Review of the uptake of afforestation

In advance of the implementation of the new afforestation scheme under the MacSharry CAP reforms, the Forest Service commissioned an evaluation of the forestry measures in Ireland in effecting change in land-use from agriculture to forestry between 1981 and the end of 1992. The evaluation reported the “almost exponential increase” of a net extra 90,000 ha of agricultural land (predominantly cattle and sheep grazing) that had been afforested (duQuesne Ltd. 1993). However, the report concluded that the positive impact of the forestry measures was being eroded by the availability of CAP and related support measures for conventional agricultural enterprises, particularly headage payments for livestock which were payable on the number of livestock held on the farm. Extensification payments at the time were payable up to a maximum stocking density of 1.4 livestock units (LU) ha⁻¹ but as the majority of farmers were stocked below these limits, they essentially had the option to increase stocking up to the maximum to increase their headage payments rather than plant “surplus” areas. The duQuesne report includes a recommendation that the premium payment should be increased considerably to make it competitive with agricultural payments. While the afforestation rate had increased year-on-year, the total area of 33,500 ha planted under the OPF had fallen well short of the target of 77,500 ha (Government of Ireland 1991), although the 1920s government target of one million acres (404,686 ha) of forest cover was finally reached in 1993.

The reform of the Common Agricultural Policy

In the previous decade, agriculture had undergone major change but the reform of the CAP promised even more change for Irish farmers and speculation continued concerning the impacts of CAP reform on the afforestation programme. Under the MacSharry Reform of the CAP which was agreed in May 1992, prices and market supports for beef were significantly reduced. However increased direct payments were made available to beef farmers on the basis of stocking rate reductions. Farmers in LFA’s could avail of these new payments while also continuing to avail of the LFA payments.

The “Accompanying Measures” in the CAP reforms included an Agri-Environmental Scheme (EEC 1992a), an Early Retirement Scheme for farmers (EEC 1992b), and an Afforestation Scheme for agricultural land (EEC 1992c). Extensification payments

were available to farmers with a livestock density below 1.4 LU⁶ ha⁻¹. In 1993, O'Connor and Kearney estimated that 71% of the grassland area of the state was stocked at less than the threshold stocking rate of 1.4 LU ha⁻¹. This meant that many farmers had the option to increase stocking to 1.4 LU ha⁻¹ to maximise their payments, rather than afforest surplus areas. The rate of afforestation was rising rapidly during the 1990s. According to Gillmor (1998), private planting made up 79% of annual afforestation by 1996, having risen from just 3% of all planting in 1921.

Agricultural and forest subsidies – post CAP reform

In May 1994, the Afforestation Grant Scheme and Forest Premium Scheme was introduced under EU Council Regulation 2080/92. Eligibility for the payments under this scheme was back-dated to include new forests approved for planting after August 1st 1992 and planted from January 1993 onwards. Both grant and premium payments were significantly increased and for the first time, this scheme provided a grant to cover 100% of the planting costs (up to set limits). Differential grant payment rates were introduced for a range of broadleaf/conifer mixtures (see Table 2.2 for more detail). Differential forest premium payments were introduced for LFA designations, i.e. higher forest premium payments were available for planting more productive land in non-LFA areas (£220 (€444) ha⁻¹) for non-diverse conifers, while the lowest payments were available on less productive MSH areas (£155 (€313) ha⁻¹). This new classification incentivised farmers who were not in receipt of disadvantaged area payments for livestock to plant better quality non-disadvantaged land.

Forest premium payments were also increased and eligibility criteria for availing of the higher farmer rate of premium became more restrictive. The payment to eligible farmers was calculated on the basis of compensation for loss of agricultural income. In order to qualify for these payments, landowners had to practice farming, own or lease 3 ha of land, derive at least 25% of their income from farming and live within 70 miles of the forest. These “guaranteed” 20 year premiums were not reckonable for income tax purposes. There was no longer any upfront cost to the farmer. Also, farmers who had planted in 1993 were able to avail of the higher payments retrospectively. All of these factors in combination led to a dramatic increase in the

⁶ Eligible LUs: Adult bovines over two years (except dairy cows) represent 1.0 LU; Dairy Cows, 0.8 LU; other Bovines 6-24 months, 0.6 LU.

level of private afforestation which saw private afforestation peak at 17,343 ha in 1995.

Rural Environment Protection Scheme (REPS)

On the agricultural front, REPS was launched in 1994. The scheme provided supplementary income for farmers for a period of five years in return for undertaking environmental measures. At this time, environmental issues in both agriculture and forestry were gaining in prominence culminating in the publication of the Heritage Council published a 'Policy Paper on Forestry and the National Heritage' which addressed a broad range of issues around species, biological diversity, water, archaeology, landscape and legislation (Heritage Council 1999).

The REPS scheme was of huge importance to rural Ireland and peaked with over 60,000 farmer participants, with average annual payments of approximately €5,000 (DAFM 2014b). However, as a land use policy measure, it was in direct conflict with the afforestation policy as farmers could opt for either REPS or afforestation payments on a plot of land, but it was only possible to draw down both payments on large farms in excess of the 40 hectare (later 55 hectare) area limit and this acted as a disincentive to afforestation for many farmers (McCarthy et al. 2003). Initial REPS payments of £119 ha⁻¹ were available for up to 40 ha⁷ and these payments were increased substantially in later REPS programmes. (Similarly, participation in the Early Retirement Scheme (ERS) precluded farmers from availing of afforestation premiums as retired farmers were no longer allowed to undertake farming activity and were thus not eligible for the farmer rate of premium for new planting.

National Forestry Forum

In 1996, a forum of forestry stakeholders was established by the then Minister for Agriculture to comment and advise on the future direction of the forest sector. The National Forestry Forum cited the forest premium payment as the most significant factor affecting the rate of farm afforestation, with the caveat that the uptake is "dependent on the agricultural subsidies and market prices available to farmers" (National Farm Forestry Forum 1996). One of the outcomes of the Forum was the

⁷ Teagasc Management Data for Farm Planning (various years)

need for a comprehensive strategy which would take on board the increase in afforestation by farmers, coupled with the growing importance of the social and environmental aspects of forestry and the demands of a growing timber processing sector.

A Strategic Plan for Forestry

This led to the publication of *Growing for the Future* (DAFF 1996), an ambitious Government strategy for the development of the forestry sector in Ireland. The afforestation strategy involved increasing forest cover from to 1.2 million hectares (17% of total land area) by 2030 in order to reach a scale of timber production large enough to support the growing range of timber processing industries. The strategy would achieve this aim by increasing afforestation levels to 25,000 ha yr⁻¹ to the year 2000 and 20,000 hectares per annum from 2001 to 2030. At the time, these ambitious targets did not seem implausible as private afforestation rates had reached a peak of 17,343 hectares in 1995 and only dropped marginally in 1996. However, private afforestation dropped to just over 10,000 hectares in 1997. Barrett and Trace (1999) found evidence in a time series analysis that the accompanying measures of the MacSharry reforms, in particular the Rural Environment Protection Scheme were reducing the rate of afforestation at this time. Indeed, they commented that the area of land that went into REPS in 1997 was 25 times the area that was afforested.

To encourage additional afforestation, a 13.5% increase across all categories of forestry subsidies was announced in late 1997. The farmer rate of premium then ranged from £175 (€318) ha⁻¹ for non-diverse conifers in MSH areas to £340 (€617) ha⁻¹ for broadleaf forests in non LFA's. For the first time, the issue of the small scale of farm forests was addressed by applying supplementary payments on forests over 6 and 12 ha respectively.

Until 1998, the first premium payment was made to the farmer one year after the date of completion of initial planting. From October 1998 onwards, the premium was to be paid in the year of planting and in the spring of each year thereafter. This was seen as a positive development as prior to this, farmers had no income from planted land within the first year. The next change in forestry payments came into being for the 2000 planting season and saw grant rates increase with a single rate of premium now payable for each species category, regardless of disadvantaged area status. In bringing

all of the disadvantaged area categories to one rate of payment, the largest increases were applied to the severely disadvantaged category which increased by £90 (€163) ha⁻¹ for a forest of less than 6 hectares whereas the non-disadvantaged area increased by £15 (€27) ha⁻¹. All land afforested since January 1993 was eligible for the new increased rates of payment. Additional payments of £10 ha⁻¹ and £20 ha⁻¹ were introduced for forests greater than 6 ha and 12 ha respectively to encourage the planting of larger blocks. Afforestation increased again in 2000 (14,231 ha) 2001 (15,147 ha) and (14,735 ha).

Decoupled payments

In a further reform of CAP, LFA payments were decoupled from production in 2001, and were replaced by a flat rate per hectare, known as area-based compensatory allowances. The distinction between MSH and LSH was continued and the highest Disadvantaged Area Scheme (DAS) payment was available in MSH areas.

The Single Farm Payment (SFP) was introduced in 2005 to further 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. Eligibility for payment was contingent on maintaining the land in “good agricultural and environmental condition” but did not require the farmer to continue to carry livestock. The average SFP for cattle farmers since 2005 was approximately €315 ha⁻¹ (DAFM 2014b). While the SFP was not payable on afforested land, it was possible to plant up to 50% of the farm holding and “consolidate” the Single Payment onto the remaining land without losing SFP but the land base eligible for future agricultural payments was reduced by the afforested area. In 2008, a regulation change obviated the need for consolidation as afforested land became eligible for payment. Thus from 2009 onwards, farmers already in receipt of SFP could continue to claim payment on afforested land without reducing the SFP eligible area. It was expected that this would lead to a considerable increase in farm afforestation, but this was not the case. Having increased annually to 2002, annual afforestation dropped back to 8,969 ha in 2003 and since then has been in the region of 6,000 to 8,000 hectares annually.

Anecdotally, the fear of losing future SFP has been a factor in the reticence of farmers to permanently commit land to forestry due to fears that a reduction in agricultural

area could endanger future area based payments. The phenomenon of farmers anticipating future developments and acting accordingly is recognised by Vellinga et al. (2013) in comparing standard static CGE models (in which agents only respond to past developments) with forward-looking models, in the context of assessing the impact of decoupling of farm payments. The upward trend in forestry subsidies continued through 2005 when forestry grant rates were increased with larger proportional increases for broadleaf categories. In 2007, grants were increased marginally and an increase of 15% was applied to forest premium payments. In an attempt to combat the competition between REPS and afforestation, the Forest Environment Protection Scheme (FEPS) was introduced in 2007, which allowed farmers currently participating in REPS to avail of annual payments (in addition to the forest premium) to establish more environmentally focused forests. However, since the closure of the REPS 4 scheme in July 2009, farmers are no longer eligible to apply for FEPS.

The Suckler Cow Welfare (SCW) payment introduced in 2008 was a coupled payment, paid on a per head basis. The scheme lasted until 2012 but payments were halved due to the large numbers of farmers wishing to join the scheme. The range of generous cattle subsidies over the period led to a large increase in suckler cow numbers of 162% to approximately 1.12 million cows between 1987 and 1998. The number of cows varied slightly in the interim but remained largely unchanged at 1.13 million cows in 2012 (McCormack and O'Donoghue 2014).

Reduction in forest premium

However, recession hit and the upward trend in payments came to an abrupt halt in 2009 when for the first time since the inception of subsidised private afforestation, payments decreased by 8% across all premium categories. This reduction in payments caused much concern in the sector and among landowners, in relation to the long-term security of what had been considered to be “guaranteed” payments and was expected to lead to a drop in the afforestation level. Yet, this was not the case as afforestation increased in 2010 by almost 700 hectares to 8,310. However, this apparent anomaly may be accounted for by the fact that 2009 was one of the worst farming years on record. The average Family Farm Income declined by 30% in 2009, on top of a 13.7% decline in 2008 income figures (Connolly et al. 2009). In the cattle systems in

particular, which were already heavily reliant on subsidies, the proportion of subsidy income increased to 204% of income in 2009 i.e. returns from the marketplace were not sufficient to cover total production costs. Despite an increase in planting in 2010, the annual afforestation area fell to just over 6,500 ha in 2011 and has remained at or below this figure in recent years (Forest Service 2014).

Revised targets

In recognition of the falling afforestation rate, the target was reduced to 14,700 ha⁻¹ in 2011 (DPER 2011). However in 2014, a review of Ireland's forest policy re-emphasised the importance of forestry in the provision of timber and non-timber benefits and introduced new targets of 10,000 ha⁻¹ to 2015 and 15,000 ha⁻¹ to 2046 (DAFM 2014a).

Over the period of this study, there were many policy changes in both forestry and agriculture which may have resulted in both incentives and disincentives for farmers to consider forestry. The summary of payments presented in Table 2.2 illustrates some of the complexity in terms of the relative eligibility and payment criteria (further detail on agricultural subsidies is presented in Tables 4.3, 4.4 & 4.5).

2.3 SUMMARY AND FUTURE DIRECTIONS

In the early 1990s, there was uncertainty and much speculation around the CAP reform process and how it would impact on farmers' incomes, both in terms of forestry and agricultural payments. This is reflected in a fall-off in planting after the CAP reform agreement in May of 1992, as some farmers delayed planting in the expectation of higher payments arising as a result of the CAP accompanying measures. Bulfin (1992, 1994) raised the necessity for improved grants and the introduction of an annual income if farmers were to be persuaded to plant, as they were not in a position to wait 15-20 years for the first income from the forest. This is echoed by duQuesne (1993) who conclude that the economics of farm forestry are determined by the availability of an adequate planting grant and an annual premium (subsidy) that compares favourably with agricultural returns. In addition, O'Connor and Kearney (1993) also conclude that "other things being equal, the expected returns from forestry must show a premium over the return from agriculture before landholders will seriously consider the forestry option." They also consider that

Table 2.2 Summary of historic conifer (Sitka spruce) and broadleaf (ash) forest premium payments with agricultural payments and subsidies⁸

Year	Forestry		Agriculture	
	Scheme	Forest premium (farmer)	Scheme	Subsidy payments
1975			Disadvantaged Area Payments	Headage (payment per head of cattle)
1981	Western Package Grant Farmers: 85% Others: 70%		More Severely Handicapped (MSH) area payments:	8 or less cattle: £32 per head (€121) 9-30 cattle: £28 per head (€136)
1987	Farm Forestry Scheme-max £24,000/farm	Forestry headage: £74 ha ⁻¹ (€177) 15 yrs		Max headage payments (livestock + forestry): £3,762 yr ⁻¹
1989	OPF/Forest Premium scheme Max: £6,000	£116 ha ⁻¹ (€261) Conifer (Con) (15 yrs) Broadleaf (20 yrs)		Off-farm income threshold for forestry and agricultural subsidies: £11,000 yr ⁻¹
1992	Revised scheme	As above + £50 ha ⁻¹ (€102) – part-time		Off-farm income threshold increased to £13,900 yr ⁻¹
1993	Afforestation Grant & Premium Scheme Grant: 100% Premium: 20 yrs	⁹ Con non-diverse (MSH): £155 ha ⁻¹ (€313) 75-100% ash (non LFA) ¹⁰ : £300 ha ⁻¹ (€606)	CAP Reform S. Cow : Beef 10 month: Beef 22 month: Extensification: Slaughter premium:	£79 per head (€159) £53 per head (€107) £53 per head (€107) £26 per head (€53) £53 per steer (€107)
1994			Rural Environment Protection Scheme (REPS)	1-20 ha: £120 ha ⁻¹ (€236)
1998	Revised CAP scheme 13.5% increase	Con n/d (MSH): £175 ha ⁻¹ (€318) Ash (100%) (non-LFA): £315 ha ⁻¹ (€572)		
2000	Rural Development Programme, no LFA supplement	Con n/d: €336 (€450) ha ⁻¹ Ash : €442 (€592) ha ⁻¹		
2001			Disadvantaged Area Scheme (DAS)	Area based compensatory allowances
2005			Single Farm Payment	Average of payments for 2000/2001/2002
2007	FEPS (if in REPS)	€150 - €200 ha ⁻¹ (€155 - €206) for 5 yrs		
2007	15% premium increase	Con n/d: €387 ha ⁻¹ (€399) Ash: €508 ha ⁻¹ (€523)		
2008			Suckler Cow Welfare (SCW)	€80 (€79) per cow
2009	8% reduction	Con n/d: €356 ha ⁻¹ (€370) Ash: €467 ha ⁻¹ (€486)	REPS 4	1-20 ha: €234 (€243) ha ⁻¹
2011	New planting only	Con n/d: €369 ha ⁻¹ (€376) Ash: €481 ha ⁻¹ (€491)		

Source: Author's collation of Teagasc, Forest Service and personal grey literature and documents

⁸ Amounts in brackets represent Euro values relevant to the year in question (converted using the consumer price index).

⁹ Premium payment for new planting comprised of “non-diverse” (n/d) conifer (con) (i.e. Sitka spruce) in MSH areas.

¹⁰ Premium payment for new planting comprised of minimum 75% ash in non-LFAs.

farmers in receipt of the extensification premium (which acted as an incentive to keep stocking rates below 1.4 LU ha⁻¹) and the improved headage payments for cattle, would be unlikely to contribute to the achievement of high afforestation levels.

In the qualitative literature on afforestation in Ireland, there are a number of common themes. Duesberg et al. (2013) examine farmers' afforestation goals and objectives and find that these are complex and often contradictory and that the majority of farmers surveyed did not make the decision to afforest or not on the basis of maximising profit, rather on the basis of strongly held values about farming versus forestry.

Much of the rationale for continued support for afforestation is closely linked to a "paradigm shift in EU agricultural policy from a productivist to a post-productivist agricultural regime" i.e. a shift from intensification to extensification (Ilbery and Bowler 1998). Ultimately, many farmers retain a productivist mindset and have a preference for full utilisation of agricultural land. Farms with higher stocking rates and farms with relatively better land quality are less likely to consider converting land to forestry - this is supported by Ní Dhubháin (1994) and O Leary 2000 who report that farmers don't want to plant land that is "too good for forestry." On the other hand, Howley (2013) conducted a nationally representative survey in which farmers reported that "I make more money from having land in forestry use than if I was farming it"; "I had bad land that was good for nothing else"; and "the premiums were very attractive".

There are complex motivations surrounding the decision to plant or not to plant. In reviewing the policy environment for both agriculture and forestry, it is evident that the policies add to this complexity. However, there are clear indications that factors such as soil type, financial drivers, having a productivist mindset and a desire to stay farming, or a negative cultural attitude towards forestry, all have an impact on whether farmers will even consider afforestation. The importance of soil type and physical and productivity-related characteristics in particular, dominate much of the literature. Chapter 3 takes an overview of where afforestation took place over the period, in order to examine the spatial distribution of private afforestation in Ireland in relation to soil type which determines both agricultural and forest productivity.

Chapter 3. THE PHYSICAL, ECONOMIC AND POLICY DRIVERS OF LAND CONVERSION TO FORESTRY IN IRELAND

3.1 INTRODUCTION

Ireland offers a particularly interesting example of forest expansion policy as it possesses one of the lowest areas of forest cover in Europe, despite having excellent growing conditions for commercial forestry (O'Carroll 2004) and a history of ambitious afforestation policies. Land conversion to forestry is a complex issue that is influenced by social, economic and environmental factors that policy-makers should account for in the development of forest policy and the setting of targets (Beach et al. 2005).

The objective of this chapter is to examine the spatial and temporal distribution of afforestation in Ireland to get a greater understanding of the inter-relationship between these social, economic and environmental factors over time. This necessitates a modelling approach that combines multiple sources of data. Spatial econometric models offer the potential to investigate and quantify the effects of these factors on land conversion while explicitly addressing the spatial nature of the data (Radeloff et al. 2012).

Land conversion to forestry

Land use change modelling requires combining both physical and economic spatial data if it is to be used to understand policy developments and predict future land-use changes (Seto and Kaufmann 2003). In the absence of data concerning the economic implications of land-use decisions, interpreting historic change, particularly in relation to policy developments, poses a significant challenge (Bockstael 1996). Although physical drivers of land conversion may be identified, the causal relationship between characteristics and change may be less clear (Irwin & Geogheghan 2001). This is perhaps of most relevance in enterprises where state and regional policies have a defining and widespread impact, such as agriculture and forestry. Despite the recognition of the importance of including economic data in spatial models, researchers may be constrained by data limitations or the scale at which data are available. In agricultural research, spatial data on farm incomes at the individual or local level is limited. One approach to overcoming this issue is to adopt a spatial

micro-simulation approach in order to simulate individual farm data from broader regional or national data (O'Donoghue et al. 2012).

Land conversion policy incentives

Historical afforestation policies and establishment in Ireland have a distinctive locational bias defined by the quality of the underlying land (Upton et al. 2012). Initial efforts by the State to expand forest cover were enthusiastic but poorly planned and resulted in relatively low levels of planting (O'Carroll 2004). Planting was limited to sub-marginal land, often at higher elevations on peat soils. Plantation forests can achieve high productivity rates even on poorly drained mineral soils (Farrelly et al. 2011), giving forestry a productivity advantage on soils that are only marginally productive for agriculture. Nonetheless, farmers have been reluctant to plant forestry due to a range of factors. These include the non-pecuniary costs, related to a change in land use and lifestyle. According to Beach et al. (2005), land conversion to forest by private land-owners is a complex issue with multiple underlying factors, including, but not limited to, the incentives and restrictions of state policies.

The effects of policy changes and market conditions on afforestation rates in Ireland have been explored using time-series and panel data (McKillop and Kula 1987; McCarthy et al. 2003). In general such studies find that the profitability of agriculture and forestry are significant factors in determining afforestation rates. Researchers have examined afforestation in Ireland at the county level but failed to account for the spatial nature of the data in the modelling process or the physical characteristics of the land (McCarthy et al. 2003). Examinations of private afforestation in Ireland have shown that land quality is a defining aspect of the decision-making process by farmers (Ní Dhubháin and Gardiner 1994; Howley et al. 2012).

Land quality underlies the productivity and profitability of alternative land uses, making it an essential element in understanding land conversion. In addition, forestry has been recognised as an enterprise only “suitable” for the worst quality land by land-owners (O'Leary et al. 2000). This may be driven by the belief that land should be used for the production of food if at all possible, rather than an aversion to forestry *per se* (McDonagh et al. 2010). However, strong negative views of afforestation have been identified in parts of Ireland, particularly in those areas that saw significant expansion of forest cover over a relatively short time-period (O'Leary et al. 2000).

It has been suggested that conservation policies related to protected habitats or species have reduced annual afforestation rates and discouraged applications from relevant areas (Collier et al. 2002). The EU habitats (92/43/EEC) and birds (79/409/EEC) directives resulted in the identification of special areas of conservation and special protection areas, which complemented the Irish specification of natural heritage areas. Habitats and species related to these areas are given legal protection and applications for afforestation funding within these areas require approval from the Irish National Parks and Wildlife Service. Forests can increase soil acidity through the capacity of trees to scavenge industrial air pollutants or sea-salts (Dunford et al. 2012). Where this occurs on soils with poor buffering capacity, adjacent water-ways may become acidified. The Forest Service in Ireland has identified areas that are considered at risk of acidification due to the poor buffering capacity of the soil and afforestation is controlled in these areas.

Spatial models of land conversion

Spatial models of land-use change are employed to gain greater insight into the drivers of change, the effectiveness of policies and to predict future land conversion (Lubowski et al. 2008). Land-use change studies have been conducted on a diverse range of issues including urban expansion (Seto and Kaufmann 2003), deforestation (Wyman and Stein, 2010) and afforestation (Clement et al. 2009). Land quality, related to factors such as soil, elevation and slope, is one of the essential determinants of private land-use decision-making and should be incorporated into spatial models given its underlying effect on productivity (Lubowski et al. 2008). Soil type and other physical characteristics have been identified as significant factors in land use change models (Fu et al. 2006; Chakir and Parent 2009). Ultimately however, the financial implications of land-use change should be included in models if the decisions made by private land-owners are to be understood within an economic framework (Bockstael 1996).

In developing spatial models of land-use change, researchers generally employ satellite imagery from different time-periods and explore change at the single land-parcel or pixel level over a set period (e.g. Radeloff et al. 2012). Alternatively, researchers may examine total changes across administrative boundaries which can facilitate the incorporation of economic data more readily (Seto and Kaufmann 2003).

In modelling spatially derived data, researchers should test for spatial autocorrelation amongst the observations, which can lead to biased estimations (Anselin 2010). Spatial dependence amongst the observations is considered one of the primary problems with employing spatially explicit panel data. A number of approaches to dealing with this potential source of bias have been developed (Elhorst 2003). One approach is to specify a spatial lag variable that accounts for the interaction of the dependent variable in related observations. This requires the specification of the spatial relationship between observed units, which can be expressed in a spatial weights matrix.

Understanding the drivers of afforestation should assist in explaining afforestation patterns and help to inform meaningful forest policy. Afforestation by private land-owners may be affected by a combination of market drivers, policy variables, owner characteristics and land conditions (Beach et al. 2005). In the context of this chapter, it is hypothesised that the underlying characteristics of the land, the financial implications of conversion and the constraining effects of conservation policies influence afforestation. Thus, the primary aim of this chapter is to test the nature of these effects in explaining afforestation in Ireland and their significance to forest and broader land use policies. A combination of (a) Geographic Information System (GIS) analysis, (b) the microsimulation of farm-level incomes and (c) financial analysis techniques are employed to build a panel dataset to explore the importance of physical, economic and policy related factors in explaining annual afforestation in Ireland between 1993 and 2007. A random effects and a spatial autoregressive random effects model (that account for the spatial correlation of observations¹¹), are employed to model the data.

3.2 METHODOLOGY

The boundaries of electoral divisions (EDs) are employed as the spatial unit in which observations would be specified as they represent the smallest spatial unit for which economic data are available. Ireland is divided into 3,440 EDs in total but those which occur within cities and those for which agricultural data are not available are removed, resulting in a sample of 2,811 observations (Figure 3.1(a)). Employing a GIS, these boundaries are intersected with available spatial data, including grant-aided

¹¹ Regressions are adjusted for spatial correlation where the error term ϵ is adjusted to account for points being related to each other using a weights matrix.

afforestation, to produce a panel dataset describing the physical characteristics of the areas and the annual afforestation occurring within them. Rather than rely on data from satellite imagery, this analysis employs vector data supplied by the Forest Service that details forest cover in Ireland, derived from aerial photography and afforestation grant applications. These data cover all forests in 2007 including most grant-aided plantations from 1990. Given their connection to financial supports these data are considered to be of high quality and offer the advantage of identifying the date of forest establishment, thus facilitating the development of a detailed data set of annual afforestation. As data for some early years are incomplete, the analysis focuses on the years 1993 to 2007. It should be noted that this dataset consists of private grant-aided afforestation only and thus forest establishment by state agencies or non-funded private sector planting is not captured.

Using the digital soil map of Ireland (Fealy et al. 2009), it is possible to identify the area of different soil types in each ED. Great soil groups are grouped into peats, poorly drained mineral soils and well-drained mineral soils, representing the most significant divisions from a forestry and agriculture perspective (Table 3.1). Other areas consisting of un-plantable areas such as water, artificial surfaces and bare rock are also grouped as a single category. Table 3.1 presents the mapped divisions.

Table 3.1 Soil divisions and their associated great soil groups

Soil description	Great Soil Group
Well-drained mineral soils	Acid Brown Earths, Brown Podzolics, Grey Brown Podzolics
Poorly-drained mineral soils	Surface-water Gleys, Ground-water Gleys, Peaty Gleys, Podzols
Peat	Blanket Peats, Basin Peats

Financial measure

Discounted Cash Flow (DCF) is the most widely used methodology for determining the economic value of a forest or a parcel of bare land to be afforested (Hiley 1954; Bettinger et al. 2010). The DCF methodology involves the calculation of the net present value (NPV)¹², using the “Faustmann” formula developed in Germany in 1849 (Hiley 1954). Using NPV to generate the future value of the forest involves the prediction of future costs and incomes (which can accrue unevenly over the rotation) and discounting these costs and incomes to the present day at a target rate of interest (Hiley 1954 & 1956). Depending on their objectives, other analyses have used

¹² NPV (Net Present Value) is the sum of the present values of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as income and cost cash flows.

variants of the discounted cash flow method (DCF) which include (Land Expectation Value (LEV), Net Present Value (NPV), Internal Rate of Return (IRR) and Annual Equivalised Value (AE).

The analysis in this chapter examines the return to forestry across the distribution of all private forests (established by farmers on their own land and bought and established by investors) and therefore needs to utilise a measure of forest income that incorporates the underlying land value (for investors who purchased the land) in addition to the timber revenues and subsidies. Among the measures of the profitability of investing in forestry, the Land Expectation Value (LEV) (Klemperer 1996) which takes the value of the underlying land into account is particularly appropriate for this analysis. In later chapters NPV (net present value) is used as a measure of return as the focus is on farm afforestation (therefore the purchase of land for afforestation by investors is not of concern).

For the purposes of this analysis, the LEV per hectare includes the costs of management, future timber revenues and forest subsidies, in addition to the opportunity cost of converting agricultural land. Thus the LEV is calculated (in equation 3.1) as the sum of discounted revenues and costs for each ED n:

$$LEV = \frac{\sum_{y=0}^t R_y (1+r)^{(t-y)} - \sum_{y=0}^t C_y (1+r)^{(t-y)}}{(1+r)^t - 1} + \sum_{y=1}^{20} \frac{P}{(1+r)^y} - \frac{A}{r} \quad (3.1)$$

Where R denotes revenues from thinning and clearfell, C relates to costs associated with maintenance (from year 6), insurance (years 5 to 20) and inspection paths, P are premium payments paid in years 1-20 only, A is the ED average market margin for cattle systems, r is the discount rate (5%), t is the rotation of 40 years and y is the relevant year. The analysis assumes a typical species composition with the relevant subsidies applied. Average productivity is assumed and timber output predictions are based on UK Forestry Commission (Edwards and Christie 1981) yield models.

Simulated data

Although the Irish Census of Agriculture describes the general characteristics of farms in EDs it does not include data on farm incomes at this level. However,

microsimulation models have been developed that derive spatially explicit simulated farm level income data based on the Teagasc National Farm Survey (NFS), a detailed annual survey of farm economic activity from a representative sample of Irish farms. Data from the NFS are assigned to simulated farms in EDs following a quota sampling approach based on farm characteristics, including farm size, farm system, soil quality and whether a farmer is part-time or not. A full description of the microsimulation model, SMILE (Spatial Microsimulation model of the Irish Local Economy), is outlined in O'Donoghue et al. (2012).

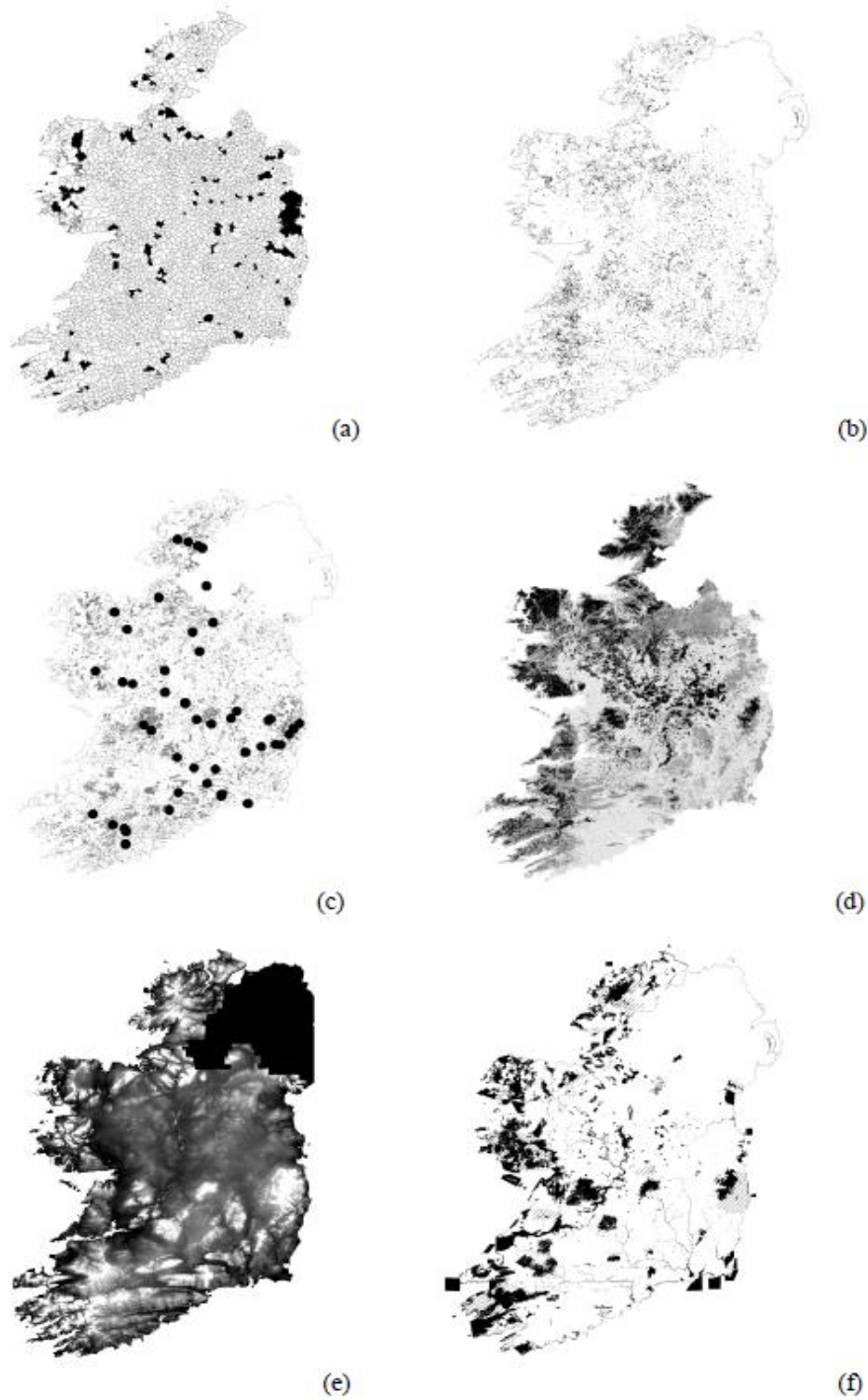
As forestry is most competitive with cattle enterprises (Breen et al. 2010) and cattle farmers are more likely to plant forestry (Howley et al. 2012), the average market gross margin (defined as gross output less subsidies) (Hennessy and Moran 2015), for this enterprise in each ED is included to account for the opportunity cost of land conversion. Thus it is possible to generate the average LEV per hectare for a move from agriculture into forestry per ED and year. Forest Service statistics suggest that farmers made up almost 90% of private planting during the period.

Elevation can play an important role in agricultural and forest productivity. the average elevation in metres across each ED was calculated from a digital elevation model of Ireland. The distance from the centroid of each ED to the nearest sawmill was included to investigate the effect of available markets and local commercial forest activity on planting rates. Land prices are an important factor in changes in land use, however there is currently no reliable source of land price data for Ireland over the period of interest and regional data is particularly sparse. However, the NFS collects self-reported farm valuations, which are used to generate per hectare land values across eight regions over the time-period and are considered a reliable proxy for market data.

Spatial data

Figure 3.1 displays the primary spatial data employed in the analysis. The area afforested between 1993 and 2007 (Figure 3.1 (b)) suggests that spatial clustering of afforestation may be present.

Figure 3.1 (a) ED boundaries (missing data black) (b) Total afforestation 1993-2007 (c) Forest cover pre-1993 & location of sawmills (d) Soil type: peat (black), poorly drained mineral (light grey), well-drained mineral (dark grey) (e) DEM of Ireland (f) SAC/SPA/NHA (black) Acid Sensitive (hatched)



Sources: Forest Service – (b), (c), (f); EPA – (e); Teagasc – (d)

Table 3.2 Moran's I test for spatial correlation amongst ED afforestation per year

Year	Moran's I	P>z
1993	0.09	0.000
1994	0.14	0.000
1995	0.20	0.000
1996	0.15	0.000
1997	0.14	0.000
1998	0.10	0.000
1999	0.09	0.000
2000	<i>i</i> 0.18	0.000
2001	0.25	0.000
2002	0.19	0.000
2003	0.16	0.000
2004	0.14	0.000
2005	0.12	0.000
2006	0.12	0.000
2007	0.10	0.000

Spatial correlation between annual afforestation in EDs was tested using Moran's I and found to be significant, although relatively small, in each year (Table 3.2). The results suggest that ED afforestation may be spatially clustered.

Correlation amongst the dependent variables in a model invalidates the assumption of independence and may lead to biased estimates. This correlation can be accounted for by employing a spatial autoregressive (SAR) model (Elhorst 2003). The SAR model accounts for the correlation in the dependent variable explicitly by estimating a spatial lag parameter that describes the effect of the extent of the dependent variable in surrounding observations.

The data primarily relate to the characteristics of the EDs and are thus time-invariant limiting the options for modelling the full data-set. A random effects model assumes no individual specific effects and can thus incorporate time-invariant characteristics as independent variables. The basic model takes the form of:

$$Y_{it} = \beta X_{it} + \alpha + \mu_i + \varepsilon_{it} \tag{3.2}$$

Where *i* is the individual ED, *t* is the time period, *Y* is the rate of afforestation, *X* are the characteristics of ED, β are the coefficients to be estimated, α is the constant term, μ is the time invariant individual specific random effect and *e* is the error term. To account for the identified spatial correlation a second model is specified that takes the

form of a spatial autoregressive random effects model, which incorporates a spatial lag of the dependent variable:

$$Y_{it} = \lambda W\beta X_{it} + \alpha + \mu_i + \varepsilon_{it} \quad (3.3)$$

Where W is the spatial weights matrix (SWM) that describes the relationship between the observed ED and those surrounding it and λ is the associated coefficient to be estimated.

In this study the correlation of afforestation rates may stem from a number of sources that are not accounted for in the model, such as the influence of additional physical site characteristics, land-owner interactions and local industry and state promotional and advisory agents. Thus a binary contiguity spatial weights matrix, where EDs that share a boundary are identified as related, is considered most appropriate. Each matrix row is standardized so that the binary effect is divided between neighbours equally¹³.

Both models are simulated using maximum likelihood estimation. The SAR model is estimated using the `splm` package in R (Millo and Piras 2012). As the size of the ED may bias the area related variables, the percentage of afforestation and percentages of soil type, forest cover and protected areas are modelled rather than the area. Summary statistics for the model variables are contained in Table 3.3.

Table 3.3 Summary statistics of model variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Afforestation (%)	42165	0.17	0.45	0.00	12.02
Peat soils (%)	42165	15.63	19.52	0.00	92.66
Poorly drained mineral soils (%)	42165	25.79	22.37	0.00	95.93
Well-drained mineral soils (%)	42165	42.64	28.37	0.00	99.99
Elevation (m)	42165	99.89	61.28	0.00	453.10
Distance to sawmill (km)	42165	19.94	12.25	0.06	64.51
Private forest cover (%)	42165	3.22	3.44	0.00	31.57
Public forest cover (%)	42165	4.55	7.47	0.00	73.95
SAC/SPA/NHA (%)	42165	6.80	15.91	0.00	100.00
Acid sensitive (%)	42165	5.46	21.32	0.00	100.00
Average farm size (ha)	42165	35.63	14.79	12.21	153.47
Reported land value (1,000s €)	42165	11.83	4.48	6.76	40.50
Forest LEV (1,000s €)	42165	2.74	2.85	-9.09	17.51

¹³ Dummy variables representing time periods and the Counties in which EDs are located are included in the model to account for time and general spatial effects but are excluded from the reported results for brevity.

The afforestation variable is highly skewed and is therefore log-transformed before model estimation. As the log of zero is not defined, afforestation of 0.001 ha replaces zero observations before transformation.

3.3 RESULTS

The correlation between the independent variables is generally low except between the soil variables, which is expected, given that they are proportional to each other (Table 3.4). Thus, multi-collinearity is not deemed to be a significant issue in the models. All included variables have a significant effect on afforestation and there are no major changes in the sign or scale of coefficients between models (Table 3.5). However, the coefficient of the spatial lag is significant and positive indicating that afforestation in one ED is positively related to afforestation in adjacent ones. In addition, the increase in the log-likelihood suggests that the spatial model performs better, which is confirmed with a likelihood ratio test (LR=-114835.80, P<0.001). It should be noted that the soil percentages are relative to the remaining area which is composed of un-plantable land. Thus, although the percentage of well-drained mineral soils is negatively correlated with afforestation, it has a small positive effect in the models. Given the combination of units in which the variables are expressed, direct comparison of the scale of some coefficients is less meaningful.

Table 3.4 Matrix of Pearson correlation coefficients of model variables

	Affor	Peat	P soil	W soil	Elevation	Sawmill	Pr for	Pu for	SAC	Acid	Size	Price	LEV
Affor	1.00												
Peat	0.10	1.00											
P soil	0.13	-0.07	1.00										
W soil	-0.13	-0.52	-0.59	1.00									
Elevation	0.11	0.09	0.06	-0.24	1.00								
Sawmill	-0.02	0.03	0.26	-0.22	-0.10	1.00							
Pr for	0.21	0.18	0.12	-0.23	0.21	-0.07	1.00						
Pu for	0.10	0.19	0.00	-0.20	0.50	-0.14	0.24	1.00					
SAC	-0.03	0.25	-0.07	-0.24	0.20	0.06	0.19	0.22	1.00				
Acid	-0.03	0.23	-0.14	-0.22	0.12	-0.03	0.08	0.12	0.20	1.00			
Size	-0.02	-0.23	-0.12	0.22	0.12	-0.14	-0.01	0.04	-0.05	0.02	1.00		
Price	-0.07	-0.13	-0.05	0.11	0.06	-0.08	0.13	0.01	0.05	-0.02	0.16	1.00	
LEV	0.02	0.31	0.14	-0.34	0.04	0.08	0.27	0.09	0.31	0.12	-0.19	0.39	1.00

Table 3.5 Results of random effects and spatial autoregressive random effects models

Log (Afforestation %)	RE Model			SAR RE Model		
Variable	Estimate	Std. Error.	P>z	Estimate	Sdt. Error	P>z
Peat soils (%)	0.033	0.003	0.000	0.028	0.002	0.000
Poorly-drained mineral soils (%)	0.032	0.002	0.000	0.025	0.002	0.000
Well-drained mineral soils (%)	0.009	0.002	0.000	0.007	0.002	0.000
Elevation (m)	0.015	0.002	0.000	0.013	1.412	0.000
Sq. Elevation	-4.05E-05	5.04E-06	0.000	-3.35E-05	4.65E-06	0.000
Distance to sawmill (km)	-0.015	0.003	0.000	-0.011	0.003	0.000
Private forest cover (%)	0.210	0.019	0.000	0.200	0.017	0.000
Sq. private forest cover	-0.008	0.001	0.000	-0.008	0.001	0.000
Public forest cover (%)	0.035	0.009	0.000	0.029	0.008	0.000
Sq. public forest cover	-0.001	2.40E-04	0.001	-0.001	2.21E-04	0.000
SAC/SPA/NHA (%)	-0.011	0.002	0.000	-0.011	0.002	0.000
Acid sensitive (%)	-0.009	0.002	0.000	-0.007	0.002	0.000
Average farm size (ha)	-0.007	0.002	0.002	-0.005	0.002	0.008
Reported land value (1,000s €)	-0.049	0.009	0.000	-0.038	0.000	0.000
Forest LEV (1,000s €)	0.057	0.017	0.001	0.039	0.016	0.012
Constant	-10.414	0.324	0.000	-8.094	0.030	0.000
Spatial lag	-	-	-	0.239	0.007	0.000
Log likelihood	-115419.29			-114835.80		
N	42165			42165		

The random effects model is re-estimated with standardized independent variables and the coefficients can be interpreted in relation to a change in the standard deviation of the independent variables (Table 3.6). This standardized random effects (SRE) model highlights the importance of physical land characteristics in explaining the conversion of land to forestry and shows that the proportion of poorly drained mineral soil in an ED has the greatest relative effect. Conversely, changes in the LEV have a relatively small effect.

Table 3.6 Results of SRE model of standardized independent variables

Log (Afforestation%)	Estimate	Std. Error.	P>z
Variable			
Std. peat soils	0.66	0.05	0.000
Std. poorly drained mineral soils	0.76	0.05	0.000
Std. well-drained mineral soils	0.25	0.06	0.000
Std. elevation	0.26	0.04	0.000
Std. distance to sawmill	-0.23	0.04	0.000
Std. private forest cover	0.29	0.03	0.000
Std. public forest cover	0.08	0.04	0.025
Std. SAC/SPA/NHA	-0.21	0.03	0.000
Std. acid sensitive	-0.18	0.04	0.000
Std. average farm size	-0.11	0.03	0.002
Std. reported land value	-0.22	0.04	0.000
Std. forest LEV	0.13	0.05	0.010
Constant	-8.36	0.24	0.000
Log likelihood	-115493.52		
N	42165		

It is important to note that the previous models ignore the dynamic effects of variables over time. For example, if interactions between soil type and 5-year time period (1998-2002 and 2003-2007) dummy variables are included in the original RE model it is evident that significant changes have occurred in the effect of soil type over the time period (Table 3.7). The influence of peat soils has declined over time while that of poorly drained mineral soils shows an increase. This can most likely be explained by the introduction of stricter environmental policies that recognise the value of bogs for carbon sequestration and biodiversity preservation. In addition, it may reflect an awareness of the lower productivity rates that can be achieved on such sites.

Table 3.7 Coefficients of soil and time period interactions from RE model

Variable	Estimate	Stan. Err.	P>z
Peat (%)	0.039	0.003	0.000
Peat (%) 1998-2002	-0.004	0.003	0.197
Peat (%) 2003-2007	-0.014	0.003	0.000
Poorly-drained mineral (%)	0.022	0.003	0.000
Poorly-drained mineral (%) 1998-2002	0.018	0.003	0.000
Poorly-drained mineral (%) 2003-2007	0.013	0.003	0.000
Well-drained mineral (%)	0.006	0.003	0.030
Well-drained mineral (%) 1998-2002	0.001	0.003	0.594
Well-drained mineral (%) 2003-2007	0.009	0.003	0.002

3.4 DISCUSSION

The results highlight the importance of underlying physical land characteristics in understanding afforestation. Physical site characteristics, such as soil and elevation, are essential factors in understanding the natural distribution of forests (Felicísimo et al. 2002) and have been shown to be important predictors of land-use change such as land abandonment (Sluiter and de Jong 2002) and forest expansion (Fu et al. 2006). Such findings highlight the limitations imposed by site quality on both the range of land uses that can be practiced and their productivity and profitability. This study finds that the percentage of poorer quality soil, both poorly drained mineral and peat, are found to be important variables in explaining annual afforestation in Ireland. Such soils are associated with lower levels of agricultural productivity but can result in relatively high growth rates for forestry depending on other factors and management (Farrelly 2009).

Thus forestry, as an enterprise, has a greater competitive advantage on such soils. Peat soils have been associated with afforestation in Ireland in the past but planting has been regulated in areas of acid sensitivity and lower yield classes, to ensure a minimum level of forest productivity and to control potential effects of forest activity on water quality. This has

resulted in significant decreases in peat afforestation in recent decades (Black et al. 2008). This is highlighted in Table 3.7 which demonstrates how the contribution of peat soils has declined over time while mineral soils show an increase.

Forestry is unlikely to compete financially on higher quality soils and farmers are unlikely to consider better quality sites for afforestation (Breen et al. 2010), thus it is unsurprising that well-drained mineral soils have the smallest effect amongst the soils and are found to be negatively correlated with afforestation in general. Elevation is also an important element in land productivity due to its links with physical and meteorological factors. Areas with higher average elevations are more likely to convert to forestry in the model. However, this relationship is non-linear which is likely to reflect limitations of any commercial land-use in high elevations.

As stated in Chapter 2, early afforestation efforts particularly by the state, concentrated on upland peat dominated sites, which were considered sub-marginal for agriculture. More recently such areas have been increasingly valued for their role in the conservation of biodiversity. Predicting biodiversity changes as a result of land conversion to commercial forestry is difficult and may be either negative or positive depending on management and planning issues. However the most negative impacts are likely to occur in biodiversity rich habitats (Brockhoff et al. 2008; Buscardo et al. 2008). The provision of environmental benefits is one of the goals of afforestation in Ireland and the recognition of the environmental sensitivity of some areas has resulted in the implementation of policies that attempt to counteract the potential negative impacts of afforestation (DAFF 1996). This includes controlling afforestation in areas which are deemed acidic or otherwise environmentally sensitive. Applications for grant-aided afforestation in special areas of conservation (SAC), special protection areas (SPA) or natural heritage areas (NHA) must be approved by the National Parks and Wildlife Service. The results of this analysis suggest that these areas have decreased afforestation rates in the EDs in which they occur.

The LEV of moving from agriculture into forestry has a significant and positive effect on afforestation rates. Given the assumptions made in the calculation it is important to note that this effect is reflective of the relative changes to the forest premium rate and the market margin of cattle enterprises over space and time. The importance of state supports in achieving afforestation is recognised generally in the literature (Beach et al. 2005). Targeted supports have been found to be important explanatory factors in land use change in Europe

(Serra et al. 2006). The average farm size in the ED has a negative effect, which may relate to the profitability of enterprises associated with larger farms. Land prices are recognised as having a significant effect on the attractiveness of afforestation, particularly given the long-term nature of the investment (Kula 1992). In this study self-reported values are employed as actual sales data are lacking. The negative effect of land price is likely to reflect the perceived higher opportunity cost of planting as land prices increase.

The effect of existing forest cover and access to markets is particularly interesting from a planning perspective. Forest cover, both public and private, has a positive but non-linear effect on afforestation. In addition, the distance to sawmills has a negative effect on afforestation levels which is likely to reflect a combination of factors including relative profitability due to lower transportation costs and economies of scale and an increasing awareness of forest benefits amongst residents. Clement et al. (2009) found a similar relationship and suggested that this was evidence that afforestation was driven by local timber demand.

The presence of commercial forest activity also has the potential to increase landowner's awareness of the benefits of forestry as a profitable land use in addition to introducing a level of acceptability of forestry as a land conversion activity (O'Leary et al. 2000). At higher levels of forest cover the effect reverses and becomes negative, which may indicate an exhaustion of "suitable" forestry land in some EDs. As the competitiveness of forestry is strongly linked to land quality, this suggests that the availability of poor quality land for forestry is limited in some areas. In addition, high levels of forest cover have been linked to negative attitudes amongst individuals where forests may be viewed as encroaching on agriculture, landscapes or communities (O'Leary et al. 2000; Carroll et al. 2011). Thus local landowners may view afforestation as a threat, irrespective of its commercial benefits.

This chapter highlights a significant challenge in land-use policy. Forest expansion is considered desirable for the provision of ecosystem services, particularly in relation to the ability of forests to sequester carbon (Nijnik and Bizikova 2008) and rural economic diversification (Kanowski 2010). However, this requires the replacement of an existing land-use. Traditionally, afforestation occurs on sub-marginal land but this is increasingly valued for biodiversity and recreation (Buckley et al. 2009; Bullock et al. 2012), which may be impacted negatively by afforestation (Buscardo et al. 2008). Such areas are therefore becoming less available for land conversion in general, including for afforestation.

In the past, there has been little conversion of better quality land to forestry, therefore intensification in such areas is unlikely to impact significantly on planting rates. Indeed, such a scenario could offer opportunities for forest expansion on marginal land where forestry is a commercially attractive land use, assuming that land use within such areas is not restricted by conservation measures, and that local land owners are willing to engage with an afforestation programme.

3.5 CONCLUSIONS

Overall this chapter highlights the potential for economic and physical spatial data to be combined in a meaningful way to understand spatial variations in annual land conversion to forestry. Fundamental to understanding the land use change from agriculture to forestry is the influence of the physical characteristics of the land, particularly soil quality. 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. Conservation policies have impacted negatively on land conversion and limitations on land availability may be an important factor in some areas.

As shown in this chapter, an examination of the relative profitability of forestry compared to agriculture also plays a role in annual afforestation rates. In the wider land use context, the Food Harvest 2020 (DAFF 2010) and Food Wise 2025 (DAFM 2015a) policies set ambitious targets to increase agricultural output significantly. If this expansion results in increased profitability of competing agricultural enterprises, either through increased intensification or the expansion of more profitable enterprises, commercial forestry may lose competitiveness as a land-use option. However, targets set for agricultural sectors are value rather than volume targets and may not require farmers to expand their land base. On the other hand, if agricultural intensification occurs only on the best quality land this could result in the availability of marginal land for alternative uses (Feehan and O'Connor 2009).

A recent report on land availability for afforestation states that an additional 510,000 ha of afforestation would be required to achieve the 18% forest cover target by mid-century (COFORD 2016). Farrelly & Gallagher (2016) identify a total of 423,000ha of wet grassland and unimproved land that occurs on the margins of productive agricultural land and in marginal agricultural areas, that is productive for forestry. Indeed such a scenario could offer opportunities for forest expansion on marginal land where forestry is a commercially

attractive land use, assuming that land use within such areas is not restricted by conservation measures, and that local land owners are willing to engage with an afforestation programme.

The analysis in this chapter shows that when developing targets for forest expansion, policy makers must be cognisant of conflicting land use policies, the availability of land and the impact of changes to the profitability of alternative land uses if realistic targets are to be developed. A further investigation of the agricultural opportunity cost of afforestation is thus warranted.

Chapter 4. AN EXAMINATION OF THE RELATIVITY OF AGRICULTURAL AND FOREST SUBSIDY PAYMENTS USING A HYPOTHETICAL MICROSIMULATION MODELLING APPROACH

4.1 INTRODUCTION

An overview analysis of the economic and spatial drivers of private afforestation in Ireland undertaken in Chapter 3 concludes that the opportunity cost incurred in the afforestation process is a factor that warrants more detailed examination. As most afforestation on privately owned land in Ireland has been undertaken by farmers, the land use change decision involves a trade-off between the economic return from the potentially superseded agricultural enterprise and the potential return from the alternative forest enterprise. Both agricultural and forest incomes are comprised of market income and subsidy income. The inter-play between the market and subsidy aspects of the opportunity cost of farm afforestation is complex and will be examined in depth in Chapter 6. This chapter focuses only on the subsidy component of agricultural and forest incomes in order to observe the magnitude of the agricultural subsidies foregone by farmers in undertaking afforestation.

The payment of substantial subsidies to farmers is a relatively new phenomenon in Ireland and dates largely from Ireland's accession to the then European Economic Community in 1973. The Common Agricultural Policy (CAP) of the European Union (EU) enjoys a reputation not only as the oldest Community policy (Piccinini and Loseby 2001) but also as a highly complex, evolving and expensive policy for European taxpayers (Zhu and Lansink 2010). The policy objectives driving the payment of national and EU subsidies to farmers for agricultural and forestry enterprises, have undergone huge change over the period of the CAP. This in turn has led to changes in levels of payment and eligibility criteria for both agricultural and forest subsidies. While subsidies for agriculture and forestry are both CAP policy instruments, they have often been historically mutually exclusive. For instance, farmers in the Rural Environment Protection Scheme (REPS), which was introduced in 1994, had to weigh up the loss of agricultural subsidies against the benefits of receiving forest subsidies (Collier et al. 2002; McCarthy et al. 2003).

The role of subsidies has been recognised as central to understanding afforestation rates. In reporting on a drop in annual planting in 1992, duQuesne Ltd. (1993) conclude that the gains from increased forestry subsidies were eroded by the availability of animal subsidies, which encouraged farmers to increase their stock numbers. Collier et al. (2002) find that the

majority of farmers retained their land in agriculture to avail of agricultural subsidies, particularly since the reform of the CAP in 1992. The duQuesne (1993) report also notes that “changes (or even anticipated changes) in (agricultural) subsidies have an immediate and demonstrable effect on the uptake of the forestry support measures”.

It is also evident from Teagasc National Farm Survey (NFS) annual reports that the reliance of farmers on agricultural subsidies has increased significantly since the early 1990s, particularly in the cattle rearing (suckler cow) system where subsidies can comprise a larger proportion of farm income than that achieved from the marketplace (Connolly et al. 2009). These studies point to the fact that short-term subsidy payments are very important to farmers and their potential loss may be a greater influencing factor in the afforestation decision than the longer-term market returns.

Previous research has shown that the sector most likely to benefit financially from afforestation is the cattle sector (Breen et al. 2010; Ryan et al. 2008) as they have low farm gross margins relative to other systems. On this basis, the analysis in this chapter is confined to the cattle sector which is the largest sector in Irish agriculture, both in terms of the number of farmers and the area of land dedicated to beef production. The cattle sector is also the largest beneficiary of CAP payments.

Despite their importance in the afforestation decision, a detailed modelling of the loss of agricultural subsidies once land is afforested has not been previously undertaken. This is due to the complexity associated with different agricultural subsidy payments, which have changed radically over the past 30 years (as evidenced in Chapter 2). The level of complexity is particularly high for livestock systems, yet Chapter 3 provides evidence that the change in land use from agriculture to forestry is not economically viable on good quality soils and is profitable on soils that are marginal for agriculture. Thus cattle (and sheep) farmers stand to gain most on average by afforesting some land. This is also consistent with earlier research undertaken by Breen et al. (2010) which suggests that afforestation makes financial sense for many cattle farmers. As cattle systems account for over half of all farms in the NFS, we focus on a comparison of the subsidies available for cattle enterprises and compare these to the relevant forest subsidies.

However, farm forestry and cattle enterprises are difficult to compare as afforestation grants and premiums are paid on a per hectare basis, whereas many of the payments to livestock

farmers were historically allocated on the basis of cattle numbers and stocking density. Therefore, a methodology is necessary that abstracts from the complexity of other farm characteristics to identify the impact of changes in a single component of farm income, that is, subsidies. The use of hypothetical microsimulation is a mechanism which although frequently used in labour and taxation economics, is only recently becoming popular in land use analyses. Microsimulation techniques are typically adopted when;

- data are unavailable, limited or inconsistent over a certain time period; and/or
- the research question involves highly complex and dynamic systems, both in terms of the natural biological changes that occur at farm level and the changes in policy conditions.

In undertaking a comparative analysis of cattle and forestry subsidies, both of these situations occur. McCormack & O'Donoghue (2014) detail the data disparities and gaps in calculating all of the relevant cattle subsidies available in any given year. They also justify the use of a hypothetical approach to deal with the complexity of the policy environment, in terms of rules, eligibility conditions, the number of different schemes, the level of heterogeneity at farm level, and the dynamic nature of farming. This complexity is exacerbated when introducing eligibility and species parameters for forest subsidy payments.

The objective of this chapter is to compare the relativity of the subsidies that prevailed in each year from 1984 to 2012 on a per hectare basis and advance reasons to explain how this may have affected the afforestation decision. To achieve this, a modelling framework for simulating the impact of individual policies over time is developed. In this section, the structure of the hypothetical microsimulation model is described which facilitates the examination of trends in cattle-specific subsidy payments over time.

The first section examines the agricultural subsidies available to the cattle sector and comments on their impact. The next section summarises the forest policies and subsidies described in Chapter 2. The microsimulation methodology used to model agricultural and forest subsidies is described and the methodological choices are justified. The forest subsidy and agricultural subsidy models that provide the data for the bespoke hypothetical farm model are then described. Employing this model, annual forestry and cattle subsidies are compared utilising a “typical” farm framework, which allows for the isolation of the agricultural and forestry subsidies available to a farmer on a per hectare basis, in each year of

the period. Results are presented for a typical cattle farm and a typical forest and discussed in relation to afforestation targets and evolving forest policy.

4.2 THEORETICAL FRAMEWORK

Agricultural policy

The complexity around farmer behaviour in response to subsidies is illustrated by the vast literature which explores the economic performance of an agricultural sector in which support policies are in place. The first CAP direct payment scheme was the Less Favoured Area (LFA) scheme which was introduced in 1975 in the form of headage payments (payments per head of livestock). The main objective of the scheme was to provide farm income support in “disadvantaged” or “handicapped” areas to halt the depopulation of rural areas. These LFAs were classified as More Severely Handicapped (MSH), Less Severely Handicapped (LSH) or Mountain Grazing. When first introduced in 1975, 58% of agricultural land was classified as LFA. Subsequent revisions increased the area designated as MSH and LSH to 75%, leaving just 25% of farmland in the non LFA category (DAFM 2013). Payments were allocated on the basis of the number of eligible livestock units (LU) in the herd with the highest payments available in MSH areas. LFA payments constituted a major element of agricultural subsidies and for a period of time, also formed the basis of forest subsidies.

The time-frame covered by the analysis in this chapter extends from 1984 to 2012 and can be divided into three distinct policy regimes. The first period (1982-1992) which has become known as the “pre MacSharry” period, was characterised by market policy instruments. These instruments included intervention pricing, export subsidies and import levies. Farm incomes were boosted during this period as farmers could sell their produce above world prices (Daugbjerg 2007; Swinbank 1980).

The second period, the MacSharry era (1993-2004), began with the “MacSharry CAP reform”¹⁴ which shifted policy toward “direct” payments which were coupled to production. A number of different production based subsidies (premium payments) were introduced (as outlined in Tables 4.3, 4.4, 4.5). Eligibility criteria varied for each subsidy, but a livestock density limit, measured in livestock units per hectare (LUha⁻¹), was applicable to all farms (Fennell 1992; Cardwell 2002). According to Rizov (2013), coupled payments, directly

¹⁴ named after the then EU Commissioner for Agriculture, Ray MacSharry

linked to production, may distort decisions towards less profitable subsidised activities, whereas decoupled payments break the link between production and payments.

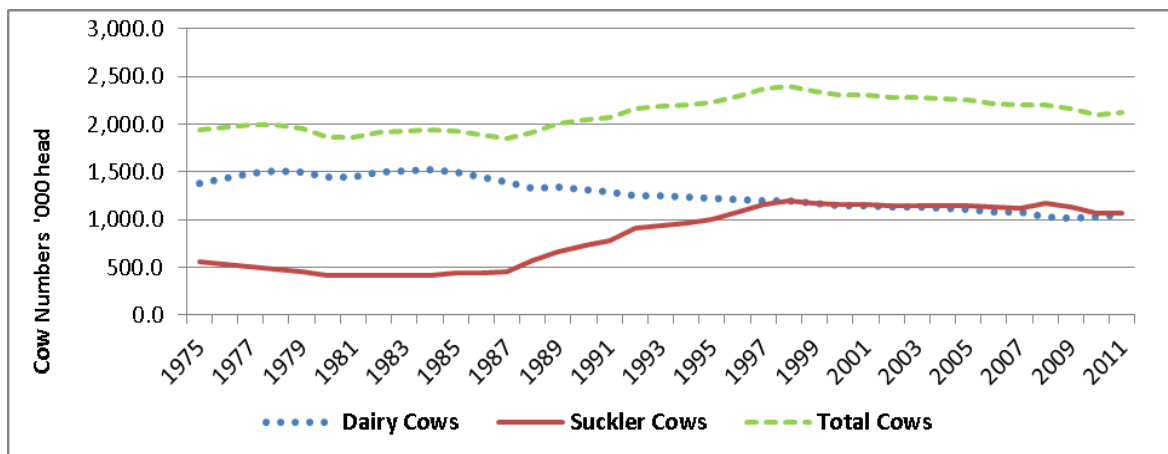
The third time period under consideration (2004-2012), saw the decoupling of direct payments from production with the introduction of the Single Farm Payment (SFP) Scheme. This payment was based on the area farmed and the level of coupled direct payments received during a historical reference period (2000-2002). This essentially meant that farmers could receive these payments on the basis of historical farming activity, as opposed to current farming intensity. In the case of unprofitable farms, this meant that farmers could cease or reduce farming and still receive payments. However, this did not happen to any great extent and much has been written about the apparent irrationality of cattle farmers who continue to subsidise loss-making cattle enterprises with the SFP (Daugbjerg 2006; Swinnen 2010; Hennessy and Thorne 2005).

The Irish cattle sector and related policies

For the purpose of reporting to the EU Farm Accountancy Data Network (FADN), farms are categorised on the basis of the dominant system. In Ireland, the Teagasc National Farm Survey (NFS) has collected micro-data at farm level for over 40 years. In 2013 over 50% of Irish farms are categorised as cattle rearing (suckler) farms or cattle other (finishing) farms (Hennessy et al. 2013). However, farms categorised as specialist dairy, dairy other or tillage also engage in some cattle farming, thus almost four out of every five farms (79%) have some cattle on the farm.

The largest structural change in Irish agriculture came in 1984 with the introduction of a milk production quota to curtail over-production in the dairy sector. Dairy cow numbers began to decrease rapidly from just over 1.5 million cows in 1983 to 1 million in 2009 (McCormack and O'Donoghue 2014). In order to incentivise production, a subsidy to increase the number of suckler cows was introduced around the same time. The initial subsidy was relatively low at £25 per cow. However this was increased to £75 in 1987. As a result, suckler cow numbers began to increase dramatically. Figure 4.1 illustrates the structural changes that occurred in cow numbers in Ireland from 1975 -2011.

Figure 4.1 Changes in cow numbers in Ireland over time



Source: McCormack & O'Donoghue (2014) based on CSO data – various years

In 1993 as part of the MacSharry CAP reform, a suckler cow quota was introduced based on the number of suckler cows in the herd in 1992. The introduction of this quota and conditions for eligibility were announced well in advance, and suckler cow numbers increased further in anticipation of the measure. This quota was not a production quota; it did not limit the number of suckler cows in the herd, but was a quota on the number of “entitlements” to payments on the farm. For example if a farmer had ten cows in 1992, the farmer was eligible to draw payments on ten cows from 1993 onwards.

Yet from 1993 to 1999, suckler cow numbers continued to rise (Matthews 2000) (most likely due to other premium payments which were available on the offspring). From the late nineties onwards, there is a levelling out of suckler cow numbers with a slight increase in 2008 when the Suckler Cow Welfare (SCW) scheme was introduced. Dairy cow numbers also increased in recent years in anticipation of the removal of dairy quota in 2015. Between 1987 and 1998, the total number of cows increased by 29%, however suckler cow numbers increased by 162% during the same period, reflecting the growing reliance on the cattle sector amongst farmers. The information in relation to regulations, eligibility and payment rates for these cattle subsidies forms the basis of a cattle subsidy model developed by McCormack and O'Donoghue (2014) which feeds into this analysis.

Forest Subsidies

Since the introduction of the first EU funded forest subsidy in 1981, forest policy has changed dramatically in terms of focus and the magnitude of the subsidies paid. Initial subsidies were untargeted and were available to all land-owners. However, from the late

1980s onwards, many forest subsidies were only available to farmers. This changed in the early 1990s when differential subsidies were introduced for farmers and non-farmers. Since then, farmers have been eligible for considerably higher payments for longer periods of time. These differential payments continued until the 2015-2020 Afforestation Programme (DAFM 2015b) came into operation.

In earlier years, afforestation grants covered the majority (but not all) of the expenditure involved in planting. In recent years, the afforestation grant covers 100% of forest establishment costs and a maintenance grant is paid at the end of the fourth year so the establishment of forests is cost neutral. An additional annual subsidy was available to farmers to compensate for the loss of agricultural income on planted land since the late 1980s. These “forest premium” annual subsidy payments were paid for a period of up to 20 years and were designed to bridge the income gap until thinnings are harvested from forests. The payments have increased a number of times since they were initiated and now form a substantial component of total forest income. Payments for broadleaf species on fertile land are considerably higher than for conifers on land that is marginal for agriculture. These subsidies (which are described in detail in Chapter 2) form the basis of a forest subsidy model (ForSubs) which is used to deepen the analysis.

Thus farmers considering forestry are essentially faced with an economic trade-off in relation to the potential loss of agricultural subsidies and the potential gain from forest subsidies. As is evident in Chapter 2, there were periods when agricultural and forest subsidies were mutually exclusive and this may have acted as a disincentive to farmers to plant. This trade-off is also influenced by other factors such as:

- the opportunity cost of market income foregone from the superseded agricultural enterprise;
- the potential reduction in hours worked as a consequence of afforestation;
- the potential change in land value as a result of “tying up” land in an inflexible land use; and
- negative attitudes towards forestry and a desire to continue farming.

In this chapter the analysis is confined to a detailed examination of the subsidy component of the agricultural opportunity cost of afforestation i.e. the subsidy trade-off which is implicitly facing farmers who consider afforestation. Given the importance of subsidies to both the cattle and farm forestry sectors, this analysis aims to highlight the trends in relation to the

relative importance of these instruments over almost 30 years of changing policy environments. It is hypothesised that farm livestock density is likely to have an effect on the level of agricultural subsidies in a given year. In addition, the LFA status of a farm is expected to affect the level of agricultural and forest subsidies. It is also hypothesised that the relativity of the agricultural and forest subsidies changes over time and should provide an insight into the relative competitiveness of cattle farming and forestry, and the possible role of subsidies in falling afforestation rates.

4.3 METHODOLOGY

The objective of this chapter is to understand the impact of changes in agricultural and forest policy on the consideration of converting farmland to forestry by potential planters. This is achieved by developing a modelling framework to simulate the impact of individual policies over time. This framework will also be useful for market simulations in later chapters of this thesis. This section describes the structure of the hypothetical microsimulation model which will allow for the examination of trends in subsidies over time, which will be referenced in later chapters in this thesis.

The complexity of the agricultural and forest policy environment which was introduced in Chapter 2, is further complicated by the heterogeneity of farm systems and environmental conditions across the distribution of cattle farmers. To abstract from this complexity a hypothetical farm was considered an appropriate option. The development of an agricultural subsidies model (McCormack & O'Donoghue 2014) is a necessary and important first step in the investigation of how farmers adapted their stocking rate behaviour when financial incentives encouraged/discouraged certain intensity levels and certain animal types. This approach uses micro farm-level data to simulate a range of payments based on the types of animals on the farm and the farm size and calculates the total subsidy payment for this farm across a range of different stocking rates on a hypothetical farm that remains static during the entire period. While this approach might seem unrealistic, (the farm remains static) the objective of this chapter is to investigate how CAP schemes changed over time, and if different incentives and schemes created different types of incentives for farmers and how these policies might impact on the uptake of afforestation by cattle farmers over time.

Similarly, the afforestation premium payments generated by the ForSubs model are calculated on the basis of the payments that applied for one hectare of forest, planted by a

farmer who fulfilled the relevant eligibility criteria in any given year. Hence, a microsimulation approach allows the research to focus on a single dimension of complexity, i.e. the policy. According to O’Donoghue (2014) “As a modelling framework, microsimulation modelling is a mechanism of abstracting from reality to provide a better understanding of complex situations”.

In order to simulate these policies in relation to the regulations for each policy incentive scheme and the eligibility criteria imposed on farms that might plant forests, the focus of this analysis is on typical farms, thus abstracting from the complexity of the distribution of all farms. This is achieved by adapting a hypothetical microsimulation modelling methodology used by Burlacu and O’Donoghue (2014), which was originally utilised to model social security and taxation policies. Hypothetical microsimulation modelling is useful to disentangle the complexity of forestry and cattle subsidies available to farmers over the study period in order to analyse the relativity of cattle and forestry subsidies on an area (per hectare) basis. The use of a microsimulation approach allows for the consideration of a single dimension of complexity, the policy. As a modelling framework, microsimulation modelling is a useful mechanism of abstracting from reality to better understand complex interactions (O’Donoghue 2014).

Theory and application of hypothetical microsimulation models

Hypothetical models are applied in many research and policy areas. A review of hypothetical microsimulation models conducted by Burlacu et al. (2014), (presented in Table 4.1) highlights the diversity of research areas in which hypothetical microsimulation models are used. To date, hypothetical microsimulation models have not been used before in relation to afforestation *per se*, or in relation specifically to the land use change from agriculture to forestry.

Table 4.1 Hypothetical data applications

Area	Number of studies
Social security and Taxation	70
Media	18
Health Economics	26
Transportation, Land Use and Engineering	23
Geography, Spatial Planning & Development	17
Political science and Public Administration, Education	5
Computational Social Science	5
Agriculture	17*
<i>Total</i>	181

Source: Burlacu et al. (2014)

The use of hypothetical microsimulation models has grown in recent years in agricultural research and policy areas. Models such as those developed by the International Farm Competitiveness network have been used to compare farming systems across countries (Hemme et al. 2000). As with the hypothetical microsimulation models used for tax-benefit analysis, they can be used for comparative research where micro data are not comparable. They are particularly useful to compare the relative competitiveness of different farming systems and have been used by Thorne and Fingleton (2006) to conduct dairy system analysis.)

Hypothetical microsimulation models can also be used to for policy analysis (Doucha & Vaněk 2006). Much of the early developments in involved describing the impact of policy changes within and between European and OECD countries (Atkinson and Sutherland 1983; Buti et al. 2001; OECD 1996). As policies become more complicated, microsimulation models became more useful to explain their differential impacts.

In addition to considering the effect of existing policy, hypothetical models and synthetic data are also used to evaluate the *ex-ante* effects of policies (Evans and Williams 1999), before they are implemented and it is not possible to estimate the effects on actual populations. Synthetic data are also useful in applications in various policy areas with missing or insufficient data. They are particularly well suited for farming systems where availability of micro data is limited, such as is the case in organic farming (Zander et al. 2007).

The primary advantages of hypothetical microsimulation models are their simplicity and their relatively low data requirements. These characteristics add both to their understandability and also to the possibility of using them in countries where data availability or access to the human capital required for developing a data-based model is limited. At their simplest, hypothetical models simulate the impact of a policy on a particular unit (Phillips & Toohey 2013). As a result, they are good communication tools, abstracting from the complexity of the population.

The corollary of this however, is the main criticism of hypothetical models. Even where a range of typical units such as farms are considered, they are in fact “typical” of a very small part of the income distribution and as a result can be misleading (Atkinson and Sutherland 1983). It is worth noting that the use of hypothetical models has some additional theoretical drawbacks. The approach fails to take into account the wide variation of family

circumstances, or the differences in details (e.g. source of income, existence of tax relief on expenditure, etc.) which might have a significant effect in some situations (O'Donoghue & Sutherland 1999). Finally, the methodology is essentially a static analysis which usually does not incorporate behavioural responses (Li et al. 2014) when evaluating for example, the impact of tax-benefit systems and reforms (Berger et al. 2002).

Hypothetical models also lend themselves to being used for international comparisons. The hypothetical microsimulation models used by the OECD (Immervoll et al. 2004) are frequently used to understand comparative work incentives and unemployment replacement rates across OECD countries. In cross-national comparisons of tax-benefit systems, the stylized method based on hypothetical data has the advantage of allowing analysts to properly consider tax-benefit systems in a comparable and consistent manner across countries (Buti et al. 2001; Evans and Williams 1999).

The IFCN models à la Hemme et al. (2000) and Thorne and Fingleton (2006) are examples of farm level microsimulation models based on hypothetical data. IFCN models look at farm enterprises at a single point in time. The IFCN typical farm model is a unique methodology that is used to compare farms in a single year across a range of countries which provides a realistic database of different farm types in several different regions (Deblitz 2015). A typical beef farm is representative of farms within the region in terms of size, crops grown, livestock systems, labour organisation and production technology used. According to Deblitz (2005), the technical and economic data used to describe the typical farm are neither individual farm data nor statistical averages but are based on a consensus achieved in a panel meeting, consisting of farmers, an extension adviser and a scientist.

There are a number of advantages to using this approach. Firstly, the cost of collecting farm level data on a regular basis is hugely expensive and therefore the typical farm concept offers a realistic alternative. Secondly, understanding agricultural production systems and farmers' decision making requires an accurate picture of the real farm situation, but the use of individual case studies invariably contains some particularities.

Methodological choices

While hypothetical microsimulation models may appear simplistic, they involve many of the methodological choices of more detailed microsimulation models, although some of the simplified assumptions are used to reduce the complexity of a hypothetical model. A wide

range of dimensions and types of parameters have been identified throughout the literature, including:

- the type of microsimulation (what)
- the unit of analysis & variation (who) and
- the unit of measurement (how & how much).

After deciding on the type of analysis, the choice of the target group or the unit to be investigated (a farm, a company, a household) is the next step in carrying out the analysis.

The methodological choices that need to be made include:

- Unit of Analysis
- Interaction with another model
- Period of Analysis
- Unit of Variation
- Analytical Measure

The modelling options required for hypothetical microsimulation models are presented in the following sections, referring in particular to the model developed for this thesis, namely the Forest Subsidies Model (ForSubs).

Unit of Analysis

As is the case with most microsimulation models, the unit of analysis is a key decision of a model builder. Across the hypothetical microsimulation models considered by Burlacu et al. (2014), the choices of analysis unit (presented in Table 4.2) vary from single individual to multi-individual models to models at the firm or farm scale. While the ForSubs model is developed to be representative of a typical farm, for comparative purposes between agricultural and forest policies, the common unit of analysis is land. Thus the comparative analysis is conducted in relation to subsidies or incomes at the hectare level. The ForSubs model generates the forest subsidy relevant for the conversion of one hectare of land from an agricultural land use to a forestry land use, in a given year. Therefore, to some extent, it is a sub-component of the farm unit of analysis. Later analysis in this thesis will extend the unit of analysis to represent the percentage of a farm planted, ranging from 0 to 50% (see Chapter 7 for further detail).

Table 4.2 Unit of analysis

	Number of studies	Percentage of the total number of studies
Unit of analysis		
Individual	35	30.4
Household/Family/Benefit Unit	55	47.8
Company	8	7.0
Farm	17	14.8

Source: Burlacu et al. (2014).

Period of Analysis

The next methodological choice is the period of analysis. This refers to the time period over which an analysis applies. The analyses described thus far relate to policies within a particular period. Of the studies reviewed by Burlacu et al. (2014), the majority focus on the current period and typically model work incentives (Immervoll et al. 2004). However some analyses are undertaken over longer time horizons such as the life-cycle (Rake et al. 1999). The conversion of agricultural land to forestry is such a life-cycle choice as the decision to plant is irreversible and involves a permanent land-use change which entails the substitution of annual agricultural incomes with early revenues from forest subsidies and long term income from timber sales.

The issue of concern for the analysis in this chapter is not the forest life cycle but the impact of the relativity of agricultural and forest subsidies in the year in which a farmer considers afforestation. Therefore each year of the period is modelled separately but due to the long time horizon for forest crops, it is necessary to build-in the capacity to model life-cycle and multiple life cycle decisions at a later stage in the analysis (this methodology is described in Chapter 7).

Unit of Variation

While many hypothetical models report a single measure in relation to the specific policy (Bradshaw and Finch 2002) or undertake an analysis for a particular family type (OECD 1995), some models vary the characteristics of the unit of analysis to assess the impact on the measure of concern, i.e. the unit of variation. Examples include where disposable income is calculated as hours vary (O'Donoghue 2002) or where the wage rate changes (Burlacu & O'Donoghue 2014). Other dimensions of variation are used in comparative research, whether across countries (Bradshaw and Finch 2002; OECD 1995; Thorne and Fingleton 2006) or inter-temporal (O'Donoghue 2002). Over one third of the papers surveyed by Burlacu et al.

(2014) utilised cross country comparisons, while less than a quarter of studies involved temporal comparisons.

The units of variation which can be employed using the ForSubs model are species, yield class (a measure of forest productivity related to soil class) and LFA¹⁵ status which depends on location and determines the rate of forest subsidy payable during part of the time period examined. The primary units of variation in the agricultural subsidies model are the livestock density (LUha⁻¹) and the LFA status.

Interaction with another model

Within the hypothetical microsimulation literature, hypothetical simulations can be undertaken by linking to more substantial external models such as EUROMOD (Berger et al, 2001) and STINMOD (Harding et al. 2006). However, most analyses use bespoke models such as the OECD models (Immervoll et al, 2004), or cross-border analysis (Burlacu and O'Donoghue 2014; Burlacu et al. 2014). All examples of hypothetical analysis in agriculture utilise bespoke models. The bespoke hypothetical microsimulation model which is developed for this analysis forms an integral part of a larger forest bio-economic system (ForBES) model which is described in Chapter 5. However, the model developed for this analysis will bring together the agricultural subsidy model developed by McCormack and O'Donoghue (2014) and the forest subsidy model (ForSubs) described here. Both models were developed in Excel on compatible platforms where subsidies are recorded on a per hectare basis annually, in order to facilitate the hypothetical modelling process.

Analytical Measure

Fundamental to the analytical choice is the specific analytical measure used. In the simplest of models, the level of a policy (Bradshaw & Finch, 2002) or the relevant income concept is used (Phillips & Toohey 2013). The afforestation decision is essentially an investment decision as farmers “invest” their land in forestry. Many analyses of policy focus on the rate of return to investments or contributions. For example O'Donoghue (2002) considers the lifetime return to a social insurance pension system depending on the number of contributions made. There are many examples also of what are called “Money's Worth” analyses (James & Villas 2000; Thorburn et al. 2007). The analytical measures used to model the return on

¹⁵ See Chapter 2 for further detail

investment vary from nominal values to benefit-to-tax ratio (James & Villas 2000; Thorburn et al. 2007) to Net Present Value (NPV) (Geanakoplos et al. 1998) to Internal Rate of Return (IRR) (Burlacu & O'Donoghue 2014), depending on the type of investment.

Within the field of agriculture, the primary focus is on quantifying the cost associated with a given level of production, quantifying the relative profit margin, the total cost and the opportunity costs of different production systems (Thorne & Fingleton 2006). In the case of examining the land use change from agriculture to forestry, the analytical measures of return which need to be adopted are those which incorporate the inter-temporal nature of the decision but also facilitate comparison between the opportunity cost of the annual (agricultural) income and multi-annual (forest) income. Therefore the net present value (NPV) is used to reflect the inter-temporal nature of the afforestation decision. In later analysis, multi-annual forest incomes are examined on a comparable basis with annual agricultural incomes, therefore the annual equivalised (AE) value of the NPV is utilised as an additional analytical measure (this topic is covered in greater detail in Chapter 5).

Structure of the hypothetical “typical” farm model

In this chapter the subsidies associated with forestry as a land use, are compared to those associated with a cattle system land use, drawing on analysis based on the “Typical Farm” methodology developed as part of The International Farm Comparison Network (IFCN). In the IFCN methodology, a hypothetical cattle farm is generated to be representative of Irish cattle farms in terms of size, livestock systems, labour organisation and production technology used. Typically, the methodology compares farms in a given year across a range of countries. However this analysis uses a time series of data on agricultural and forest subsidies within a single country across a range of years. This chapter extends this methodology (which is scalable to other IFCN countries) to model the forest enterprise and forest policy. This methodology is also utilised to model an inter-temporal life-cycle dimension in later chapters.

The scope of the IFCN approach is extended beyond examining at a typical/representative farm at a single point in time, to examine changes in direct payments across time. Therefore the approach utilised here incorporates an inter-temporal dimension. The unit of measurement is the farm. The complexity of modelling at farm level stems from the large degree of population and behavioural heterogeneity. Hypothetical microsimulation modelling is a novel

approach to abstracting from the level of heterogeneity at farm level and the subsequent issues of aggregation bias associated with such heterogeneity. Individual farmers, operating at different livestock densities, generate a different direct payments schedule for each farm. By adopting a static typical farm methodology, it is possible to abstract from this complexity and create an optimal direct payments schedule. This identifies the optimal livestock density which maximises direct payments. It is assumed that as all farmers are bound by the same eligibility criteria, i.e. they could in theory adapt their behaviour to maximise their direct payments.

The literature on the changes in agricultural and forest subsidies (presented in earlier chapters) forms the basis of a typical farm model in which each agricultural and forestry subsidy is defined by the parameters for eligibility for afforestation schemes as generated by the ForSubs model. The eligibility and payment parameters for agricultural subsidies over the period are generated by an agricultural subsidies model developed by McCormack and O'Donoghue (2014). These models are described in the next sections.

ForSubs Model

With the overall aim of developing the capacity to model forest market incomes and forest subsidy incomes over time, for a range of species, across a range of forest yield classes and LFA designations over time, an excel based forest subsidies model (ForSubs) was developed as a component of a more comprehensive forest bio-economic system (ForBES¹⁶) model.

A thorough examination of (mostly grey) literature on forest policies and the related regulations, eligibility criteria and payment rates was conducted and is presented in Chapter 2 (and summarised in Table 2.2) This information allows for the paramaterisation of annual changes in subsidy eligibility criteria, payment rates, forest species composition, and area limitations in the ForSubs model. The main factors which determine the rate of payment of forest subsidies are:

- Year of afforestation – changes in schemes from one year to the next give rise to considerable year on year payment differences
- Location of the farm – early schemes were restricted to specific counties;
- Eligibility as a “farmer” - criteria and regulations changed significantly over time;

¹⁶ The ForBES model is discussed in detail in Chapter 5

- LFA status – higher subsidies were paid on farms designated as more severely handicapped for some of the period;
- Species choice – conifer and broadleaf species were paid at differential rates which were governed by General Planting Categories (GPC's) as laid down by the Forest Service. Across almost all but the very early schemes, pure broadleaf crops (or mixed broadleaf/conifer crops) attracted considerably higher payments as a compensation for considerably longer rotation lengths. While conifer crops could potentially be harvestable in less than 40 years, broadleaf rotations could extend from up to 60 years for ash (*Fraxinus excelsior*), to 120 years in the case of oak (*Quercus robur*). The choice of species is largely governed by forest yield class which is a measure of the average volume production over the lifetime of a stand of timber. Thus in selecting a suitable site and species, farmers may have to make a trade-off between higher short-term subsidy income from broadleaves or earlier timber income from conifers.¹⁷
- Afforestation area – minimum payment areas applied in most schemes and some schemes offered tiered payments for larger areas (> 6 hectares or >12 hectares).

Teagasc Typical Farm Subsidies Model

The simulation of typical cattle farms is achieved by utilising the¹⁸ (Typical Farm (Subsidies) Model (TFSM) developed by McCormack and O'Donoghue (2014) to simulate typical cattle farms. The model is constructed using actual NFS data from 1995. From these data, a stylised farm scenario is developed. The TFSM characterises a typical farm for the main agricultural systems (dairy, cattle, sheep and tillage) and for three classes of economic performance (top, middle, bottom)¹⁹ based on gross margin per hectare (Hennessy et al. 2015). As cattle farmers are the most likely to consider afforestation (Ryan et al. 2009; Breen et al. 2010), this analysis is based on a typical middle performing, cattle rearing system where calves are reared and fattened until they are ready for slaughter. This hypothetical farm composition comprises 34 hectares of land with suckler cows, 10-month and 22-month steers, heifers and a bull. Although this framework has been developed to evaluate the role of subsidies as

¹⁷ This chapter deals with species selection from the perspective of the level of forest subsidy only, as it is only the subsidy payment available in any given year that is of interest here. As part of a wider bio-economic model, Chapter 5 contains a more detailed discussion on species selection from the perspective of timber market returns.

¹⁸ Agriculture and Food Development Authority

¹⁹ Top, middle and bottom performers economically are categorised on the basis of farm gross margin

drivers of land use change from agriculture to forestry in Ireland, there are opportunities to extend this framework to other countries within the IFCN network.

The objective of this chapter is to observe the relativity of agricultural and forest subsidies in any given year across the time period. It is assumed that farmers considering afforestation make decisions based on the current value of available subsidies. Thus for the purpose of comparing agricultural and forestry subsidies in each year of the dataset, nominal subsidy values are used and the appropriate CSO (Central Statistics Office) price indices are applied for a given year to make them comparable. The hypothetical model is based on the farm and varies the livestock density and the direct payments. The unit of analysis for both forestry and agricultural subsidies is the hectare.

All of these factors have an impact on the relativity of agricultural and forest subsidies. The eligibility parameters governing the interaction between afforestation and agricultural subsidies are also a key element of the ForSubs model, as the complementarity between agricultural and forest subsidies changes over time, with some agricultural and forestry schemes being mutually exclusive. The payment and eligibility details presented previously in Chapter 2, illustrate the complexity in terms of the changes in forest subsidy eligibility and payment criteria from year to year.

4.4 DATA

The sources of data used in the typical farm model include:

- Farm structure and livestock density information (NFS longitudinal data)
- Forest subsidy information (ForSubs model)
- Farm subsidy information in TFMS (McCormack and O'Donoghue 2014).

The parameters used to generate annual subsidies per hectare are livestock density and land area. All subsidies are applied to the static farm over the period 1984 to 2012. The agricultural subsidies modelled include livestock headage payments, LFA payments, extensification payments, REPS, SFP and SCW payments. REPS and SFP were calculated from 1994 and 2005 onwards respectively, on an area basis²⁰. In this way, the impact of different livestock densities and LFA designations on the level of subsidies per hectare received on a typical farm can be evaluated.

²⁰ All payments are summarised in Tables 2.2, 4.3, 4.4 & 4.5

The relevant livestock payments that applied in each year are calculated for each LFA designation. Livestock densities are allowed to vary across a range from 0.1 LUha⁻¹ to 3.1 LU ha⁻¹. Livestock densities are also calculated to represent a low (0.7 LUha⁻¹) livestock density; a medium (1.39 LUha⁻¹) livestock density which maximises headage payments up to the extensification threshold of 1.4 LUha⁻¹; and a high (1.75 LUha⁻¹) livestock density rate at which farmers have higher headage payments but are not eligible for extensification payments. Total payments from all subsidies (Tables 4.3; 4.4; 4.5) are used to create a direct payments schedule which represents the marginal rate of return to the farm from all subsidies.

Table 4.3 Agricultural subsidies: Direct payments (all farmers) prior to 1993 (1992 payments)

Suckler Cow Premium	No limit	£52.73 per head
Beef Premium Derogation	Male cattle over 9 months. Max 90 head	£35.15 per head
Ewe Premium	Min number 10 ewes	£19 per head

Source: Teagasc Management Data for Farm Planning (various years).

Table 4.4 Agricultural subsidies: Payments available in Less Favoured Area (1992)

Animal Category	LFA Subsidy
Cattle Headage (MSH)	£40 on first 8 LUs. £33 for each LU from 9-30 LUs
Beef-cow headage (MSH)	£84 per cow. Maximum number of cows: 40
Beef Cow Scheme (LSH)	£75 per cow. Maximum number of cows: 30
Sheep headage (MSH) and (LSH)	£10 per ewe for first 200 ewes. Max payment £2,000 per farm

Source: Teagasc Management Data for Farm Planning (various years).

Table 4.5 Agricultural subsidies: MacSharry Cap Reform Payments (1993)

Suckler Cow Premium	Individual farm quota based on the number of suckler cows held in 1992. Payment per head. Upper livestock density limit per farm of 3.5 LUha ⁻¹ in 1993 which reduced to 2 LUha ⁻¹ by 1996	£79 (€100)
Special Beef Premium	Paid in two instalments on steer cattle at 10 months and 22 months. Payment per head. Upper limit of 90 animals increasing to 180 animals in 2000. Upper livestock density limit similar to suckler cow premium.	£52.73 (€67)
Slaughter Premium	Paid automatically on the number of animals slaughtered. Payment per head. No limit on the number of animals eligible. Livestock density limit per farm 1.8 LUha ⁻¹	£52.73 (€67)
Extensification Premium	Paid automatically on suckler cows or male animals if a livestock density per farm of 1.4 LUha ⁻¹ or lower is achieved	£26.36 (€33)
Ewe Premium	Individual farm quota based on the number of Ewes held in 1992. Payment per head. Minimum livestock density of 10 ewes Upper limit of 1000 in Less Favoured Areas and 500 in Non Less Favoured Areas	£17 (€21)
Rural World Premium	Extra payment to farmers in less favoured areas. Payment per head. No limit.	£5.25 (€6.60)

Source: Teagasc Management Data for Farm Planning (various years).

Where rules in the conditions of a subsidy change, an increase/decrease in payment, a livestock density limit is reached or a maximum payment per farm/hectare is reached, the marginal return to the farm changes thus creating a change in the slope of the direct payments

schedule. All payments for individual subsidies are calculated and totalled for each year to illustrate the optimal return to the typical farm from all subsidies, in each year of the time period²¹.

Many conifer species require less demanding site conditions in terms of fertility and shelter and can produce high timber volumes on sites which are not suitable for broadleaves and are only marginal for agricultural production. The most commonly planted Irish conifer is Sitka spruce, (*Picea sitchensis* (Bong.) Carr.), accounting for 57% of all private and public planting in Ireland (DAFM 2014b). Sitka spruce (SS) is relatively undemanding from a management perspective but is highly productive on wet mineral soils which are marginal or sub-marginal for agriculture (Farrelly et al. 2011). For the purpose of illustrating the relativity of cattle and forestry payments, the focus is on forestry headage and premium payments for the widely planted conifer “non-diverse” (n/d) and “diverse 20%” Sitka spruce planting categories on enclosed land.

While the spread of ash dieback disease (*Chalara fraxinea*) into Ireland has virtually stopped new planting of ash (*Fraxinus excelsior* L.), owing to its popularity over the last 20 years, ash is the dominant broadleaf species. In recent years, broadleaf afforestation has accounted for approximately 30% of annual afforestation (DAFM 2013a). Thus the “broadleaf other: 40-100%” and “broadleaf other: 75-100%” broadleaf categories are selected to represent payments for broadleaf planting in the ForSubs model.

As this analysis is conducted on a per hectare basis, the forest subsidy values for one hectare are used. The ForSubs model generates forest subsidies and eligibility criteria available by species in each year of the period examined. In later analysis, the TFSM is further developed to incorporate forest planting data and associated market incomes simulated in Chapter 5 using the ForBES model.

4.5 RESULTS 1. LIFE-CYCLE ANALYSIS OF FOREST AND AGRICULTURAL SUBSIDIES

The hypothetical microsimulation methodology allows us to abstract from the heterogeneity and complexity at individual farm level on cattle rearing farms, to model the policy (subsidies) in isolation. The Teagasc Typical Farm (Subsidies) Model (TFSM) specifically allows us to vary livestock density and LFA designation on cattle farms to simulate the subsidies. It also allows us to vary species, forest productivity and LFA designation to

²¹ Further information on the agricultural subsidies model is available in McCormack and O’Donoghue (2014).

simulate the forest subsidies. The influence of (a) LFA designation and (b) stocking density on cattle payments are examined initially.

Figure 4.2 Subsidies available to suckler cattle farms at medium stocking density in MSH, LSH and non-LFAs from 1984 to 2012 (€ ha⁻¹) (based on TFSM outputs)

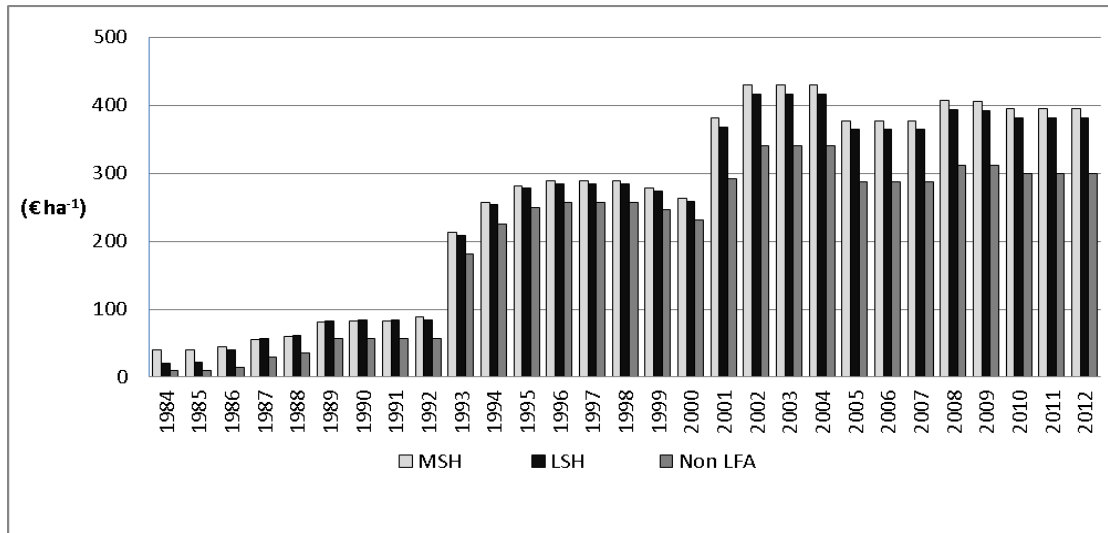
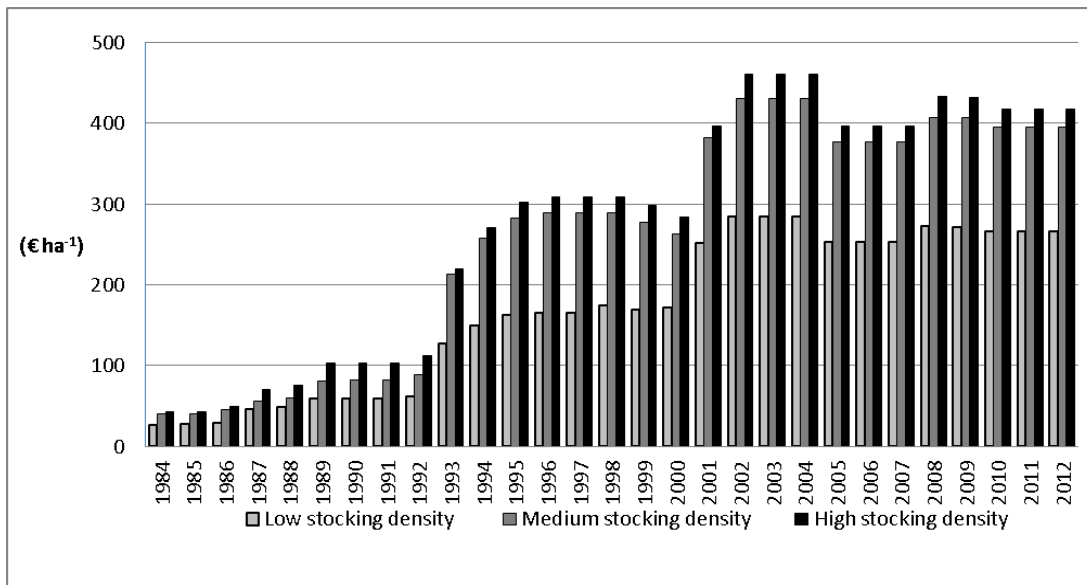


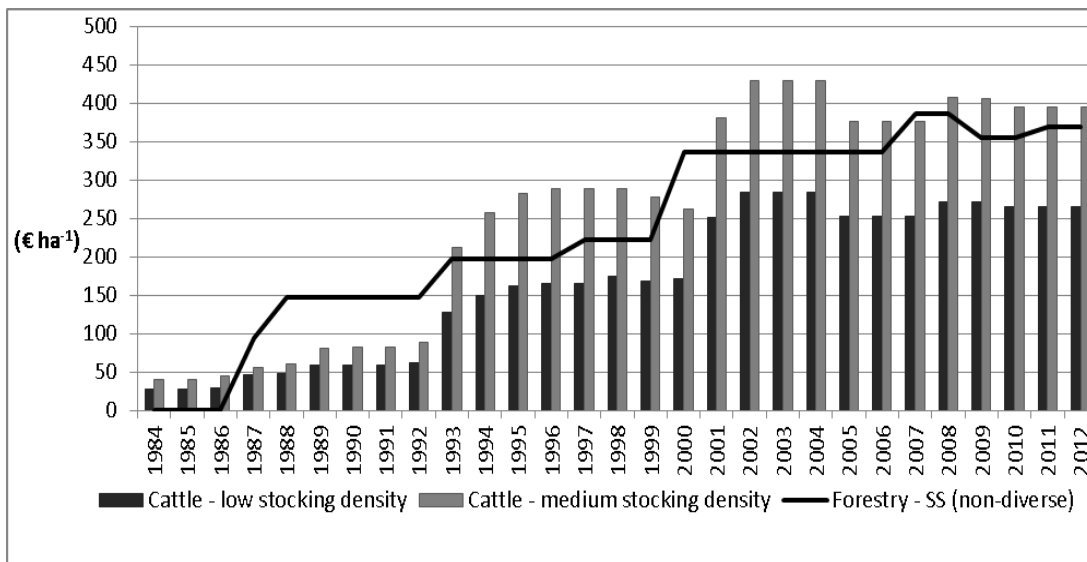
Figure 4.2 shows the impact of LFA designation on cattle subsidies, keeping the livestock density constant at 1.39 LU ha⁻¹. It is evident that the payments available to farmers in non-LFA areas are lower than in LFAs, although there is little difference in the payments available to farmers in MSH and LSH areas. As 75% of the land in Ireland is designated LFA (MSH & LSH), the relevant payments in MSH areas only are evaluated here, simplifying the comparison of cattle and forestry subsidies. Payments for low, medium and high livestock densities on the typical farm are presented in Figure 4.3 (keeping LFA designation constant at MSH). A large differential between payments for the low livestock density (0.7 LU ha⁻¹) and the medium/high densities (1.39 and 1.75 ha⁻¹) emerges. The payments for low density stocking are considerably less than the medium and high livestock densities across the period. Above a livestock density of 1.4 LU ha⁻¹ payments no longer include extensification and increasing cattle numbers above this livestock density provides only marginal subsidy gains. The average livestock density on cattle farms between 1993 and 2012 was 1.06 LU ha⁻¹ (NFS various years).

Figure 4.3 Subsidy payments available to suckler cattle farms at low, medium and high stocking densities in MSH areas from 1984 to 2012 (€ ha⁻¹)



Therefore, to simplify presentation, the 0.7 and 1.39 LU ha⁻¹ livestock densities are compared against the forest subsidy for a crop of pure Sitka spruce in Figure 4.4.

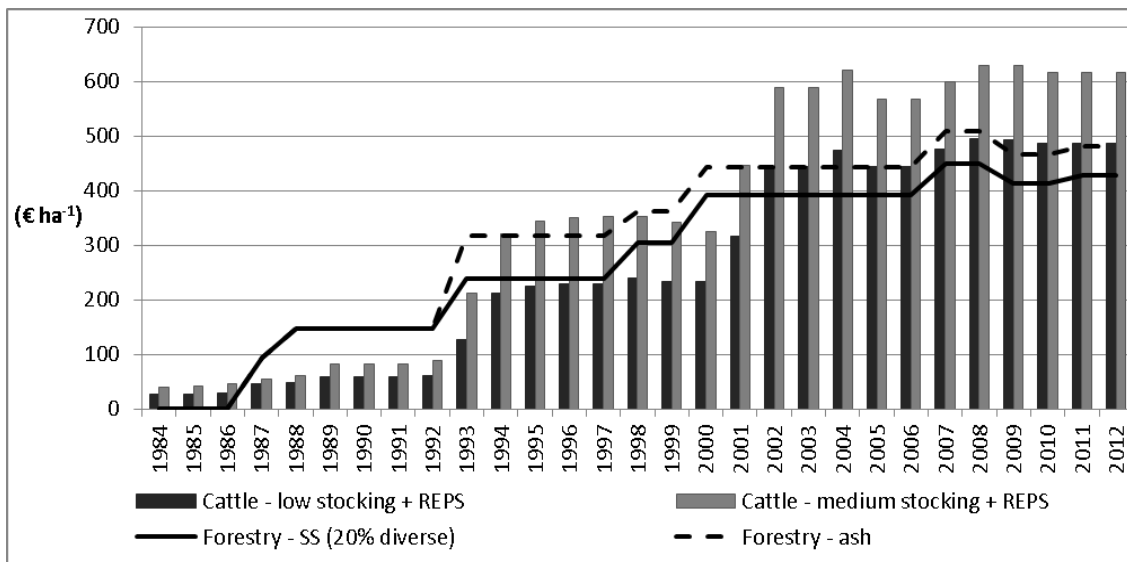
Figure 4.4 Payments available in MSH areas from 1984 to 2012 (€ha⁻¹) for suckler cattle farms (low & medium LU ha⁻¹) and for Sitka spruce (non-diverse conifer)



Cattle payments for low and medium livestock densities (0.7 and 1.39 LUha⁻¹) are compared here. It is only in the initial Western Package and OPF schemes that forestry premium payments are higher than cattle subsidies, regardless of livestock density or LFA designation.

From the 1993 MacSharry CAP reform onwards, cattle subsidies are higher than conifer (Sitka spruce) premiums for medium-stocked farms. Only the lower-stocked extensive suckler farms could have increased their subsidy payments by planting trees on their land. The influence of participation in REPS is also examined and is presented in Figure 4.5.

Figure 4.5 Cattle + REPS payments in MSH areas (low & medium stocking densities) Sitka spruce (20% diverse) and broadleaf (ash) (1984 to 2012) (€ha⁻¹)



The addition of REPS payments to the cattle subsidies is specifically examined for both the low and medium livestock densities in MSH areas. These are compared with the higher conifer payments available for a Sitka spruce crop, which includes 20% of another species (Sitka spruce 20% diverse) and broadleaf (ash) premium payments.

It is evident that the inclusion of REPS payments from 1994 onwards pushes the cattle payments up to the level of the higher conifer (Sitka spruce 20% diverse) payments, except for a short period in 2000 when LFA payments were decoupled from production. From 2002 onwards, cattle subsidies for REPS farms were higher than the conifer payments, particularly for the more intensive medium stocked farms. The payments for ash are higher than the low livestock density cattle payments in the earlier years but are comparable in later years. From 2002 onwards, the cattle payments for medium stocked REPS farms are significantly higher than either the conifer or broadleaf payments. The relative payments for cattle and forestry in LSH and non-LFAs (not shown here), also display similar trends but at slightly lower payment rates.

In summary, the main results are:

- While several increases were applied to the level of forest premium payments, these tended to coincide with increases in agricultural payments which dampened their net effect;
- For most of the period in question, cattle subsidies exceeded conifer payments in MSH and LSH areas at medium to high livestock densities;
- The more intensive farms stocked at medium- and high-stocking densities had higher payments than extensive farms;
- The tiered forestry subsidies in LFAs kept the forestry subsidies above the cattle subsidies between 1994 and 1999, but were reduced to a flat rate in 2000;
- While forestry subsidies were higher than agricultural subsidies from 1987 to 1993, the available grants only covered 85% of the establishment costs;
- For cattle farms participating in REPS, cattle subsidies were higher than forestry subsidies for medium stocked farms in MSH and LSH areas which represent 75% of total agricultural area.

4.6 DISCUSSION AND CONCLUSIONS

When the SFP was introduced, many predicted the abandonment of land and the emergence of entitlement farmers. This did not happen, and the question remains as to why farmers in receipt of SFP continued to produce beef when it seemed unprofitable to do so (Hennessy and Thorne 2005; Daugbjerg 2006; Swinnen 2010).

It is evident that for much of the period reviewed, cattle subsidies were higher than forestry subsidies, particularly in MSH areas and for more intensive farms. This finding is consistent with a recent analysis of the characteristics of NFS farms with and without forestry, which concludes that farms with higher stocking densities are less likely to consider converting land to forestry (Howley et al. 2012). In essence, the opportunity cost of undertaking forestry is higher for intensive farms than for less intensive farms, in terms of the income foregone from agricultural subsidies. However, farming at high stocking densities requires “good” land which is unlikely to be considered for forestry. Less intensive farms are more likely to have been in receipt of REPS payments (DAFM 2014b) which would have added to their opportunity cost. Other studies also find that agricultural subsidies play an important part in the afforestation decision (Collier et al. 2002, McCarthy et al. 2003). This is echoed by O’Connor and Kearney (1993), who conclude that “other things being equal, the expected

returns from forestry must show a premium over the returns from land before landholders will seriously consider the forestry option”.

Financial studies of forest planting conducted in Ireland to date, indicate that forestry outperforms cattle and sheep systems over the period of one rotation (Breen et al. 2010; Upton et al. 2013). However these studies focus on the market component of income and do not include detailed analysis of the relevant subsidies. The analysis in this chapter focuses only on the forestry and cattle subsidies available to a cattle farmer in each year of the examined period and does not take into account the market income from cattle or timber sales, or the income tax exemption for forestry premium payments.

This analysis shows that the combination of cattle subsidies, LFA payments and agri-environment payments (REPS), exceeded the forestry payments available to many cattle farmers over the period. REPS schemes have been recognised as a significant competitor with afforestation schemes (McCarthy et al. 2003). The REPS scheme is now closed but by 2012, 20,000 farmers were availing of Agri-Environment Options Schemes (AEOS) at an average payment of €3,200 per applicant (DAFM 2014b). From 2015 onwards, farmers have the opportunity to enter the Green Low carbon Agri-environment Scheme (GLAS) under which the payment is €5,000 per applicant for a maximum of 50,000 applicants (DAFM 2014b).

It is recognised that financial analysis alone may not explain planting patterns. This chapter does not take into account the fact that the permanency of the afforestation decision is a barrier to many farmers (McDonagh et al. 2010). The expectation of future (direct) payments has been recognised as affecting land use decisions as farmers position themselves to ensure they are in a position to avail of future payments (O’Donoghue and Whitaker 2010). This flexibility is not available to farmers who afforest land. Duesberg et al. (2013) conclude that the reason why forestry is not an option for some farmers is that “it simply isn’t farming”. This desire to continue farming is not a uniquely Irish phenomenon. Gorton et al. (2008) examine farmer attitudes in EU countries and conclude that even post-decoupling of payments from production, farmers retain their productivist objectives and prefer to utilise their land by farming it.

A detailed examination of the cattle and forestry subsidies available to farmers who may have considered forestry over the time period has not previously been undertaken in the Irish literature. Previous studies (duQuesne 1993; Collier et al. 2002; McCarthy et al. 2003)

explicitly comment on the sensitivity of farmers to the level of agricultural and forestry subsidies. The results presented in this chapter highlight the potentially significant opportunity cost of the agricultural subsidies lost by cattle farmers converting to forestry. Stocking density, LFA status and participation in REPS all contribute to the magnitude of this potential loss. While there was a significant increase in forest subsidies up to 2009, when these are examined in conjunction with concurrent increases in cattle payments, the increases in forest subsidies in general, did not exceed those available for cattle farming, particularly for intensive farms with high livestock densities and for extensive farms participating in REPS.

Overall it is evident that the increases in forest subsidies only served to maintain the relativity with cattle subsidies rather than providing forestry with a financial advantage over cattle farming during that period. This analysis reveals that the subsidy component of the opportunity cost of farm afforestation may have been greater than was previously recognised. The slower than expected uptake of afforestation in Ireland may not be surprising in this context.

Chapter 5. MODELLING FINANCIALLY OPTIMAL AFFORESTATION AND FOREST MANAGEMENT SCENARIOS USING A BIO-ECONOMIC MODEL

5.1 INTRODUCTION

This chapter focuses on developing a mechanism to establish the market returns to farm afforestation. The economic return on afforestation is a function of the interaction of agronomic and economic factors. The choices made at forest establishment and harvesting, result in different growth, cost and income curves and ultimately, different rotation lengths and economic optimisations.

The long time period involved is alien to farmers who are more familiar with annual agricultural income cycles. In establishing a forest, farmers need to know the production implications of planting land of different quality (given specific environmental conditions) and they need to know the implications of choice of species and how this can affect both long term timber returns and subsidy payments. Farmers considering afforestation also need to know the economic implications of different management and harvesting regimes. In addition, farmers want to understand the impact that prices can have on long-term forest returns in order to capitalise on market opportunities. This information enables decisions on (a) whether afforestation will be profitable for them; (b) how to optimise the returns from the forest depending on owner objectives and (c) what are the outcomes of different optimisations? The quantification of these life-cycle components of forest income under different circumstances is necessary to estimate the different outcomes arising from different optimisation objectives.

While farmers are concerned with optimising their individual forest returns, policy makers are concerned with optimising the range of ecosystem services provided by forests. These include maximising merchantable volume production, carbon sequestration potential of forests and the production of biomass for the renewable energy sector.

There is a considerable and growing volume of scientific literature that describes models which integrate bio-physical and economic parameters in answering policy or optimisation questions. The most common approach used is the development of bio-economic models (BEMs). A number of publications have reviewed BEMs developed for the general land use context and report on model objectives and specification. In his review, Brown (2000) segregates models into three categories: primarily biological models with the addition of an

economic component; economic optimisation models which vary bio-physical components as choices for optimisations; and “truly bio-economic models” that integrate the biophysical and economic model components in an interactive manner. These models are by nature multi-disciplinary and require a common understanding of bio-physical and economic interactions but nevertheless, they help to logically isolate and sort out complicated cause and impact relationships, allowing for scenario analysis to estimate the effect of alternative policy options.

Ruben et al (1998) distinguish between *positive* models (used to describe current land use patterns) (Pindyck and Rubinfeld 1991) and *normative* models (used to evaluate possible changes in land use under different technological and economic conditions (Rabbinge and van Ittersum 1994) and to indicate physical trade-offs between long-term objectives (Ruben et al 1998). Flichman and Allen (2013) suggest that while all optimisation models are in principle normative, when the objective of a bio-economic model is to make *ex ante* assessments of different impacts, these models can be applied in a positive manner which involves specifying in detail how a system works, and then by varying parameters, to use them for forecasting purposes. The goal of many BEMs is to optimise a specific function where the selection of the objective function is in itself normative.

The detailed understanding and specification of the relevant assumptions and interactions is critical to BEM development and is sometimes the greatest challenge faced by interdisciplinary researchers (Flichman & Allen (2013), Janssen et al (2010). Janssen et al (2010) make the specific point that BEMs tend to be developed for a given location or purpose and are rarely re-used, while Flichman and Allen (2013) emphasise the need for clarity in relation to the assumptions underlying bio-economic models which are developed by multidisciplinary teams of researchers.

In order to answer the research questions posed by this thesis, it is necessary to develop a bio-economic model that provides information on a number of questions.

- Primarily, the model needs to have the functionality to re is a need to vary input parameters to reflect the afforestation and harvesting choices available to farmers and how these impact on the optimum forest rotation.
- Secondly, the model needs the flexibility to vary the production objectives of forests to conduct scenario analysis of how different policy objectives might result in different optimisations of rotation length, volume production and overall economic return.

- Thirdly, the model should be able to address (at least in a generalised way) new policy evaluation needs such as biomass estimation for carbon and renewable energy optimisation.
- There is also a need to incorporate the capacity to include forest subsidies and agricultural opportunity costs in order to model farm afforestation decisions at individual farm level.

These questions all involve *ex ante* assessments or predictions and as such rely on modelled rather than actual data. To date, it would appear that there is not an integrated methodology which addresses these agronomic, economic, policy and market optimisation questions in relation to farm afforestation. With the objective of improving model transparency and re-useability, the model described in this chapter includes a detailed description of the possible agronomic and economic choices and their optimisations, allowing for the systematisation of the process of developing this multidisciplinary forest BEM.

In this chapter, the biophysical theory underpinning the optimisation of forest growth is reviewed, in order to understand the range of afforestation and management choices that farmers can make. Next, the scientific literature on forest-specific bio-economic models is reviewed in order to inform the assumptions necessary to model the relevant choices. The assumptions and data requirements are justified and illustrated with descriptive statistics. The bio-economic model generates growth, cost and income curves by species and site productivity for different optimisations and for different input scenarios. The model results are discussed in relation to afforestation targets and evolving forest policy.

5.2 THEORETICAL FRAMEWORK

Before farmers consider taking land out of agriculture for afforestation, they need to know the potential economic and environmental consequences of choosing different species, site types, cost, management and harvesting regimes. They also need information on the number of years it takes for a forest to mature (the forest rotation) and the challenges involved in predicting returns which are dependent on price scenarios that change over time.

The afforestation choices made by farmers depend on their objectives.

- If they are focused on the environmental sustainability of forests they may prioritise environmental returns over economic returns.

- If they have a preference for short term financial returns, they may choose species which maximise subsidy income in the early years.
- If the preference is for longer term retirement income, farmers may choose species that eventually produce larger timber volumes or higher value timber.
- If the objective is to maximise profit in the shortest possible timeframe, fast-growing conifer species will deliver a shorter rotation length.
- Additionally, planting more productive land can result in faster growth and greater timber yield and/or a shorter rotation.

At a later stage, farmers need to make harvesting decisions such as: whether to incur intermediate costs and returns by removing some of the trees on a regular basis (thinning); or whether to harvest early and shorten the rotation; or whether to allow the trees to continue increasing their biomass. Farmers need to understand the implications of the choices they make. For example:

- How does varying the species, the productivity of the planting site, the harvesting regime or the rotation length impact on the optimum return?
- What impact does varying the costs, subsidies, timber prices and interest rates have on the return?
- What is the optimal rotation length for different species and different objectives?

Only with information on the relativity of the returns dictated by the choice of species, yield and harvesting options can farmers make informed decisions on how to optimise their forest investment.

Policy makers are interested in being able to analyse the wider policy implications of changing long-term policy objectives. Over the last hundred years, the rationale behind forestry incentive policies in Ireland has changed hugely in both focus and form. Policies ranged from an initial objective of increasing forest cover following a prolonged period of clearance; to focusing on the contribution of forestry to rural development and viability objectives in the 1980s (Gillmor 1992); to focusing on sustainable forest management to build a critical timber mass for timber processing sector in the '90s (DAFF 1996); to producing fibre/biomass for renewable energy in the 2000s. Current policies focus on the broader range of ecosystem services provided by forests (DAFM 2014a). In particular, there is a current focus on the ability of forests to sequester carbon and mitigate agricultural greenhouse gases. The requirements of EU legislation on sustainable forest management,

renewable energy and greenhouse gases in particular, mean that these issues are likely to remain at the forefront of European forest policy (European Commission 2013).

In order to address all of these issues, there is a need to develop the capacity to generate forest income streams over time, under different optimisation criteria. This necessitates the generation of biophysical growth curves, along with economic cost and revenue curves. There is also a necessity to make provision (at the model development stage) to have the capacity to model forest returns for biomass production and carbon sequestration, in addition to traditional timber production. This allows us to answer questions from both the farmers' and policy makers' perspectives. It will be interesting to observe whether the optimal forest return from the farmers' perspective coincides with optimal policy objectives. The author puts forward the hypothesis that different outcomes for different optimisations will be observed.

Tree growth

This section addresses the scientific theory underpinning the biological and economic interactions which determine forest returns under different management and financial objectives. The term “silviculture” refers to the science of growing trees and is a broad term which encompasses much more than the agronomic function of producing timber - it involves controlling the establishment, growth, composition, and quality of forest vegetation for the full range of forest resource objectives in line with the principles of sustainable forest management (SFM) “to maintain and enhance their utility for any purpose” (Smith 1986) and to “ensure the long-term continuity of essential ecologic functions, and the health and productivity of forested ecosystems” (Nyland 1996).

However, the value of ecosystem services such as biodiversity, recreation, water quality and health benefits are beyond the scope of this work. As this research is focusing on the timber (rather than non-timber) products from forests, only the range of choices and factors that can influence the timber produced and its long term value is investigated. This value is a function of the timber volume produced, the associated costs and revenues and the number of years necessary to realise a given timber volume (rotation). To elucidate the complexity and interaction of the factors involved, the initial focus is on a theoretical outline of the agronomic factors i.e. the scientific and management factors that determine forest tree growth patterns given specific environmental conditions.

Having an understanding of how forest trees grow is vital to farmers' understanding how and what to plant, when to thin or carry out a final harvest (clearfell) and how to manipulate timber yields. In general, afforestation (planting of previously un-forested land) results in even-aged stands²² of species with similar growth habits. This regularity facilitates the prediction of growth rates - in comparison with the wide variety of species and age-classes commonly found in natural forests (Davis 1966). In general, forest trees grow in both height (tips of shoots and roots) and width (cross-sectional diameter) in line with their age. Growth patterns differ between tree species in temperate and tropical climates, as well as between conifers and broadleaf species (Nyland 1996). Annual weather conditions affect the amount of growth (increment) in any given year, but overall, individual species in Britain and Ireland display similar average growth patterns over their lifetime.

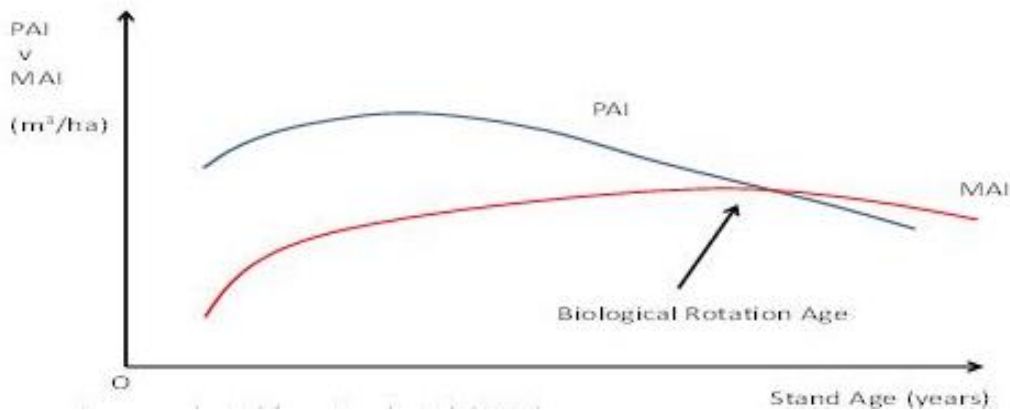
Typically, trees grow vigorously in the very early years and then begin to stabilise in terms of growth rates in the middle years, before slowing down as they get older. The mean annual increment (MAI) or mean annual growth, refers to the average growth per year that a tree (or stand of trees) has exhibited/experienced to a specified age. From a scientific perspective, the typical growth pattern of most trees approximates to a sigmoid curve (Smith 1986). The MAI starts out small, increases to a maximum value as the tree matures, then declines slowly over the remainder of the tree's life. Throughout this, the MAI always remains positive. Husch et al. (1982) calculate MAI in equation 5.1 as

$$MAI = \frac{Y(t)}{t} \quad (5.1)$$

MAI differs from periodic annual increment (PAI) because the PAI is the growth for one specific year (current annual increment (CAI)) or any other specified period of time (Bettinger et al. 2010). In economic terms, this is the marginal change in growth in an individual year (Husch et al. 1982). The point where the MAI and PAI meet is typically referred to as the biological rotation age. This is the age at which the tree (or stand of trees) is harvested if the management objective is to maximize long-term yield and is determined by differentiating MAI (t) with respect to t as represented in Figure 5.1.

²² Common forestry term used to refer to blocks or plantations of trees where the trees are all the same age

Figure 5.1 Mean Annual Increment (MAI) and Periodic Annual Increment (PAI) growth curves



Source: Adapted from Husch et al. (1982)

The intersection of the MAI and PAI curves is the point at which the maximum average volume increment could be achieved by the stand i.e. this is the point of maximum MAI (mMAI). This point defines the potential productivity of a stand of trees i.e. the yield class of a stand of trees. The yield class then determines the maximum volume production of a given species on a given site. For example, a hectare of trees with a maximum MAI of 20 cubic metres per hectare per year ($\text{m}^3\text{ha}^{-1}\text{year}^{-1}$) has a yield class of 20 and can produce on average a maximum of $20 \text{ m}^3\text{ha}^{-1}\text{year}^{-1}$ whereas a hectare of yield class 16 trees can produce on average a maximum of $16\text{m}^3\text{ha}^{-1}\text{year}^{-1}$.

Yield classes are measured in increments of two cubic metres, thus a yield class of 20 has a maximum MAI of greater than 19 but less than $21 \text{ m}^3\text{ha}^{-1}\text{year}^{-1}$ (Edwards and Christie 1981). Typically, yield classes for different species are determined by factors such as soil type, elevation, drainage and vegetation. This general pattern of growth is typical of all even-aged stands of trees but the rate of growth differs greatly by species and can vary within species under different environmental conditions.

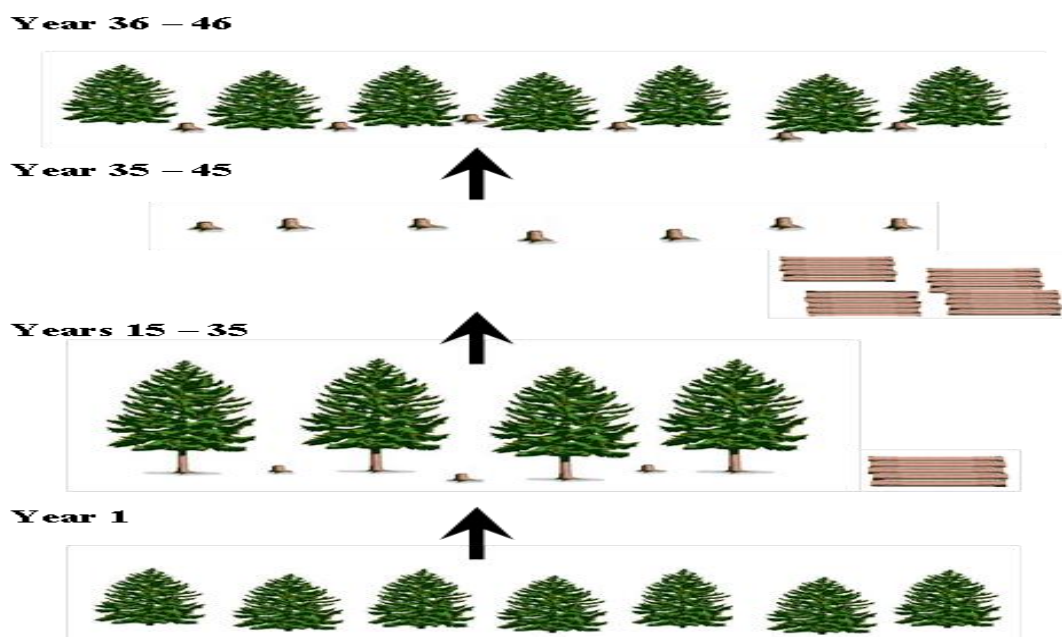
Forest management and harvesting decisions

Trees in even-aged plantation forests tend to be quite uniform as they are generally planted in close proximity to each other to force the trees to grow tall and straight. A high stocking rate (number of stems per hectare (SPH)) forces trees to compete with each other at an early stage. Interaction with other trees influences photosynthesis, growth and naturally occurring mortality. After a number of years of what is termed “free growth”, trees begin to compete

with each other and the removal of a proportion of the trees by thinning them out can be considered at this stage. Thinning (TH) interventions have an impact on the growth of the stand as more resources (nutrients, light, moisture) become available to the main crop (MC) after thinning. Thinning increases the growing space for the remaining trees and once adapted to the new situation, the trees respond by accelerating diameter growth (mostly near the base of the tree, increasing taper) and crown development.

The primary objective of thinning is to end up with a smaller number of trees of larger diameter which have higher value end uses and so increase the economic return. Thinning results in a decrease in stand level growth rate but this is eventually outweighed by the accelerated diameter growth of the remaining trees, depending on stand age, species characteristics, yield class and thinning intensity (Kerr and Haufe 2011). The thinning and clearfell system applied in most temperate plantation forests is illustrated in Figure 5.2 for a fast-growing conifer species.

Figure 5.2 Clearfell system for a fast-growing conifer species (assuming thinning).



Source: Teagasc (2015)

From an economic perspective, thinning provides periodic returns to the farm forest owner as the crop matures and improves the biodiversity of the forest. However, thinning may not always be possible if for example, road access for timber removal is not sufficient. In addition, thinning may not always be advisable, if difficult site conditions such as poor drainage preclude the use of thinning machinery, or if the site is elevated and at risk of trees

being up-rooted (wind-throw). Low levels of endemic wind-throw are prevalent and acceptable in forests, however the type of catastrophic wind-throw that occurred during recent winter storms such as Storm Darwin, can cause huge losses and is compounded by the difficulty and consequent high cost of harvesting such sites. On this basis, forest owners may decide not to risk thinning crops on less stable or exposed sites.

Not thinning (NoTH) will result in a larger number of smaller diameter trees which could be of significantly lower value. The decision on whether to thin a forest will depend largely on the owners' ultimate objectives for the forest. If the plantation is not thinned it is likely that by the time the crop is ready for clearfelling, the number of stems per hectare will be almost halved, the remainder having died off due to natural competition in the crop.

Optimal forest rotations

The general patterns of tree growth discussed here are typical of all even-aged stands of trees (i.e. plantation forests) in temperate climates but the rate of growth differs greatly by species and can vary within species under different environmental conditions. Thus generalised forecasts of tree growth can be modelled for different species in different environmental conditions on the basis of actual growth data. The data needed to forecast growth are species, age and yield class. These forecasts can be used to predict volume production at a given age and are also used to determine the optimum rotation for forests depending on the management objectives.

In population ecology and economics, maximum sustainable yield (MSY) is theoretically, the largest yield/catch that can be taken from a natural resource over an indefinite period. Biologists use this concept of maximum sustainable yield (MSY) or mean annual increment (MAI), to determine the optimal harvest age of timber. MSY can be defined as the largest yield that can be harvested which does not deplete the resource (timber) irreparably and leaves the resource in good shape for future uses.

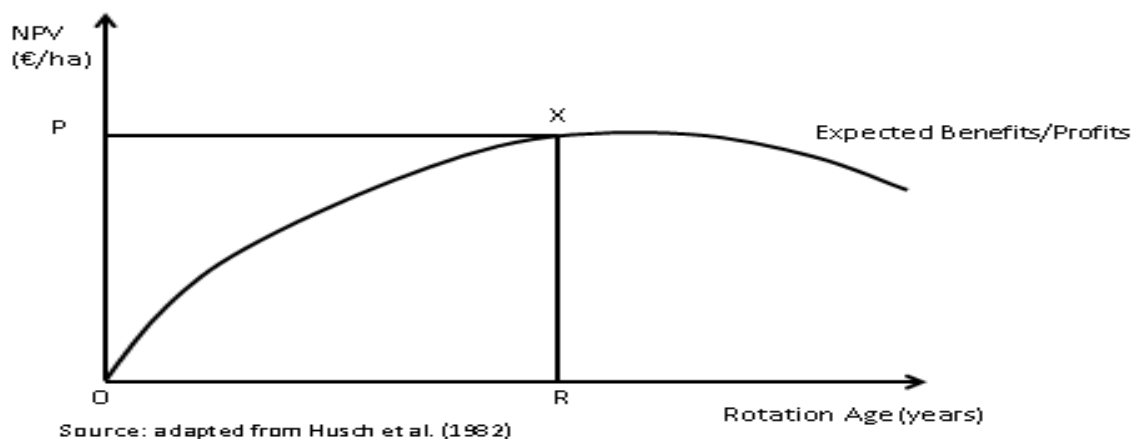
The point at which the MAI peaks is commonly used to identify the biological maturity of trees in relation to maximum volume production and their readiness for harvesting. This point is also equivalent to the intersection of the MAI and the current or periodic annual increment (PAI) curves as in Figure 5.1. Thus the biological optimum rotation is the age at which the tree or stand is harvested, if the management objective is to maximize long-term yield. Although this system has been in use for hundreds of years, it resonates strongly with modern

day sustainability criteria as in theory, if the trees in a forest were felled repeatedly at the age of maximum MAI, replanted and managed in the same way, the maximum average rate of volume production would be maintained indefinitely (*ceteris paribus*) (Edwards and Christie 1981).

Different management regimes such as thinning and pruning (removal of side branches to produce knot-free timber) are employed by foresters to increase the value of a forest, by concentrating tree growth on the main stem (trunk) of the tree. However the upper limits of timber productivity of a forest are governed by the maximum MAI. Edwards and Christie (1981) make the point that while different management regimes may impact on the value of timber harvested from a stand, the yield class of that stand indicates the maximum average rate of volume production from that stand, regardless of the time when that maximum is achieved. It is important to also note that whereas the MAI starts to decline beyond the point of intersection of the curves, the overall volume or biomass of the tree continues to increase until the point at which the tree dies, therefore the cumulative biomass volume continues to increase long after the age of maximum MAI.

However, forests may also be managed with the objective of returning the greatest revenue. Since the benefit is generated over multiple years, it is necessary to calculate that particular age of harvesting which will generate the maximum revenue. The financially optimum forest rotation occurs at the age at which the net present value (NPV) of the crop is maximised. This is calculated by discounting for future expected benefits by subtracting the present value of costs from the present value of revenue (Husch et al. 1982).

Figure 5.3 Economically optimum rotation - age of maximum Net Present Value (NPV)



The financially optimum rotation age is determined at point R in Figure 5.3 which gives the maximum net present value of expected benefit/profit. Harvesting at any age before or after R will result in a lower expected benefit/profit. In economic terms, this is the point at which the marginal benefits equal the marginal costs (Varian 2010). Growing the crop beyond this point would result in a net revenue loss.

Increasingly, the volume of biomass generated by forests is of interest to researchers and policy makers, both in terms of the level of production of fibre for renewable energy and in terms of carbon sequestration. In forests where the objective is the production of timber for sale, the “merchantable volume” (from the base of the de-branched tree up to the point at which the top diameter is not smaller than 7cm) only is included in volume estimations. However, for the purpose of renewable energy production and carbon sequestration, the total biomass production (merchantable + non-merchantable biomass volume) is the relevant measure.

In recent years, innovative systems of whole tree thinning have been developed and operate in many European countries which remove the entire tree (up to the tip and including and branches). Early forest growth models were designed to forecast only the merchantable volume (up to 7cm) from the time of first thinning onwards and do not include pre-thinning biomass volume. However, advances in computational power have allowed for the inclusion of these biomass volumes. These can be significant when measuring total biomass for carbon sequestration or renewable biomass estimations. A number of methods for estimating these early growth volumes are presented in the literature but difficulties arise as growth patterns and site conditions in different countries lead to variation in estimates (Tobin and Nieuwenhuis 2007).

While the majority of forest carbon is stored in the soil, significant amounts are also stored in live-wood. Fortunately there is an almost exact relationship between the growth rate of trees and the rate of carbon sequestration and it is therefore not very difficult to adapt tree growth models to predict live-wood carbon sequestration.

The reporting of carbon sequestered in forests for International Panel for Climate Change (IPCC) requires the measurement of whole tree biomass, which includes branches and roots. There is considerable consensus in the literature in terms of accounting for additional biomass in branches and roots, which is achieved by applying biomass expansion factors

(BEF's) to the merchantable timber volume as measured on the ground or forecasted by growth models. Considerable work has been carried out to develop country specific BEFs for the major species for IPCC reporting (Black et al. 2009; Tobin & Nieuwenhuis 2007).

When trees die, are removed for fuel or are harvested, the stand biomass decreases as does the carbon sequestration potential. In recent years, the addition of the carbon stored in harvested wood products (HWP) in IPCC inventory reporting has increased the carbon sequestration value of forests for accounting purposes. In Ireland, more than 90% of carbon stored in forests is in the soil and litter, and less than 10% is stored in the biomass (wood) pool (Donlan et al. 2013). After harvest, some of this biomass enters the harvested wood products (HWP) pool and is retained for varying lengths of time before re-entering the atmosphere. Carbon in HWP is released as products are combusted or decay naturally over time. However, some HWP have a long lifetime, particularly those used in construction or furniture.

The inclusion of HWP in Ireland's National Inventory Report provides a more comprehensive picture of the potential of the Irish forest sector to mitigate GHG emissions. This is evident in research conducted by Donlan et al. (2013) which calculates Ireland's net total GHG emissions in 2008 to be 65,969.17 (Gg CO₂) including LULUCF, which contributed (-)1470.10 (Gg CO₂) and the contribution of CO₂ stocks in HWP (in use) are estimated at -842 (Gg). The optimisation of a forest rotation for carbon production is therefore likely to be very different from maximising timber production or minimising rotation length. Instead, the optimisation of carbon could involve minimising harvest carbon losses by reducing thinning (or not thinning at all) and extending the rotation to defer harvesting and replanting (both of which lead to major carbon losses).

Another option which is becoming more popular in recent years is the implementation of a "continuous cover" management regime which involves regular selective harvesting of individual trees over a long period of time, thus avoiding a clearfell operation. While this system significantly delays carbon losses from forests, the harvesting costs incurred are considerably higher than for the clearfell system, leading to a reduction in the economic return (Ní Dhubháin 2003).

In practice, many owners manage forests to suit their own needs. Traditionally in many European countries, timber is harvested to cover the cost of family occasions such as

weddings, or to provide materials for construction. In addition, there are now many “new forest owner types” (Živojinović et al. 2015) who have very varied objectives and management schedules.²³ The characteristics of the timber demanded by the markets have also changed radically in recent years as some retail outlets will only accept timber which is “certified” as being produced in an environmentally sustainable manner.

Additionally, the modernisation of timber processing plants has improved the efficiency of recovery of sawn timber from mid-size logs. This has led to a preference for medium diameter over large diameter logs. Anecdotally, this is being capitalised on by forest owners who are harvesting timber well in advance of MAI, in order to avail of better timber prices and maximise short term returns.

This section explains how tree growth curves can be utilised to estimate merchantable timber volumes on a per hectare basis and how tree growth curves could also be used to estimate biomass production and carbon sequestration. However, while the modelling of forest biomass, continuous cover and market optimisation objectives all warrant attention, the focus in this thesis is on estimating and valuing merchantable timber production on farm forests.

While growth curves tend to be sigmoidal in shape, cost and income curves tend to be uneven, with the majority of costs arising early in the rotation and harvesting revenues arising at the end of the rotation. The challenge here is to develop a methodology to generate information based on the fundamental principles of tree growth with the flexibility to manipulate forest output and to address costs and price changes over time, to reflect a wide range of optimisation choices.

5.3 METHODOLOGY

This section focuses on the methodological development of a comprehensive forest bio-economic model. First, the objectives and methodological choices employed in answering a range of policy and optimisation questions in other models are examined. Learning from these models, decisions are made in relation to the choices that need to be incorporated. Existing yield models are utilised where possible but these models are augmented with modifications to suit the Irish afforestation context.

²³ EU COST Action Forest Land Ownership Changes in Europe: Significance for Management And Policy (FACESMAP) Country Reports (Živojinović et al. 2015).

An international literature review of models that specifically address forestry issues shows that the policy questions covered vary widely in relation to objectives and methodologies. Table 5.1 presents a summary of the variety of model types, objectives and variables analysed.

Regardless of their objectives, all the bio-economic models reviewed deal with different management scenarios and the consequences that these have on rotation length and revenue over the life-cycle of the forest. The models differ most in their optimisation objectives:

- For some, the objective is to optimise rotation length by manipulating thinning intensity and timing of harvesting, thereby accruing timber revenues earlier.
- For others, the objective is to optimise the utilisation of the timber produced by manipulating the diameter and taper on logs to produce the most valuable logs.
- These optimisations focus only on the merchantable timber volume (MTV) whereas biomass optimisation involves the inclusion of tree-tops and branch wood in biomass volume calculations.
- On the other hand, the models seeking to maximise carbon sequestration seek to lengthen the rotation by deferring harvesting to avoid carbon losses.

Only the afforestation BEMs model the full forest cycle to take account of the consequences of afforestation as well as management decisions on forest returns and are thus particularly relevant for this work. In countries such as Australia and New Zealand where a large proportion of forest cover is in farm ownership, a number of the bio-economic models are whole-farm models. The Farmula model developed in Western Australia by Kubicki et al. (1991) is used to compare alternative farm plans (such as the inclusion of forestry). Farmula is a whole farm model which was originally designed to examine land management practices. The Australian FARMTREE model (Loane 1994) assesses investments in farm forestry and contains considerable detail on tree growth rates, product recovery and stock shelter effects. FARMTREE is not a whole farm model but outputs are calculated on a per hectare basis. However, the Agroforestry Estate Model AEM (Middlemiss and Knowles 1996) developed in New Zealand also operates at the whole farm level, although this model does not directly calculate timber yields.

Table 5.1 Selection of forest bio-economic models

Reference	Question/ Policy	Objective	Variables	Unit of analysis	Study location
Standiford & Howitt 1991	Forest management	Revenue optimisation	Oak tree canopy, livestock density	Stand level \$	United States.
Halbritter & Deegen 2015	Forest management	Optimisation of LEV	Timber prices, interest rates, costs	Stand level Theoretical	Germany
Tahvonen et al. 2013	Forest management	Optimisation	Stand density, thinning intensity, rotation	Individual tree, m ³ /ha	Finland
Assmuth & Tahvonen 2015	Management Continuous cover	Carbon optimisation	Carbon subsidies Carbon prices	Stand level m ³ /ha	Finland
West et al. 2012	Management DSS	Value chain modelling	Yield, revenues, form, timber recovery	Stand & estate level	New Zealand
Tikkanen et al. 2012	Management Biodiversity	Thinning practices	Stand density, thermal sum	Stand level	Finland
Lecoq et al. 2011	Management Biomass	Forest carbon v fuelwood	Timber & carbon stocks/prices	Regional	France
Pihlainen et al. 2015	Climate change	Growth optimisation	Stand density Thermal sum	Stand level	Finland
McKenney et al. 2006	Carbon sequestration	Spatial Cost Benefit	Site, costs, Ag opportunity costs	Simulated m ³ /ha/yr	Canada
van Kooten et al. 1995	Carbon taxes/subsidies	Optimisation	Carbon biomass, price, discount rate	Theoretical t/ha/yr	U.S.
Vanclay 1998	Land Use	Decision support	Simulations	Landscape	Australia
Upadhyay et al. 2006	Land Use change	C sequestration optimisation	Ag/ & timber prices wages, population	Household	Nepal Pakistan
Verburgh et al. 2004	Land Use change	Scenario model	Review of models		Netherlands
Namaalwa et al. 2007	Deforestation	Deforestation and degradation	Diameter, mortality, socio-economic	Village	Uganda
Sankhayan et al. 2003	Deforestation	Land use and degradation	Ag yield & prices, population	Watershed	Nepal
Diaz-Balteiro & Romero 2003	Carbon capture	C sequestration optimisation	Area, forest inventory, carbon balance	Forest	Spain
Graves et al. 2007	Agroforestry	Silvoarable economics	Silvoarable, arable and forest returns	Plot & farm scale	Spain, France Netherlands
Bateman et al. 2006	Cost Benefit Analysis	Spatial forest valuation model	Parametric - Timber yield, carbon, recreation	Country	Wales
Middlemiss & Knowles 1996	Farm afforestation	Agroforestry & forestry returns	Returns, labour,	Farm & estate level	New Zealand
Loane 1994	Farm afforestation	Optimisation	Growth, product recovery, stock shelter	Hectare	Australia
Kubicki et al. 1991	Farm planning Afforestation	Whole farm model	Ag. opportunity cost	Farm	Australia
Herbohn et al. 2009	Farm afforestation	Whole farm model	Forest yield, Ag. opportunity cost	Farm	Australia

The bio-economic model which most closely reflects the Irish farm afforestation context is the Australian Farm Forestry Financial Model. As a whole farm model, the AFFFM provides information on the financial effect of adding forestry to the existing farm enterprise(s). Financial outputs include net present value, land expectation value and internal rate of return.

Timber yields are calculated for various soil types and climatic conditions using mean annual increment (MAI) estimates and yield tables but are also supplemented by growth data compiled by experts as outlined in Herbohn et al. (2009). The AFFFM when compared with other whole farm models reviewed, appears to be the most comprehensive. It includes an opportunity cost for the income foregone on planted land and an adjustment in stocking rates to reflect the reduction in agricultural area (Herbohn et al. 2009). The AFFFM is particularly useful as it contains a detailed description of the model methodology. Many of the AFFFM methodologies are utilised in developing a bio-economic model for Irish farm afforestation, adjusting them to suit the Irish environmental and policy context. However, the scope of the model goes beyond the AFFFM by incorporating the capacity to include new parameters, run iterative scenarios and sensitivity analysis of results. The capacity to model tree biomass in addition to merchantable timber volume to facilitate the development of future carbon modelling, is also incorporated into the model infrastructure.

Teagasc Forest Bio-Economic System model (ForBES)

On the basis of the choices examined in the published models, relevant methodological options are selected for each of the choices to be modelled. The detailed description of these elements, in the following sections of this chapter, along with the discussion as to how these elements may be adapted to the Irish afforestation context, essentially provides a description of how the assumptions behind the ForBES model are developed.

Methodological Choices

Having reviewed the existing relevant models, a general summary of the methodological choices and options examined in these models is presented in Table 5.2. Regardless of the type of forest or the optimisation objectives, the methodological choices analysed in the reviewed forest BEMs are quite similar.

Table 5.2 Methodological choices and options adopted in the reviewed forest BEMs

Methodological Choice	Options
Valuation methodology	LEV- infinite rotations, NPV – one rotation, AE
Unit	Tree, stand, hectare, village, region, national
Site and species selection	Conifer/broadleaf
Yield models	Dynamic/static, mathematical modelling
Tree spacing/stand density	Varies with species, country & management objectives
Thinning	Yes/No Intensity, type and interval
Pruning	Yes /no
Timing of harvesting	Rotation of MSY, financial/economic biomass Market optimisation
Log optimisation	Whole tree price size curve, assortment, end-product prices, wood energy, carbon biomass
Income streams	Subsidies, timber revenues, carbon credits, bioenergy
Timber prices	Historic price series, current assortment prices
Cost streams	Establishment, management, harvesting, contractors, own labour, farm overhead costs
Discount rate	High, low, impact of choice
Indexation of costs/prices	CPI – general or component specific
Taxation	Included/not included
Agricultural opportunity cost	Gross margin/ha
Carbon sequestration	Live wood, soil carbon, HWP
Software	Combination of model outputs, custom or generic programmes, Excel, SPSS, Stata

Valuation methodology

In order to capture the life-cycle implications of different afforestation and forest management choices, it is necessary to utilise a life-cycle framework. Depending on their objectives, other models have used variants of the discounted cash flow method (DCF) which include (Land Expectation Value (LEV), Net Present Value (NPV), Internal Rate of Return (IRR) and Annual Equivalised Value (AE).

DCF is the most widely used methodology for determining the economic value of a forest or a parcel of bare land to be afforested (Hiley 1954; Bettinger et al. 2010). The analysis in this chapter requires the generation of returns for a single forest rotation in order to compare agricultural returns over a similar period. There is also a need to look at the returns over a longer time horizon for biomass/carbon optimisation. The DCF methodology involves the calculation of the net present value (NPV)²⁴, using the “Faustmann formula” developed in Germany in 1849 (Hiley 1954). In recent years, the inclusion of non-market values in sustainable forest management (SFM) requires broader thinking and more complex models but the Faustmann formula continues to have a direct application for sustained yield plantation forestry (Kant 2003).

²⁴ NPV (Net Present Value) is the sum of the present values of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as income and cost cash flows.

A common application of the formula known as the Land Expectation Value (LEV) is essentially the NPV of all revenues and costs associated with growing timber on the land in perpetuity (not just those associated with one timber rotation). LEV is thus a special case of DCF where a perpetual stream of revenues and costs are considered (Hiley 1956). If the NPV of all cash flows expected from growing timber on a given parcel of land is estimated, the expected value of the land has been estimated (Grainger 1968).

In the models reviewed, the choice of calculation methodology depends on whether the period of analysis reflects one rotation or an infinite number of rotations. This analysis examines the case of land that is already owned by the farmer and is thus concerned only with valuing the return on the timber crop and not the land. The primary interest of this analysis is to be able to ultimately compare annual returns from an agricultural enterprise with a forest rotation. Thus NPV for one rotation will be calculated, with the flexibility to extend the rotation to estimate carbon storage over the growth cycle of trees. Using NPV to generate the future value of the forest involves the prediction of future costs and incomes and discounting these costs and incomes to the present day at a target rate of interest (Hiley 1954 & 1956), thus in Equation 5.2

$$NPV = \frac{I}{(1+r)^n} \tag{5.2}$$

where n is the number of years into the future that the income amount (I) will be received, or spent if the income amount is negative.

In the case of a forest, income and costs can accrue unevenly over the rotation, thus the net present value (NPV) of the whole income stream is the sum of the present values of the annual amounts in the income stream as presented in equation 5.3 (assuming a constant discount rate).

$$NPV = \frac{I_0}{(1+r)^0} + \frac{I_1}{(1+r)^1} + \frac{I_2}{(1+r)^2} + \dots + \frac{I_n}{(1+r)^n} = \sum_{i=0}^n \frac{I_i}{(1+r)^i} \tag{5.3}$$

All market and non-market incomes should be included in the calculation of income streams. For the purpose of this analysis, forest subsidies, timber revenues and the possibility of future carbon payments are included. Future timber volume production is estimated on the basis of

specific agronomic and management factors. Timber revenues are calculated by multiplying the volume by the relevant timber prices for given log size categories. All establishment, management and harvesting costs are subtracted from incomes to arrive at future net cash or income flows. These are then discounted to give the economic return on a forest, given specific afforestation and management choices to optimise specific objectives. In calculating forest market income in the context of a land use change from agriculture to forestry, the opportunity cost of the superseded agricultural enterprise should be included. This is discussed in detail in Chapter 6.

A number of points arise in examining the calculation of the NPV (holding all other factors constant):

- • Firstly, when income amounts are high, the NPV will be high and vice versa.
- • It also holds that the NPV will be higher if profits arise earlier during the rotation.
- • The life span of the investment (rotation) also has a large effect on the economic return as longer forest rotations will have lower NPVs than shorter rotations.
- • In the case of a forest, income and costs can accrue unevenly over the rotation (generally costs arise in the early years and incomes accrue in later years).

This highlights a limitation of the methodology in that it is only possible to directly compare the NPV return on two investments (in this case, land uses) if both investments have the same life spans (Boardman et al. 2011). This is particularly important in the case of the ForBES model development, which needs to have the capacity to be used as a forest extension tool in the context of a land use change decision support. Thus the NPV needs to be annualised so that it can be expressed on the same basis as annual agricultural returns. The AFFFM which is used in an extension capacity also calculates forest returns in terms of annual equivalised (AE) values of the NPV (Herbohn et al. 2009). The AE value is calculated using equation 5.4.

$$AE = \frac{r.NPV}{1-(1+r)^{-n}} \quad (5.4)$$

In order to examine multi-annual forest life-cycle incomes, a discount factor must be employed. Essentially, current (2015) input prices are examined and adjusted forward for the life-cycle using a consumer price index (CPI). The NPV calculation then discounts this back to the present day value. The discount rate chosen for the NPV calculations can significantly

increase or decrease the NPV of an afforestation project. There are essentially two components within the discount factor, one which accounts for time preferences and represents the return to money in the bank and the second which accounts for risk. The convention in Ireland is to use a real rate of 5% (Clinch 1999), reflecting an interest rate of 3% and a risk premium of 2% for risk elements such as fire, wind-blow and market risk (Phillips 2013).

For a forest investment with the common pattern of incurring costs in the early years and not accruing profits until later, a higher discount rate will reduce the NPV. In relation to policy recommendations, a high discount rate favours or strengthens the case for short term projects where benefits are front-loaded, whereas a low discount rate favours projects with back-end loaded benefits (Boardman et al. 2011). The convention is to ignore any effects of possible inflation, as this cannot be predicted. Therefore, the return is regarded as a 'real' rate of return. Phillips et al (2013) note that there are many opposing views about the “correct” discount rate to use, internationally as well as nationally. Therefore the capacity to conduct sensitivity analysis of the discount rate adds greatly to any forest valuation exercise. In relation to the treatment of taxation, the ForBES model does not include a taxation component. The convention for forest valuation is to generate pre-tax values for agriculture and forestry as per the International Accounting Standard (IAS 41 – Agriculture) (EC 2009).

Unit of analysis

One of the model choices is the unit of analysis, which varies depending on the objective and data availability.

- Individual tree analysis is the most data demanding level of forest growth analysis but much of the research addressing carbon measurement is moving in this direction in recent years.
- Catchment and regional analyses are the least data demanding but give limited information at the farm scale.
- Stand and per hectare analyses enable more localised comparisons but ignore inter-tree variability.

This analysis is conducted on the basis of a one hectare unit, which facilitates later per hectare comparisons between forest and agricultural returns. The size of the average farm forest in Ireland is just 9.1 ha (Forest Service 2013a) and therefore economies of scale are

unlikely to arise. The AFFFM also expresses returns on a per hectare basis to allow for ease of comparison with agricultural returns.

Site selection and Species choice

As farmers who plant are essentially making an inter-temporal choice by electing to have their land and capital tied up for multiples of decades versus achieving an agricultural return on an annual basis, the length of the forest rotation has a large impact on the economic return and thus on site selection and species choice.

The decision to plant slow growing broadleaf species is generally made on the basis of environmental or aesthetic concerns as the slow growth rates lead to long rotations and low economic return. In Ireland, broadleaf species have longer rotations than conifers and more fertile soils are more productive for both broadleaf and conifer species. However, broadleaf species are more site-demanding than conifers and require reasonably fertile soil types. Broadleaves are also less tolerant of exposure to wind and require sheltered, well-drained soils. The commonly planted broadleaves in Ireland include ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*) and to a lesser extent, oak (*Quercus robur*) and beech (*Fagus sylvatica*). Owing to its popularity over the last 20 years, ash is the dominant broadleaf species, however since the spread of ash dieback disease (*Chalara fraxinea*) into Ireland, planting of ash has virtually stopped.

On the other hand, many conifer species require less demanding site conditions in terms of fertility and shelter and can produce high timber volumes, on sites which are not suitable for broadleaves and are only marginal for agricultural production. The most commonly planted Irish conifer is Sitka spruce (*Picea sitchensis* (Bong.) Carr.), accounting for 57% of all private and public planting in Ireland (Forest Service 2013a). Sitka spruce (SS) is relatively undemanding from a management perspective but is highly productive on wet mineral soils which are marginal or sub-marginal for agriculture Farrelly et al. (2011).

Another factor that affects species choice is the availability of differential afforestation grants and annual subsidies for broadleaf and conifer species for up to 15 or 20 years. In general, the annual subsidies for broadleaves are considerably higher than conifers. Thus in selecting a suitable site and species, farmers may have to make a trade-off between higher short-term subsidy income from broadleaves, as against earlier timber income from conifers. A range of subsidies have been available to farmers from the early 1980s onwards as outlined in Ryan et

al. (2014) which also outlines the subsidy parameters and choices available to farmers if they chose to plant in any given year from 1984 to 2014. Using these parameters and values allows for the accurate estimation of past and current subsidy income streams.

In earlier years, afforestation grants covered a large portion (but not all) of the expenditure involved in establishing a forest. In recent years, the afforestation grant covers 100% of forest establishment costs and a maintenance grant is paid at the end of the fourth year, which essentially means that establishment of farm forests is cost neutral. An additional annual subsidy was available to farmers to compensate them for the loss of agricultural income on planted land since the late '80s. These "forest premium" annual subsidy payments were paid for a period of up to 20 years and were designed to bridge the income gap until forest thinnings are harvested. The payments have increased a number of times since they were initiated and now form a substantial component of forest income. Payments for broadleaf species on fertile land are considerably higher than for conifers on land that is marginal for agriculture. The most recent Afforestation Programme allows for the payment of establishment grants and annual subsidies to both farmers and non-farmers for a period of 15 years (DAFM 2015a). While the main objective of this chapter is to develop a mechanism to estimate forest market returns, NPVs are calculated with and without subsidies, in order to assess their impact on overall forest income.

Forest yield models

Forest timber yields are both species and site specific. Forest yield models provide predictions of potential timber volumes given specific environmental conditions such as soil type, elevation, exposure, drainage and vegetation cover. The forest yield models utilised in the reviewed BEMs have been developed to reflect country/region specific growth rates and timber production under given environmental conditions. Yield models may be either static (assume a given starting position and management regime) or dynamic (actual growth data are inputted and management regimes can be manipulated). Many of the reviewed BEMs are concerned with manipulating stand growth where actual growth data exist (Halbritter & Deegen 2015; Tahvonen et al. 2013; Diaz-Balteiro & Romero 2003; West et al. 2012; Pihlainen et al. 2015; Vanclay 1998) and are thus in a position to use mathematical dynamic models which allow for optimisation of timber production growth by varying management choices such as thinning intensity, timing of thinning and timing of ultimate harvest (clearfell).

Conversely, BEMs that deal specifically with afforestation need to utilise static models as growth data do not exist, either because the stand is not sufficiently old to collect the required data, or because the model is required to produce a growth prediction for an (as yet) unplanted forest. Static models assume that stands are managed to prescribed patterns over the rotation and thus do not allow for manipulation of thinning intensity and timing, as forecasts are based on a specified harvesting regime. Within the European context, the Forestry Commission (management tables developed for Britain by Edwards and Christie (1981)), are the best-known example of static yield models (Broad & Lynch 2006). Since its inception in 1919, the Forestry Commission (FC) has collected data quantifying the characteristics of plantations of different yield classes. The models are based on actual stand growth data from British forests and have been collated across varying species and management regimes (Edwards and Christie 1981). They show for each species and yield class, how tree volume increases over time and can be used to forecast volume production on the basis of the mean tree volume.

The FC yield models (Edwards and Christie 1981) are widely used in Ireland, however they may not fully predict the higher than expected farm forest growth rates on land which was previously in agriculture, versus the lower average historic growth rates in forests in State ownership (Farrelly 2011). In recent years, Irish dynamic yield models have been developed for the most important commercial species. The GROWFOR models (Purser and Lynch 2012), which can generate user defined forest management regimes, can be applied to actual plantation characteristics rather than trying to align the plantation to a set management regime as in a static yield table. In addition to facilitating interactive modelling of different management regimes, GROWFOR has some additional functionality such as (a) a forest revenue tool and (b) the option to define different timber size assortments (Purser and Lynch 2012).

The mathematical GROWFOR models predict higher timber volumes for Sitka spruce under Irish conditions than those predicted by the FC models. However, there is a limitation associated with the use of the GROWFOR models as they have not yet been fully field verified using actual growth data. In generating the forecast of round-wood production from private forests, Phillips et al. (2009) note that the FC based static yield model forecast for total net volume over a 20 year period was 1.5% less than the forecast generated by the dynamic GROWFOR model.

Despite their shortcomings, the FC models have provided a uniform platform from which to forecast volumes for the calculation of forest revenues for valuing the return to forestry. (Phillips et al 2011). For the reasons outlined above and as this analysis involves the prediction of timber volumes in the absence of growth data, it was decided to build on the FC (Edwards and Christie 1981) static models in developing the Teagasc Forest Bio-Economic System model (ForBES).

Tree Spacing

Trees are initially planted close to each other to encourage tall, straight growth. The narrower the spacing, the greater the stand density and number of stems per hectare. Thus the trees compete with each other earlier in the rotation and the requirement to reduce competition between the trees is greater. If competition is not reduced by harvesting (thinning) a portion of the trees, then natural thinning will occur whereby the tallest, most vigorous (dominant) trees (which can avail of more light, moisture and nutrients) will suppress the less dominant trees which will eventually die.

The range of species, environmental conditions and objectives analysed in the forest BEMs result in a wide variety of stand densities. For instance, in the agroforestry context, the stand density is very low to allow for agricultural crops or pasture between the trees. Cumulative volume production is greater when trees are planted at wide spacings (up to the point at which fewer widely spaced trees are less able to utilise 100% of the area), but this can be offset by quality downgrades such as increased taper and branching. In addition, thinnings occur later in widely spaced stands. In Ireland, research findings have changed the recommended stand densities over time, but since EU forest subsidies became available in the late 1980s, the Forest Service (DAFM) (who oversees payments) regulate initial spacings. Conifers tend to have lower stand density than broadleaves as they have a straighter growth habit, whereas broadleaves need competition from other trees to force them to grow upwards instead of outwards. Stand density and thinning were the most manipulated factors in the reviewed forest BEMs.

With a growing awareness of the decline of biodiversity across Europe (EC 2013), new forests are required to allocate a percentage of the total area for biodiversity enhancement. In relation to the model being developed here, this is reflected in the percentage of total area

assigned as productive area, with consequent reduction in merchantable timber volume (MTV) production.

Thin or no-thin?

Once trees begin to compete with each other for light and moisture and soil nutrients a decision is needed as to whether to thin the forest or allow it to grow to maturity without thinning. Thinning can be costly, (particularly the first thinning) as the cost of harvesting a large number of small, low value logs is high. In Ireland, as many forests are planted on exposed or poorly drained land that was marginal for agriculture, these forests may be at risk from wind-blow and forest owners need to carefully consider whether thinning is appropriate for a particular site. An un-thinned forest has a high number of low diameter trees, whereas a thinned forest of similar yield class has a smaller number of larger diameter trees. The dbh (diameter at breast height)²⁵ of a tree, determines the end-use of the logs produced, which in turn determines the value. In general, larger dbh trees are more valuable as they have a wider range of end-uses and there is more scope for optimisation of log output during processing. Ultimately, the difference in return between thinned and unthinned forests may depend on the log categories and the relative category prices prevailing at time of harvest.

Thinning intensity, type and interval

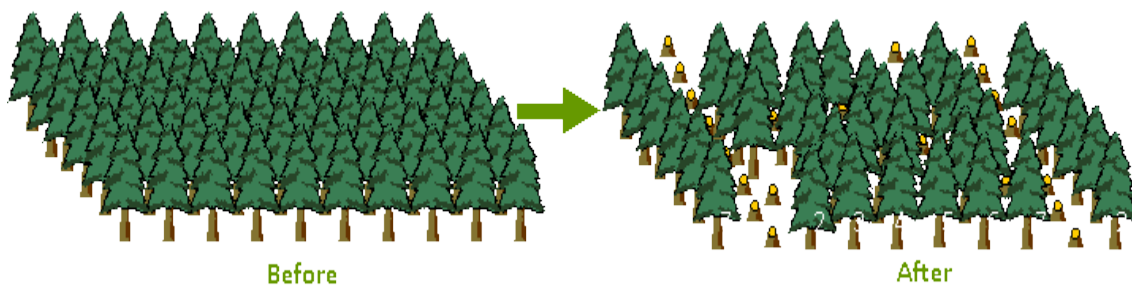
Optimisation of timber returns in the reviewed BEMs included varying the thinning intensity, thinning type and thinning interval to manipulate the thinning volume and log categories. Thinning intensity defines the volume of timber to be removed from the stand during each thinning. In many European countries, forest laws dictate that the volume of timber harvested within a given period must be less than the volume increment for that period. The standard approach employed in Britain and Ireland is marginal thinning intensity (MTI) which is the maximum rate at which volume can be removed without causing a loss of cumulative volume production. The maximum sustainable intensity of thinning is defined as 70% of yield class

²⁵ Dbh (diameter at breast height) is the simplest and most convenient measure of living tree size and is measured 1.3 metres above ground level using a measuring tape. The mean dbh of a stand of trees is the quadratic mean. Other more complex measurements include top height which is the mean height of the 100 largest dbh trees /ha and is measured using a hypsometer which triangulates the distance to the base of the tree against the angle to the top of the tree to give the height of the tree.

per hectare per year ($\text{m}^3\text{ha}^{-1}\text{yr}^{-1}$). Thus thinning yield at MTI is defined by Kerr and Haufe (2011) in equation 5.4²⁶, for a yield class 14 crop, which will be thinned at 5 year intervals as

$$\text{Thinning Yield (MTI)} = 0.7 \times 14 \times 5 = 49 \text{ m}^3\text{ha}^{-1} \quad (5.5)$$

In Ireland, the most common first thinning method involves the removal of every 7th line and removal of selected trees in between, are removed to marginal thinning intensity as illustrated in Figure 5.4. Before and after first thinning at Marginal Thinning Intensity



Source: Teagasc (2015)

The largest removal of stems per hectare is at first thinning. In subsequent thinnings, the volume of timber removed is spread over a smaller number of larger diameter stems. Generally, thinning types can vary from a light “low thinning” where trees are removed from the lower canopy, to the more common “intermediate” thinning and the heavier “crown” thinning. Thinning changes the form of trees and encourages greater mean dbh at harvesting, which may result in a greater proportion of timber in the larger and more lucrative volume assortments (Nyland 1996).

Timing of thinning and harvesting

In static yield models, the timing of thinning and clearfell is dictated by the models and is a function of the age and the top height of the stand. The tables present thinning (TH), maincrop (MC) after thinning and cumulative mean tree volumes at five year intervals which when multiplied by the stems per hectare give the volume of the stand. A description of the parameters used in the model is presented in Table 5.3.

²⁶ These are gross standing volumes which are different than actual harvested volume for revenue purposes due to harvest losses.

Table 5.3 FC Forest yield table parameters (Edwards and Christie 1981)

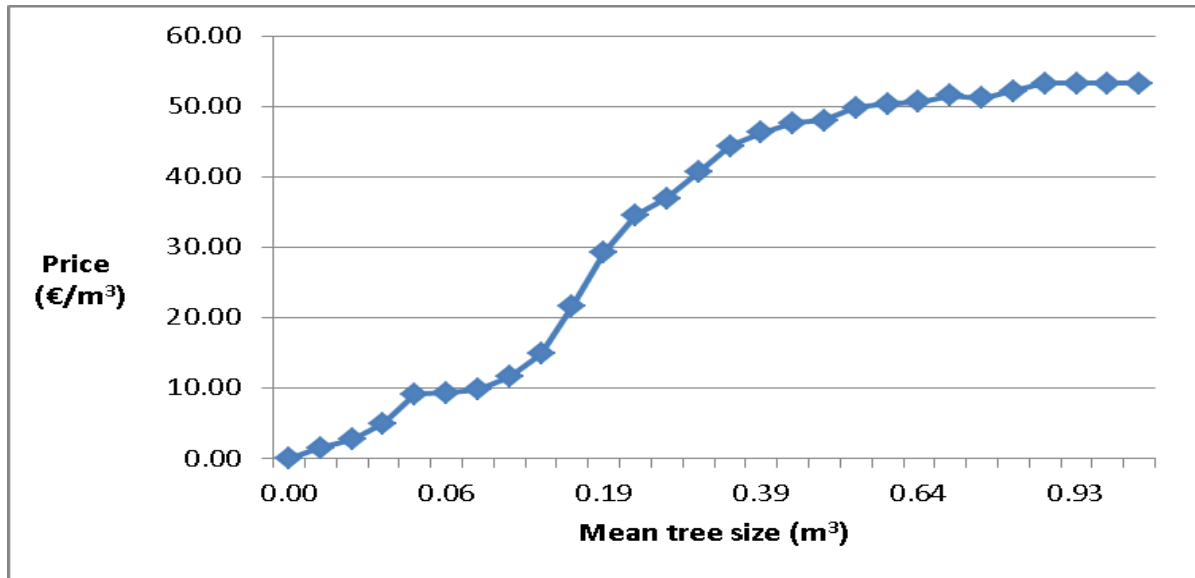
Sph (trees/ha) - Maincrop (MC) after thinning Sph - TH	2,311 at age 18 0 (no thinning until year 23)
Mean dbh (cm)	Quadratic mean diameter (the diameter of the tree of mean basal area) of all live trees in stand
Basal area (BA ²⁷)/ha	Basal area/ha is the sum of the cross-sectional area of the trees measured at 1.3 m aboveground level in m ²
Mean volume (m3)	Average volume of all live trees
Vol/ha	Overbark volume of live trees (up to 7cm top diameter)
MAI (Vol/ha)	Mean annual increment (cumulative vol/age)
Age of MAI	58 yrs
Intermediate thinning	Note: Mean dbh (TH) is less than mean dbh (MC after TH) thus smaller and average size trees removed

Due to fast growth rates in Ireland for some conifer species, the current silvicultural practice is to grow crops to rotation of maximum mean annual increment (mMAI) with the exception of Sitka spruce (*Picea sitchensis*) which is grown to mMAI less 20%; Norway spruce (*Picea abies*) mMAI less 30% and coastal lodgepole pine (*Pinus contorta* var *latifolia*) mMAI less 30%. This practice is known colloquially as the “reduced rotation” and is based on an economic analysis undertaken in 1976 by the then State Forestry Board (Anon 1977). More recent economic analysis on rotation lengths (Phillips 1998, 2004) indicate that current practice is more or less in line with the theoretical financially optimum rotation for the major tree species. While there are differences, they are not generally so significant as to warrant a change in rotation length apart from some minor exceptions (Phillips 2004).

Timber products

The methodology applied to the calculation of timber revenues is a critical factor in predicting the market return to forests. In general, dynamic models have greater flexibility than static models in relation to assortment and price optimisation. There are essentially two methods used, which depend largely on the availability of data in relation to price and to the allocation of logs to end-products. The first method uses the mean tree volume predicted by the FC static models to calculate the economic value of the timber produced by plotting relevant timber prices (€) against tree size (volume of mean tree in m³). This generates a price-size curve which gives the value per cubic metre expressed in euro of a stated mean tree volume as illustrated in Figure 5.5. The average tree volume is then multiplied by the number of stems to arrive a value for volume per hectare, having allowed for volume reductions due to unproductive area and losses during harvesting.

Figure 5.4 Conifer price size curve: mean tree size plotted against average timber prices over a ten year period (2013 base year)



Source: Teagasc Forest Bio-Economic System model

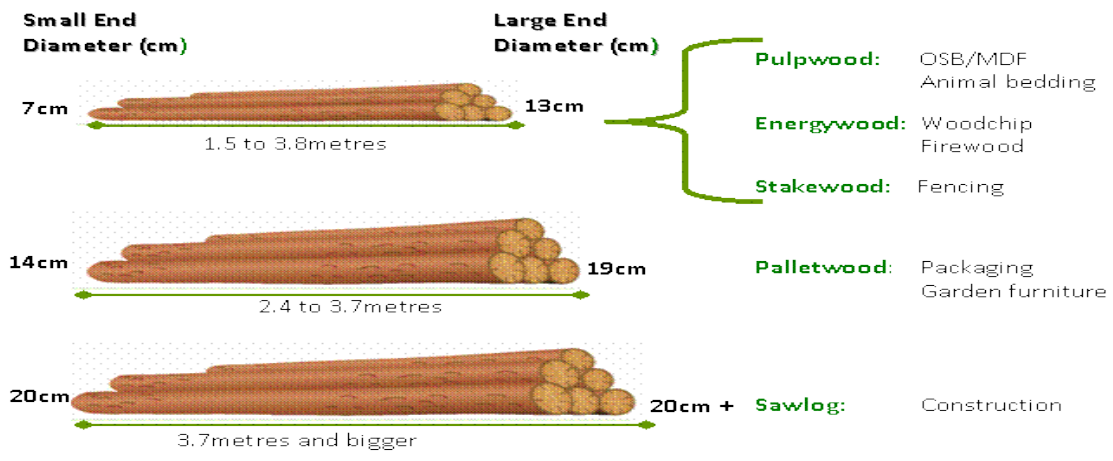
An interesting feature of timber prices which is illustrated by the price size curve, is the tailing-off of prices for larger average tree sizes, indicating that from a financial perspective, there would appear to be little marginal gain in growing timber beyond a mean volume of 0.4 to 0.5 m.³ This is largely because of technological advances in the timber processing sector which allow for improved sawn-wood recovery from smaller logs, while fewer and fewer mills can handle these larger tree sizes due to technical limitations of their design. In return, this has led to a reduction in the optimum log size in recent years. Thus forest owners may have the opportunity to manipulate the intensity of thinning and/or the timing of harvesting to coincide with strong market prices paid for specific categories of timber.

In Ireland, there are essentially two methods of selling timber which ultimately dictate the pricing structure used. Timber is commonly sold either “standing” (un-harvested) or harvested and pre-cut into specific lengths depending on the product required. In the case of “standing” sales, the buyer buys the stand un-harvested on the basis of the volume of the average tree (average tree size) as measured on the ground or generated by a forest yield model. In this case the relevant price is approximated by a price size curve based on the mean tree size.

Alternatively, harvested timber (already cut into appropriate end-products dependent on log diameter) is sold either on the forest roadside (in which case the buyer/processor incurs the

cost of haulage to sawmills) or is delivered directly to a sawmill (in which case the owner incurs the haulage cost). Harvested sales are thus based on the relevant prices for the volumes of the assortments or end products. Mill-gate prices can be considerably higher than forest roadside prices. Figure 5.6 shows the common assortments and potential end-products ranging from low-value small diameter round-wood from small diameter trees and tree-tops to large diameter logs produced from the lower section of the stem and from larger trees. In general, only round-wood from later thinnings and clearfell is large enough to qualify as sawlog.

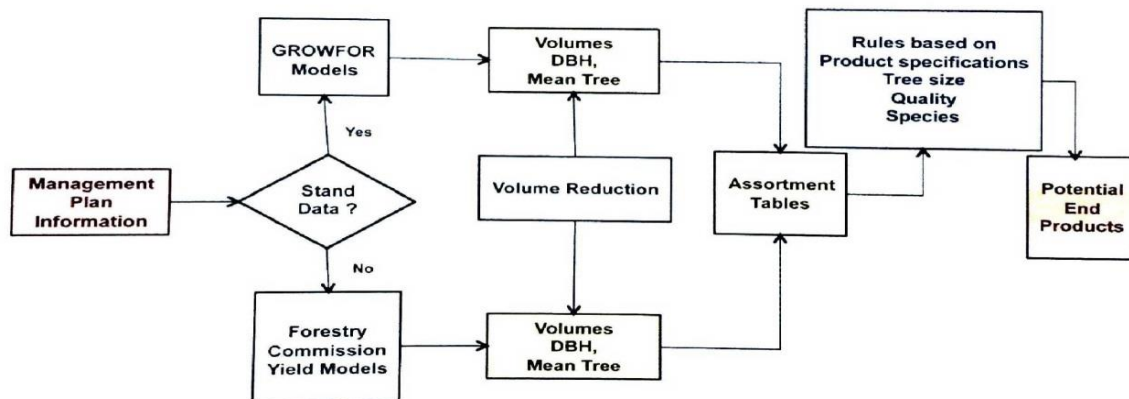
Figure 5.5 Round-wood size categories (timber assortments) and potential end products



Source: Teagasc 2015

It is important to note the difference between volume assortments based on specified diameter ranges and the range of potential end products which are defined by log length and specific quality criteria such as straightness, taper and knot area ratio. The prediction of revenues for harvested timber sales involves having information on prices for different end products and on the percentage recovery of these products from the harvested volume which varies with crop quality and technical specifications of the different products. PEPing refers to the pre-harvest prediction of potential log product yield (potential end products) defined by several descriptors including species, length, small end diameter range and quality specifications. The process is illustrated graphically in Figure 5.7.

Figure 5.6 Pre-harvest prediction (“peping”) of potential end products



Source: Phillips et al. (2013)

There are two principal types of PEPing system. Indirect prediction is based on an initial estimate of assortments from an assessment of tree size and form, irrespective of stem quality, followed by a generic percentage downgrade to account for stem quality trends identified within a stand. Direct prediction based on a combined assessment of the size, shape and quality of individual trees. The indirect method is the one most widely used currently in Ireland. Utilising the mean tree volume from the yield models, values are generated for mean dbh for thinnings and maincrop for each year of the rotation. The peping process then estimates the product breakdown using stand assortment tables (Matthews and Mackie 2006) which generate the percentage of the total volume which is estimated to be in logs of greater than a stated top diameter. For example, for a stand of trees with a mean dbh of 19cm, 100% of the volume will be in the entire log up to 7cm top diameter; 70% of the volume will be in the section of the log below 14cm top diameter and 30% of the volume will be in the section with a top diameter of 20cm. The volume in each assortment/end-product is multiplied by the relevant assortment price to arrive at a value for revenue per hectare.

In relation to deciding whether to estimate revenue using price-size curves or volume product prices, the use of product prices takes into account the quality, straightness and length of logs to a specified top diameter. For an average quality stand, both pricing systems should provide more or less similar values, whereas for a stand of high quality timber, the use of product prices may result in higher timber revenues than those generated using the cruder mean tree price size curve. However, historic product price data are not as readily available as mean tree price series data. Therefore many analyses utilise historic price-size curve data, particularly when estimating timber revenues far into the future.

Income streams

Forest income streams should include any subsidies as well as market (and non-market) revenues such as afforestation grants and annual forest premium payments. Forest market income streams are calculated by multiplying the predicted timber volume by the relevant timber price. Typically market revenues depend on timber prices at the time of harvesting. However, due to the long term nature of forest crops and the fact that timber is a globally traded product which is subject to price volatility, it is difficult to predict future prices.

Obviously, the higher the timber price applied, the higher the long term return but using current prices can result in significant variation in value year on year. To overcome this, many practitioners use historic average price series (Phillips 2013). The number of years to clearfell influences the choice of the price series. The use of shorter time series is only appropriate if a forest is close to clearfell. Longer term price series should be used otherwise.

Cost Streams

The agronomic costs of establishing, managing and harvesting a forest vary according to species, site conditions and management objectives. Generalised costs are usually readily available as many of the operations are standardised and as such have standard procedures and operating costs. In general terms, the majority of costs are incurred within the first four years and generally consist of ground cultivation and drainage, fencing, planting, fertilising (on less productive sites only), replacement of dead trees and vegetation management. The more difficult the environmental conditions of a site and the more difficult a given species is to manage, the higher the establishment and maintenance costs over this initial period. However, the burden of these costs may have to be carried for the life-time of the rotation, unless they can be offset by subsidies. High harvesting costs can also lead to reduced residual profit as difficult sites are likely to have higher harvesting costs.

The cost of reforestation after clearfell is generally substantial as the subsidies apply only to afforestation of previously agricultural land and therefore do not apply to reforestation. However, under the 1946 Forestry Act, reforestation is a condition of approval to clearfell forests in Ireland as in many other countries. The treatment of reforestation costs varies in the reviewed BEMs. Models that use LEV attribute the reforestation cost to the next rotation, however if only one rotation is being valued, debate exists over whether the cost of reforestation should be included as a cost at the end of the current rotation or the start of the

next rotation. The argument here is that forest owners cannot legally harvest without replanting. From this perspective, the capacity to assess the sensitivity of the NPV to the inclusion or exclusion of reforestation cost is also necessary in the ForBES.

Costs associated with preparation for harvesting

In general, buyers will not buy a stand of timber without being able to access the forest for examination purposes via inspection paths. This cost is generally incurred in conifer stands around year 14 when access is restricted by dense branching. This is a once-off cost and is borne by the forest owner. If the forest terrain is difficult and would not support the heavy machinery required to remove the timber, the construction of a forest road may be justified but is generally only carried out where the forest is of sufficient size to warrant grant aid. Many farm forests have existing internal access roads which suffice for harvesting but may need to construct a loading bay if timber is to be loaded at roadside for transportation to sawmills, for which a grant is available from the Forest Service (DAFM 2015b). Most importantly, buyers will require access to a forest inventory which details the area of plots by species, sph, yield class, average dbh and volume estimates.

The collection of forest inventory data in preparation for timber sales and harvesting is time-consuming and costly (particularly in younger spruce crops which tend to be dense)It does however enable a more accurate assessment of timber volume and any appropriate volume reduction factor due to stocking or un-harvestable areas. This work is generally carried out by professional foresters who may also advertise and oversee the harvesting operations. Because of the lower revenues from early thinnings in particular, the cost of sales for both conifer and broadleaf forests is higher in percentage terms in thinnings than in clearfells. The cost of sales for poorer quality, lower value timber will be high compared to the percentage cost incurred for high value stands.

The model includes the option to include or exclude harvest losses which vary with harvest type and species being highest for first thinnings and lowest for final fellings. On the basis of analysis carried out by Phillips et al. (2009), losses arising as a result of timber being damaged or left behind can be significant and inclusion of losses is recommended. Higher losses are incurred on more difficult sites. All conifer merchantable timber volumes (MTV) generated by the model are net of harvesting costs and harvest losses and are thus reported as Net Realisable Volume (NRV). Harvest losses are not as big an issue for broadleaf stands

which tend to have better site conditions and less timber wastage as small and crooked logs and branch-wood can be used as firewood.

Cost and price indices

An assumption underlying many of the reviewed BEMs is that the costs and returns to the forest enterprise remain static and that all prices (e.g. establishment and continuing maintenance costs, timber and other revenues) change over time due to inflation. This means that a ‘real’ discount rate is used when discounting cash flows. However, in reality, it is rarely the case that costs and prices grow at the same rate. A farmer considering forestry is likely to make a decision on the basis of both agricultural and forestry costs and prices prevailing at that time rather than over a long time horizon. Thus it is necessary to assess the impact of different cost and price indices for specific inputs on NPVs in addition to using an average index. The impact of using average Consumer Price Indices and good/service specific indices (CSO 2014) in the calculation of NPVs is also examined.

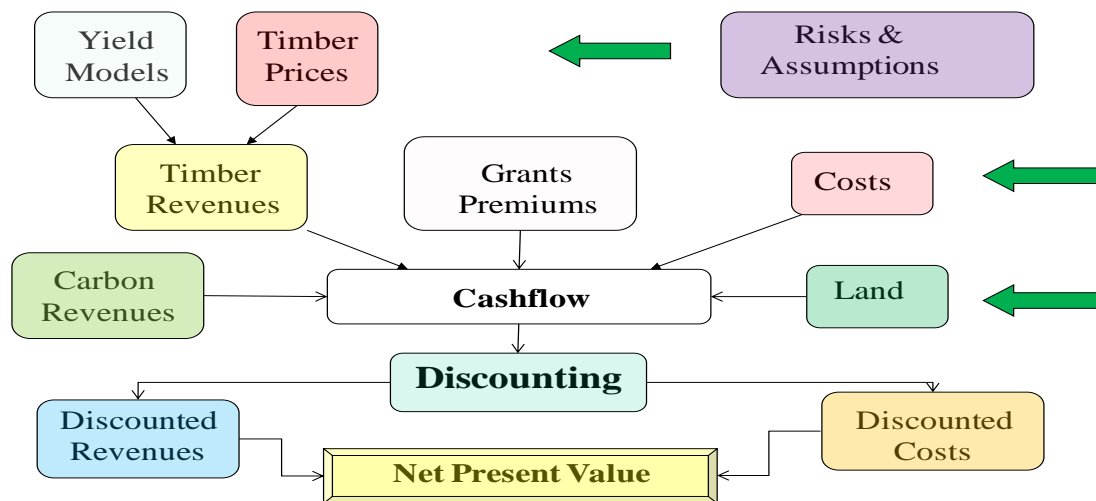
Choice of discount rate

Money received today is more highly valued than the same amount of money received at a future date. Where there is a risk of not receiving the same payment in the future, the preference for money today is stronger. It is evident from equation 5.3 that changing the discount rate changes the net present value. The rate chosen can significantly increase or decrease the NPV of an afforestation project. For a forest investment with the common pattern of incurring costs in the early years and not accruing profits until later, a higher discount rate will reduce the NPV. In general terms, a high discount rate favours short term project whereas a low discount rate favours long term projects. The convention is to ignore any effects of possible inflation, as this cannot be predicted. The discount rate is normally applied to real cash flows and is therefore expressed in real terms (Phillips et al 2013). For example, the future AE income stream for maintenance costs is generated by applying cost and price indices for each year in the life-cycle. This is then discounted back using a discount factor that incorporates both investment and risk elements. Phillips et al (2013) note that there are many opposing views about the “correct” discount rate to use, internationally as well as nationally, however the convention in Ireland is to use a real rate of 5% (Clinch 1999). The capacity to conduct sensitivity analysis of the discount rate adds greatly to any forest valuation exercise.

Development of model infrastructure and software used

The Teagasc Forest Bio-Economic System (ForBES) model described here was originally based on an Excel platform which transposed the FC static yield models from their paper format into digital worksheets, on which a forest income calculator (Forest Investment and Valuation Estimator - FIVE) was based. FIVE was developed incrementally as a farm forestry extension and research tool to estimate future forest returns. FIVE has been piloted and validated in the field over a number of years in conjunction with forest extension colleagues from the Teagasc Forestry Development Department. The inputs and outputs of FIVE are presented in Figure 5.8 and described in detail in Ryan et al. (2013).

Figure 5.7 Inputs and outputs: Forest Investment and Valuation Estimator (FIVE)



In order to accommodate the wider range of objectives and iterative scenario analysis required by this thesis, FIVE was further developed and transposed to a format which would allow for the simulation of optimal rotations; the inclusion of additional subsidy and farm data to enable future income comparisons; the facilitation of longer biomass rotations; iterative rotation generation; and scenario analysis.

The additional computational power required is provided by STATA software. Modifications and additions to the model include:

- The capacity to run iterative rotations for each species and yield class to determine the optimum NPV.
- Extension of rotation length beyond the 60 years in FIVE to 110 years in FORBES.

- Imputation of biomass volumes to tree tip versus a top diameter of 7cm merchantable volume as in FC yield tables.
- Inclusion and parameterisation of all forest subsidies from 1984 to 2014 to allow for the inclusion of actual subsidies in analysing past forest income streams.
- Simulation of NPVs in each individual year relative to subsidies and incomes in those individual years.

In future analysis in this thesis, it will be necessary to include agricultural income streams to account for the opportunity cost of farm afforestation. Thus ForBES is designed to be a simulation framework that links FIVE to the Teagasc National Farm Survey (NFS).

Scenario, optimisation and sensitivity analysis choices

Having examined the theoretical aspects of both agronomic growth and financial valuation and taking on board the range of methodologies presented in the scientific literature, a decision is made on the agronomic and economic scenarios to be optimised.. In summary, the model needs the capacity to generate a range of life-cycle growth, cost and income streams in order to analyse the following scenarios:

- Compare forest market returns with and without subsidies
- Assess the impact of site fertility and yield class on return
- Assess the impact of thin versus no thin scenarios.

The model also needs to have the capacity to:

- generate the optimal financial rotation of maximum NPV and to compare the optimal silvicultural rotation with the reduced rotation and
- model decisions taken by farmers historically as well as into the future.

To do this, a cohort bio-economic model is developed where each year from 1984 to 2014 is an individual cohort in the model, thus allowing for the generation of life-cycle growth, cost and incomes streams for each cohort. The methodologies to generate these curves are then selected. Based on the review of available methodologies, it was decided to build on FC yield models with selected inputs from FIVE in developing the bio-economic model i.e. the Teagasc Forest Bio-Economic System model. Cost and income curves will be based on industry norms in Ireland. Forest returns will be calculated in terms of NPV for one rotation and will be expressed as annual equivalised NPVs.

In addition, the model needs the capacity to conduct the sensitivity of the NPV calculation to the varying the following components of the calculation:

- Measurement period: 1 rotation versus long term (110 years)
- Compare a range of discount rates (1%-7%)
- Assess impact of using differentiated price indices – compare average CPI versus component specific CPI.

5.4 DATA

This section describes the specific data assumptions and data sources to be included in developing the Teagasc forest bio-economic system (FORBES) model in order to be able to incorporate the selected choices and scenarios. Initially the choice of species (for presentation of results) is justified and the relevant subsidies, price, cost and inflation indices are examined in detail before presenting a summary of the data sources and assumptions.

Species

The FORBES model includes growth data (based on FC models, along with cost and income data for Sitka spruce, Norway spruce, Japanese/Hybrid larch, lodgepole pine, ash and sycamore, allowing ForBES to model planting decisions that farmers made (or could have made) in the past as well as modelling future decisions. For ease of presentation and for comparative purposes, results of the NPV analysis are reported for Sitka spruce. As afforestation subsidies are only available for Sitka spruce yield classes greater than 14, the results are reported for yield class 14 to yield class 24.

Afforestation grant and premium subsidies

Grant and premium subsidy payments are allocated on the basis of General Planting Category (GPC) (see Table 5.4 for a summary of the current relevant categories) which determines the level of payment on the basis of site type and species. As the category definitions for Sitka spruce have changed slightly over the years, the categories which most closely equate to the current GPC 3 (90% SS + 10% of another species) are utilised.

Table 5.4 Selected Grant and Premium Categories (GPC's) (2014)

GPC	Description
GPC 1	Unenclosed/Unimproved land: Upland sites and marginal soils
GPC 2	Pure Sitka spruce / lodgepole pine: No longer complies with scheme requirements in isolation and can only be approved as part of a larger project.
GPC 3	10% diverse mixture of Sitka spruce / lodgepole pine with at least 10% diverse conifer (approved conifer other than SS/LP).
GPC 4	Diverse: Acceptable conifer species, other than SS/LP
GPC 5	Broadleaf: Acceptable broadleaf species other than oak and beech
GPC 6	Oak: nurse species may be planted where additional shelter is required
GPC 7	Beech: beech nurse species may be planted where additional shelter is required
GPC 8	Alder: Pure alder; up to 10% can be of other species for diversity

Source: DAFM (2014)

Price assumptions

Since the 1990s, Coillte (Irish State Forestry Board) has recorded conifer standing prices in a range of size categories on an annual basis. Data are now published quarterly by the Irish Timber Growers Association (ITGA 2014). Weighted average timber prices are presented for ranges of timber sizes i.e. $0.07\text{m}^3 - 0.074\text{m}^3$ and $0.075\text{m}^3 - 0.124\text{m}^3$. Sale prices are published by mean tree volume size categories which reflect the residual or “stumpage” value of timber i.e. the buyer buys the standing crop and incurs the harvesting, marketing and transport costs. The prices are not segregated by species, and in many cases do not include smaller tree sizes (as these are sometimes not sold, but retained for processing in Coillte pulp mills) however, this is the most comprehensive and representative source of conifer timber prices.

While timber assortment prices may give a more accurate reflection of the breakdown of the stand into end-products, there are no published price series data for assortments in Ireland to date. Therefore for the purpose of this analysis, a 10 year historic price series is generated from the Coillte standing sales information. All prices are deflated to the relevant year using the Consumer Price Index (CPI) (CSO 2014) before being averaged. It is assumed that timber prices keep pace with inflation as they have done through the period that Coillte prices have been recorded (Ryan et al. 2013). Table 5.5 shows the conifer price series for 3, 5, 7, 10 and 15 year average prices.

Table 5.5 Conifer Price Size Curves based on historic timber prices

Average Tree Size (m3)	3 Year	5 Year	7 Year	10 Year	15 Year
0.05	3.56	3.55	3.40	2.74	3.22
0.1	14.61	14.75	10.79	9.79	11.36
0.2	23.72	29.06	26.42	23.77	22.42
0.3	48.81	47.15	40.73	36.08	28.01
0.4	55.98	54.89	47.64	44.36	44.36
0.5	58.16	56.30	49.16	47.65	47.17
0.6	60.65	59.33	51.79	48.89	47.42
0.7	62.33	60.38	52.64	50.38	49.91
0.8	63.18	60.38	52.92	50.98	51.46
0.9	63.39	60.35	53.21	51.15	52.13
1	66.10	62.68	54.75	53.25	54.69

Source ITGA (2014) Note: CPI Base year: 2013

Price assumptions – broadleaves

Price information on broadleaf timber sales in Ireland is however not as readily available as it is for conifers, as the majority of timber sales involve conifers. Thus the ForBES broadleaf price size curve is generated using a combination of ash, beech, birch, cherry, oak, sycamore and alder prices published by the Woodland Trust in Britain in 2000 and a combination of Coillte broadleaf prices from 2004 (see Table 5.6). The value of hurley ash is built into the ash price and adjustments are made to the smaller size categories to take account of recent increases in prices achieved for firewood. The British prices are converted to Euro and also adjusted for inflation. The number of timber sales from which these prices represent is also much smaller than the conifer sales therefore the broadleaf price size curve is not as robust. Timber quality is also a more significant factor in the price paid for broadleaves than for conifers. An option to downgrade quality is included in the model which applies an equivalent downgrade to the relevant price. For these reasons, the returns to broadleaves must be treated with caution.

Table 5.6 Price Size Curve Broadleaf

Size	3 Year	5 Year	7 Year	10 Year	15 Year
0.05	7.89	7.87	7.55	6.09	5.19
0.1	16.92	17.08	12.50	11.33	9.76
0.2	33.83	41.44	37.68	33.91	35.95
0.3	39.58	38.23	33.03	29.26	37.69
0.4	45.34	44.46	38.59	35.93	35.93
0.5	49.06	47.49	41.47	40.19	40.60
0.6	52.78	51.63	45.07	42.55	43.87
0.7	54.58	52.88	46.10	44.12	44.53
0.8	56.39	53.89	47.23	45.50	45.09
0.9	59.21	56.37	49.70	47.78	46.88
1	62.03	58.82	51.38	49.97	48.65

Note: Base year: 2013

Assumptions - Indices

In generating NPVs of forest incomes streams using 2015 values, the discount rate incorporates future growth rates in the ForBES model. However when comparing the historic production of two goods (in this case agricultural and forest products), there are different inputs with different costs. In using the average consumer price index (CPI) to inflate values over time, it is assumed that goods change value at the same rate. However, this is not always the case. Table 5.7 presents a compilation of the good specific price and cost indices for 11 individual components of cost and income and indicates the source of the indices.

Table 5.7 Source of Price Indices

Establishment and Reforestation Cost	CPI
Maintenance Cost	MaintMaterials
Insurance Cost	POtherInputs
Roads + Repairs	PMaintMaterials
Grant	Actual amount
Premium	Actual amount
Thin Revenue	Timber price index
Clearfell Revenue	Timber price index
Once Off Revenue	CPI
Annual Revenues	CPI
Inspection Paths Cost	CPI

Establishment and reforestation costs are indexed using the consumer price index (CSO 2014), along with once-off/annual revenues and the cost of inspection paths. Grant and premium indices are based on actual amounts detailed in the forest subsidy model developed in Chapter 3. Maintenance costs, insurance and road cost indices are those used in the Teagasc National Farm survey and are generated by the Central Statistics Office (CSO 2014).

In the ForBES analysis, the individual annual inflation rates are applied to the 11 different components of cost and income. The relevant indices are detailed in the Appendix to this chapter (Tables 5.13 & 5.14)

Cost assumptions

Table 5.8 details the cost assumptions employed in the analysis.

Table 5.8 FORBES Model : Detailed Cost assumptions

			SS (€/ha)	Ash (€/ha)
Forest establishment	% of costs covered by Afforestation Grant dependent on year of planting	Allocated to Year 0	2860	4280
Forest maintenance up to end year 4	Costs covered by Maintenance Grant	Payment allocated equally over years 1,2,3 & 4	790	1155
Annual management cost	Incurred annually		20	20
Insurance	Initial payment in year 5 – runs to year 20	Recurring annually	20	20
Brash/inspection paths	One-off cost of cutting inspection paths through conifers Not relevant for ash	Incurred in year 14	35	0
Second fertiliser	Relevant only for unenclosed sites with additional nutrient requirements	Not relevant for SS-GPC3 or for ash		
Cost of Sales	% reduction in revenue	Lower in high value sites	Clearfell - 12%	Clearfell – 12%
Road costs	Only applicable if thinning	Not necessary in many small farm forests	Assume that road grant covers cost	0
Harvest losses	Timber losses due to difficult site conditions	Binary – Yes/No	1 st Th: 14% 2 nd TH: 12% 3 rd /sub TH: 8% C/fell: 5%	
Reforestation	Cost of replanting with same species post clearfell	May be allocated to first or second rotation	3500	0

A summary of the data sources and assumptions used in building the ForBES model to generate growth, cost and revenue curves for the required scenario and sensitivity analyses, is presented in Table 5.9. Cost streams are generated for each year using both average and component specific CPI. Revenue streams are generated for each year (by yield class), by applying price size curves of Irish price data to timber yields for thin and no-thin options on an annual basis. Subsidies are included in income streams in the early years. Cost and revenue streams are discounted to generate NPVs. These values are then converted to annual equivalised NPVs and are calculated for single and multiple rotations.

Table 5.9 Data Sources & Assumptions: Teagasc Forest Bio-Economic Model (ForBES)

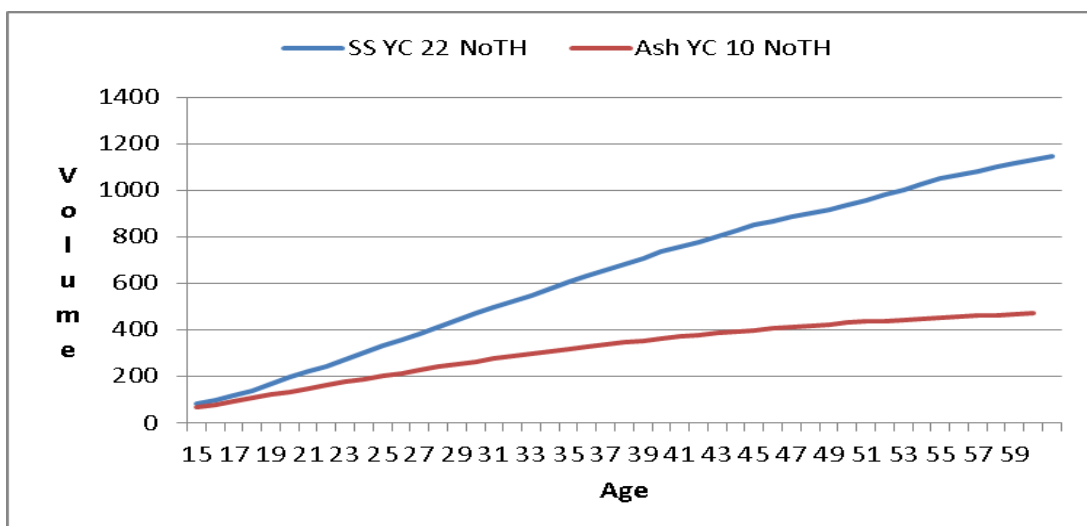
Issue	Data source	Assumptions
Establishment cost	Teagasc (2015)	€3650/ha
Subsidies	Sitka spruce (SS) (DAFM 2015b)	Establishment Grant: 2860/ha, Maint grant: €790/ha. Annual premium: €510/yr (15 yrs)
Sph (stems per hectare)	Afforestation Scheme FC static yield model	Spacing dictated by species Reduction in sph over life-cycle
Productive area	Afforestation Scheme	85%
Maintenance costs	Teagasc 2015	Management: €20/year (yr 6 onwards); Insurance: €20/yr (yr 6 to 20); Inspection paths: €35/ha (yr 14)
Maincrop (MC), dbh	FC static yield model	FC static yield model
Merchantable timber volume Net Realisable Volume	FC static yield model FIVE/ForBES model	Mean tree volume. The model provides a breakdown of volume by product category. MTV net of cost of sales, harvest losses, sph
Yield Class	FC static yield	Sitka spruce (SS) yield class 14-24
TH vs No TH	FC static yield model	Thinning assumes stable sites without undue risk Thin and No Thin options calculated for all scenarios
Thinning yield Unthinned yield	FC static yield model	Stands thinned to (MTT ²⁸).
Optimal rotations: Silvicultural Reduced MAI Financial max NPV	ForBES/ FC static yield model ForBES/ FC model ForBES	Rotation of MAI Reduced rotation Max NPV of 30 to 50 year rotations
Costs	Establishment and maintenance Harvesting	All costs which occur before the current age are treated as sunk costs. Afforestation: current age = 0
Establishment, maintenance and re-establishment costs	Teagasc Forestry Development Department	Establishment, maintenance and re-forestation costs are representative of those in common use in the farm forestry sector as determined by expert opinion in the Forestry Development Department, Teagasc.
Harvest Road costs	Only applicable if thinning	Assume costs covered by grant for farm forests
Cost of sales	FIVE/ForBES	Based on % reduction in NRV Thinning: 12%, Clearfell: 5%
Harvest losses	FIVE/ForBES	Conifers: Include % reduction in NRV.
Incomes		The model uses price size curves (PSC) based on average tree size plus volume assortments to calculate timber revenues
Log optimisation	FIVE/ForBES	The proportion in each product category is based on market knowledge and is for average quality crops.
Allocation to assortments (peping)	FC assortment tables (Hamilton 1975); Matthews and Mackie 2006); (Jordan 1992)	The model estimates the volume of large sawlog, pallet, pulp and stake material in thinnings and clearfell (no stake recovery from non- spruce or broadleaved species).
Timber prices:- conifers	Coillte 10 year price series based on average tree size (ITGA 2014)	Timber prices and costs keep pace with inflation. Uses price size curves and NRV from FIVE to calculate timber revenues.
Timber prices:- broadleaves	Timber price surveys in UK and Ireland	Broadleaf timber prices are based on smaller samples and are not as robust as conifer prices.
Subsidies	Forest Service (DAFM 2015b) Teagasc Forest Subsidies Model (Ryan et al. 2014)	Current SS subsidies: €510/ha for 15 years Historic subsidies
Price/Cost indices	CSO (2014) - See Table 5.13 & 5.14 for details	Component specific CPI and average CPI applied
Discount rate	Clinch (1999)	5%
Reforestation	Teagasc (2015)	Cost: €3,500 at end of first rotation (no subsidy)

²⁸ A sequence of thinnings prescribed by FC models over the life of a forest stand.

Summary statistics

Using the data from the FC models, present graphic displays of typical growth curves are presented. Conifers in general and Sitka spruce in particular, tend to have relatively short rotations, giving a higher economic return within a given time period, compared to broadleaf species. Figure 5.9 demonstrates the indicative difference between a representative conifer crop (Sitka spruce) and a representative broadleaf crop (ash) planted on roughly comparable sites, in terms of growth rate and cumulative volume production over a 60 year period. The mean annual increment (MAI) or mean annual growth refers to the average growth per year a tree or stand of trees has exhibited/experienced to a specified age.

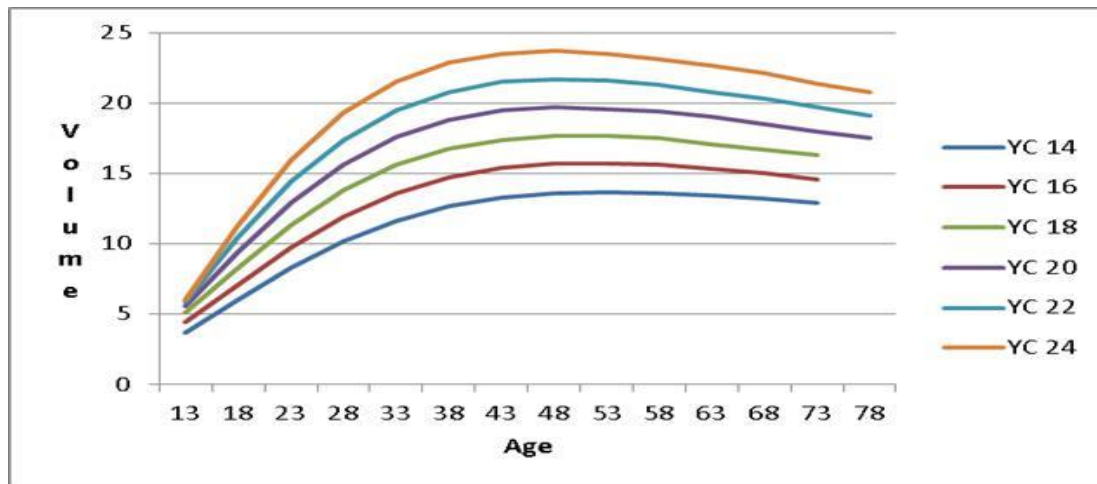
Figure 5.8 Cumulative volume production for Sitka spruce SS (YC 22) and ash/sycamore (YC 10) (No thinning) on roughly comparable sites (m^3ha^{-1})



Source: Edwards and Christie (1981)

Figure 5.10 shows how SS crops on more productive sites (higher yield class) have faster growth rates, higher cumulative volumes and reach the age of maximum mean annual increment (MAI) in a shorter time period.

Figure 5.9 Maximum MAI curves for Sitka spruce (no TH) yield classes 14 to 24 (cumulative volume in m^3ha^{-1}) by age



Source: Teagasc Forest Bio-Economic System Model (FORBES)

In reality, after species choice, the productivity of the afforestation site is likely to have the largest impact on the long-term return. The thinning decision also has a large impact on the timing and the magnitude of both costs and returns is also determined by yield class. Higher yield class forests yield thinning and clearfell revenues earlier in the forest rotation than low yield class crops. In addition, in unthinned crops, the generation of timber revenue is delayed until clearfell. This lack of intermediate financial returns from unthinned crops is not always considered by farm forest owners in advance of planting. In the next section, the results generated by the ForBES bio-economic model are presented and discussed.

5.5 RESULTS I: LIFE-CYCLE AFFORESTATION COSTS AND INCOMES

The ForBES model has significant analytical capacity with a broad range of outputs by species, yield class and forest management scenario. The model generates cost and income curves for thin and no-thin scenarios and generates annual equivalent NPVs for a range of discount rate, subsidy, rotation and indexation options. The model also calculates financial rotations of maximum NPV for thin and no-thin options. Results are reported for establishing a Sitka spruce (which accounts for almost two thirds of non-industrial private forestry in Ireland) in 2015, across a range of yield classes.

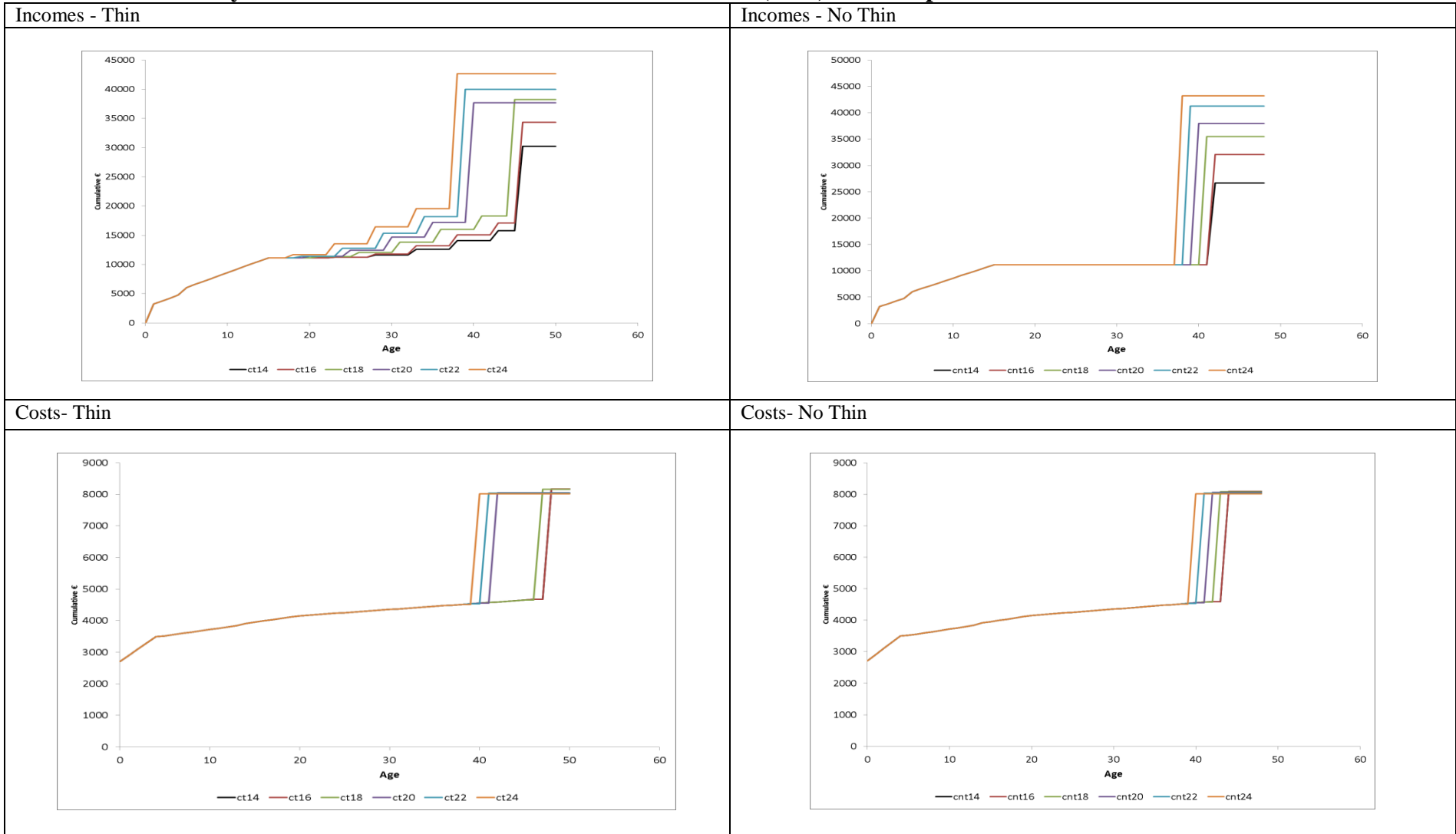
The life-cycle pattern of costs and incomes over one rotation for Sitka spruce (SS) for yield classes 14 to 24 is presented graphically in Figure 5.10. Firstly, it is evident that there is a substantial difference in the timing and magnitude of costs and incomes as displayed by the

relevant curves. There is also a considerable difference between the curves for the thin and no-thin scenarios. The distribution of income and cost in the early years of the rotation is the same for both thinned and unthinned crops, regardless of yield class as early income is derived from grant and premium subsidies which are categorised only by species (10% diverse i.e. 90% Sitka spruce and 10% of another conifer or broadleaf species), and not by site productivity.

Income begins to vary by yield class and by thinning decision at age of first thinning. Intermediate income from thinnings is small in early thinnings but grows rapidly as the rotation approaches clearfell. This is in contrast to the no-thin scenario where income remains static from the last premium payment at age 15 to clearfell age. Across the yield classes, there is an almost incremental increase in income. The “jump” in income between yield class 18 and 20 in the thin scenario, bucks this trend. This jump is reflective of an increase in rotation age from age 42 at yield class 20, to age 45 at yield class 18 as is also evident in Figure 5.10. By contrast, the no-thin clearfell age decreases almost incrementally with increasing yield class.

In relation to costs, the cost of establishment of the forest and its maintenance for the initial four years is largely offset by the afforestation and maintenance grants and is therefore essentially budget neutral. Once forests are established and have undergone initial maintenance works, costs for both thin and no-thin scenarios increase only by the amount of annual maintenance and insurance charges. Perhaps the most important element of cost which is not evident in Figure 5.10 is the cost of sales and harvest losses which can be substantial and are incurred both at thinning and clearfell. However, these costs are deducted indirectly as a percentage harvest volume reduction. These costs are obviously much higher for thinned than unthinned scenarios and result in a reduction in thinning and clearfell revenues.

Table 5.10 Life-Cycle Pattern of Incomes and Costs over 1 Rotation (2015) – Sitka Spruce



In this analysis, the reforestation cost of the next rotation is included as a cost in the first rotation and is evident in the substantial increase in costs at clearfell. Theoretically, as discussed earlier, the cost of reforestation should not be apportioned to the first rotation. However, from a pragmatic and transparency perspective, forest owners cannot achieve clearfell revenues without incurring the cost of reforestation. Therefore it's inclusion by forest extension agents has become common practice in recent years. In reality, because the cost arises at the end of the rotation and is dwarfed by the clearfell revenue, it is unlikely to have much impact on the magnitude of the NPV. An analysis of the sensitivity of NPV to the inclusion of reforestation costs in the first rotation is discussed further in the next section.

5.6 RESULTS II: THE SENSITIVITY OF NET PRESENT VALUE (NPV) TO SCENARIO CHOICE

The results of the sensitivity of the calculation of NPV to different management and methodological scenarios are presented here. Firstly, the robustness of the conclusions about the return on planting decisions in alternative situations and under a range of assumptions is tested by varying the discount rate, inclusion or exclusion of subsidies, extending the measurement period beyond one rotation to 110 years and the use of both average and component specific price indices in the NPV calculation. Due to the complexity of the model and the size of the dataset, the sensitivity analysis is undertaken on the 2015 data. Results are expressed as annual equivalised (AE) values of the NPV.

Sensitivity analysis: Discount rate

The accepted convention in Ireland for a number of years has been to use a real discount rate of 5% (Clinch 1999). Table 5.11 presents the annual equivalised NPV for a discount rate of 5% for both thin and no thin scenarios. The AE increases with yield class for both thin and no thin scenarios, reflecting the higher productivity of higher yield classes. Yield class 24 generates an AE value that is 59% higher than for yield class 14. It is noteworthy that in general the AE gap between thin and no thin scenarios rises with yield class from a lowest gap for yield class 16 of less than 1% to a gap of over 8% for yield class 24. This arises as a result of the additional income from thinning.

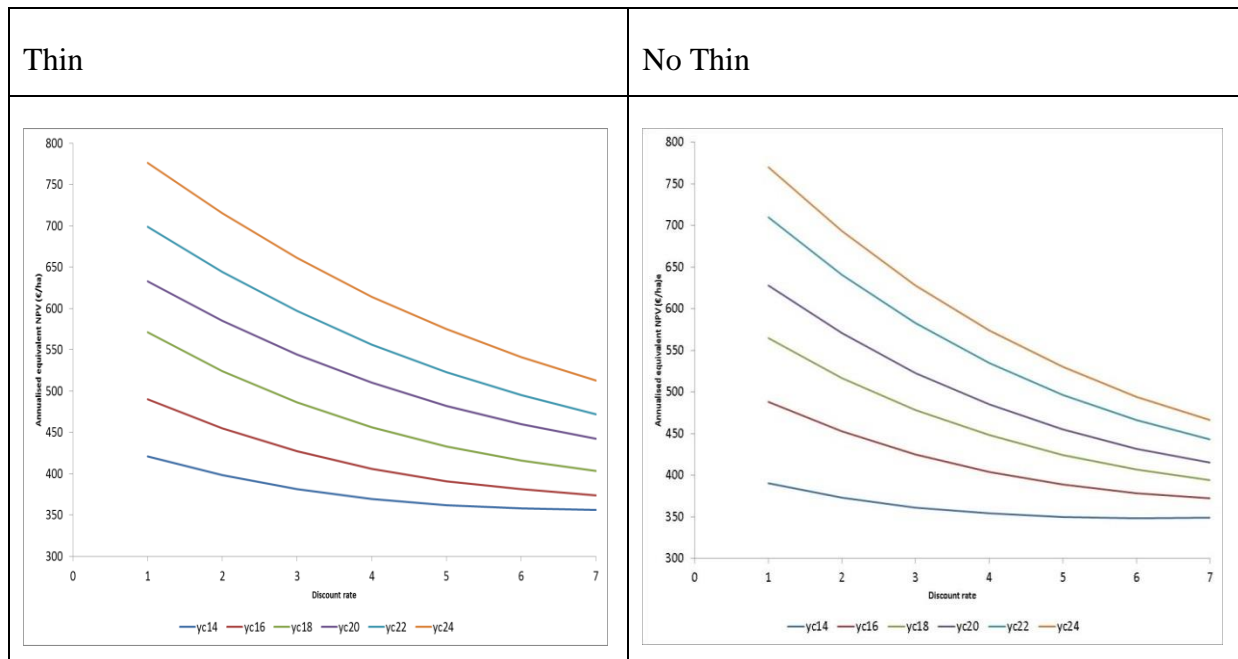
Table 5.11 Annual Equivalised NPV for Thin/No Thin scenarios (5% Discount Rate)

Yield Class	14	16	18	20	22	24
Thin	362	391	433	482	523	575
No Thin	350	389	424	455	496	530

Note. Species: Sitka Spruce; Year: 2015; Discount rate: 5%; With Premium; For One Rotation, Average CPI

The calculation of annual equivalised NPVs based on the combination of costs and revenues over a long time into the future depend critically upon the choice of discount rate. The choice of discount rate reflects the time preferences of the potential planter, the alternative return to land use and the interest rate that is available in financial markets. Because of these differences, a sensitivity analysis for a range of discount rates from 1 to 7% is presented in Figure 5.11, which graphically presents the sensitivity of the annual equivalent value to the choice of discount rate.

Figure 5.10 Annual Equivalised NPV by discount rate for yield class and Thin/No Thin scenarios



Note: The X axis in each case is the discount rate, the curves represent the yield class

It is evident that the economic return from forestry varies hugely with discount rate and is extremely sensitive to the discount rate used, due to the length of time between initial planting and final harvesting, which can vary from 30 years for conifers to 100 years for broadleaf species. The AE curves are similar in shape for thin and no thin scenarios however the values for the thin scenario are higher than the no-thin scenario across all discount rates analysed. The yield class 24 thin scenario which has the highest annual equivalent ranges from €776ha⁻¹ at a discount rate of 1% to €513ha⁻¹ at 7%, whereas the no thin scenario for yield class 24 ranges from €770 to €466ha⁻¹. The lower the discount rate the greater the difference in AE across yield classes. This is because the largest costs are expended at the start of the growth cycle, while the largest revenues result from clear-felling at the end of the rotation. The higher the discount rate, the lower the weight that is placed on these revenues from the future. It also reflects the policy motivation for paying upfront subsidies as income received today is more highly valued than future income.

Sensitivity analysis: Inclusion of annual subsidies

The annual subsidy (forest premium payment) for Sitka spruce (10% diverse) is substantial at €510ha⁻¹ for 15 years and thus warrants an assessment of the impact of these payments on the NPV. The annual equivalised NPV is presented with and without annual subsidies in Table 5.12. In line with *a priori* expectations, the inclusion of forest premium in the

calculation of the NPV has a large positive effect on forest returns. It is noted that the gap is much higher on lower yield classes. The AE for yield class 14 increases by a factor of 5 for the thin scenario and by a factor of 7 for the no thin scenario. This tails off to a doubling of the AE for yield class 24 for both thin and not thin scenarios. This reflects the fact that subsidy payments do not vary by yield class, while productivity varies a good deal, thus the AE with subsidies is essentially a measure of the market impact of forestry planting. Yield class is very important. Thinning thus has a larger impact on improving forestry productivity on poorer land.

Figure 5.11 Annual Equivalised NPV by inclusion/exclusion of annual subsidies for yield class and thin/no thin scenarios (SS)

	Thin						No Thin					
Yield Class	14	16	18	20	22	24	14	16	18	20	22	24
With Premium	362	391	433	482	523	575	350	389	424	455	496	530
Without Premium	70	99	140	181	219	269	52	91	124	154	193	224

Note. Species: Sitka Spruce; Year: 2015; Discount rate: 5%; With Premium; For one Rotation, Average CPI

The opportunity cost of planting formerly agricultural land also depends on the agronomic characteristics that are correlated with yield class. From these results it would appear that the impact of the observed variability of AE in relation to subsidies is that it disproportionately incentivises planting on poorer quality land.

Scenario analysis: Extension of measurement period beyond one rotation

Table 5.13 shows the effect of extending the period of analysis beyond one rotation to a time period of up to 110 years. Longer time periods are considered due to the fact that planting is irreversible and so forests will be replanted after clear-felling. In calculating the longer rotation, the cost of reforestation is allocated to the second rotation and no subsidies are paid after the first rotation. The results show slightly higher AE values for thin than for no-thin scenarios for the longer time period across all yield classes. However, the increases are small relative to the time period involved, ranging from 3% for yield class 14 for both thin scenarios up to 9% and 8% respectively for yield class 24 thin and no thin scenarios. In conclusion, there is little qualitative difference between the measurement period scenarios at the 5% discount rate.

Figure 5.12 Annual equivalised NPV by measurement period (one rotation vs 110 years) for yield class and thin/no thin scenarios

Yield Class	Thin						No Thin					
	14	16	18	20	22	24	14	16	18	20	22	24
1 Rotation	362	391	433	482	523	575	350	389	424	455	496	530
110 Years	373	405	453	515	563	625	362	406	447	484	532	572

Note. Species: Sitka Spruce; Year: 2015; Discount rate: 5%; With Premium; For one Rotation, Average CPI

The occurrence of the subsidies in the first rotation essentially mean that in the context of an infinite time series analysis such as the Land Expectation Value (LEV) methodology discussed in Chapter 3, the initial forest rotation has a very different composition to subsequent rotations. On this basis and as the difference in AE between the measurement periods is so small, the use of a single rotation is justified for the purpose of this analysis. The shorter analytical time frame (one rotation) will become more relevant in comparing forestry with annual agricultural incomes in a later chapter. In addition, the calculation of NPV using one rotation allows for greater flexibility and control in modelling the impact of policy interventions which may arise at different points within a specific rotation and are unlikely to be replicated in subsequent rotations over an infinite time horizon. It is therefore reasonable to model the impact of single rotations and draw conclusions from this without looking at infinite series.

Scenario analysis: Price indexation

The use of a real discount rate means that present day costs and returns do not need to be adjusted for the effects of inflation if they are projected to future dates (Herbohn et al. 2009). This essentially means that in calculating net present value, the convention is to not explicitly account for the growth in costs and incomes, rather to account for them implicitly by expressing prices in real terms. Thus it is assumed that costs and prices grow at the same rate and are cancelled out by the use of real price data. However the historical data must be adjusted to make them comparable with other time-series datasets²⁹ and therefore need to adjust the 2015 based NPV to reflect historical prices. However the sensitivity analysis around the use of price indices presented in Figure 5.14 shows that there is in fact, a difference in annual equivalised NPV when using differentiated rather than average indices. In other words the weight of inputs used for forestry is different to the weights used in the CPI and so the price index is different.

²⁹ In Chapter 6 it will be necessary to be able to compare forest income streams with historic agricultural income streams in order to generate an opportunity cost for planting.

Figure 5.13 Annual equivalised NPV by price indexation for yield class and thin/no thin scenarios (using 2010 price indices)

	Thin						No Thin					
Yield Class	14	16	18	20	22	24	14	16	18	20	22	24
Average CPI	337	362	398	440	475	519	327	361	391	418	453	481
Component Specific CPI	346	374	414	461	500	550	335	372	406	436	475	507
Ratio: Av / CS CPI	0.97	0.97	0.96	0.95	0.95	0.94	0.98	0.97	0.96	0.96	0.95	0.95

Note. Species: Sitka Spruce; Year: 2010; Discount rate: 5%; With Premium; For one Rotation, Average CPI

Across thin and yield class scenarios, the AE values using the component specific indices are lower than the AE values generated using the general consumer basket. The AE also varies by thin/no thin scenario and by yield class. The ratio of average CPI to component specific CPI decreases across the range of yield classes from 97 to 94% for the thin scenario and from 98 to 95% for the no thin scenario. The impact is small but linear and warrants the consideration of using component specific CPIs in future analysis, as it allows for greater flexibility and accuracy in predicting future returns, particularly in relation to comparing forest and agricultural returns.

5.7 RESULTS III: OPTIMAL ROTATION LENGTH

The optimal rotation length in years for three optimisation objectives i.e. a rotation of maximum MAI, a reduced MAI rotation and a financial rotation of maximum NPV are examined, in addition to the sensitivity of the inclusion or exclusion of forest subsidies in the financial rotation calculations.

Optimal rotation length: maximum MAI

Typically, trees grow vigorously in the very early years and then begin to stabilise growth rates in the middle years before slowing down as they get older. The mean annual increment (MAI) or mean annual growth refers to the average growth per year a tree or stand of trees has exhibited/experienced to a specified age. The MAI starts out small, increases to a maximum value as the tree matures, then declines slowly over the remainder of the tree's life. Throughout this, the MAI always remains positive. The point at which the MAI peaks is commonly used to identify the biological maturity of trees. This point is also equivalent to the intersection of the MAI and the periodic annual increment (PAI) curves. Thus the biological optimum rotation is the age at which the tree or stand is harvested if the management objective is to maximize long-term yield.

Table 5.12 shows that the rotation of max MAI ranges from 58 to 48 years for the thin scenario and from 53 to 48 years for the no thin scenario stands. The age of max MAI reduces with yield class and that at lower yield classes, the thin scenario takes longer to achieve maximum MAI than the no thin scenario. This is due to the interruption in growth and cumulative volume production as trees react to the “shock” of thinning before reverting to typical growth rates. At higher yield classes, (20 or greater), there is no difference in the age that max MAI is achieved for thin and no thin scenarios. Although at higher yield classes (20 or greater), there is no difference in the age that max MAI is achieved for thin and no thin scenarios, there is quite a large gap in optimal rotation lengths for lower yield classes.

Table 5.12 Optimal Rotation Length (years) for different optimisation objectives

Yield Class	Thin						No Thin					
	14	16	18	20	22	24	14	16	18	20	22	24
Rotation of max MAI	58	57	56	50	49	48	53	52	51	50	49	48
Reduced MAI rotation	46	46	45	40	39	38	42	42	41	40	39	38
NPV (inc Premium)	50	47	46	45	44	43	49	44	41	37	39	36
NPV (exc Premium)	50	47	46	45	44	43	49	44	41	37	39	36

Note. Species: Sitka Spruce; Year: 2015; Discount rate: 5%; With Premium; For one Rotation, Average CPI

Optimal rotation length: Reduced MAI rotation

In practice in Ireland, a practice of reducing the rotation length has been adopted by both public and private forest managers as a means of accounting for faster rates of growth by some conifer species in Ireland than in Britain. In the case of Sitka spruce, this involves arbitrarily reducing the age of max MAI by 20%. This practice which was initially based on economic analysis conducted by the Forest and Wildlife Service (Anon 1977) has become known colloquially as the “reduced rotation” and is considered to be more or less in line with the theoretical financially optimum rotation for the major tree species (Phillips 1998, 2004). The reduced rotation has now become the industry norm in both private and public sector forest practice and is the default rotation in the FIVE forest extension calculator as it is a simple generalised rule of thumb which doesn’t impose additional data or computational burden on the forest manager or forest owner.

As the reduced rotation is based on the rotation of maximum MAI, there is a linear relationship between both rotations and they display similar trends. The biggest difference is the substantially reduced clearfell age. This reduction ranges from 12 years at yield class 14, to 11 years at lower yield classes, to a 10 years reduction for higher yield classes in the thin

scenario. In the no thin scenario, the reduction in rotation length ranges from 11 years at yield class 14 to 10 years for yield classes from 16 to 24.

However, in reality, the financial components of the NPV grow at different rates over time and are affected by the type of price indices utilised in the analysis. Therefore the optimum financial rotation will vary over time if the components are not held constant. This justifies the need for a model such as ForBES which has the flexibility to conduct sensitivity analysis of other (new) management assumptions and to be updated regularly as new price information becomes available.

Optimal rotation length: Maximum NPV rotation

The financially optimum rotation age is determined at the point of maximum NPV of expected benefit/profit. Growing the crop beyond this point would result in a net revenue loss. ForBES runs iterative rotations from 30 to 50 years for each yield class and thin scenario to determine the point of maximum NPV. The model also calculates the maximum rotation length (with and without premium payments), to assess whether the existence of a forest subsidy changes management practices in relation to rotation length, or whether it only affects the incentives around the afforestation decision. As it happens, the pattern of optimal financial rotation length is the same for both subsidy scenarios. This topic is further elucidated in later analysis.

Firstly however, the optimal financial rotation is compared with the maximum MAI based rotation. Table 5.12 illustrates that there is indeed a substantial difference between the financial rotation of maximum NPV and the MAI and reduced MAI rotations. The thin scenario rotation lengths vary from 50 years at yield class 14 to 43 years at yield class 24. The range of the no thin rotation lengths is considerably larger with a difference of 13 years between the lowest and highest yield class. In comparison with the reduced MAI rotation lengths, the max NPV rotations are longer for all yield classes in the thin scenario with gaps ranging from 1 to 5 years. In the no thin scenario, the gap ranges from 7 years for the lowest yield class to being two years shorter for the highest yield class (24). Thus, the optimal financial rotations fall at a faster rate for the no-thin scenario than for the thin scenario, while for the max MAI, the opposite is the case. However, the differences are not linear, thus the individual NPVs are presented graphically in Figure 5.15 to extract more information. The important criterion here is the point in time at which the NPV has its highest value, not the

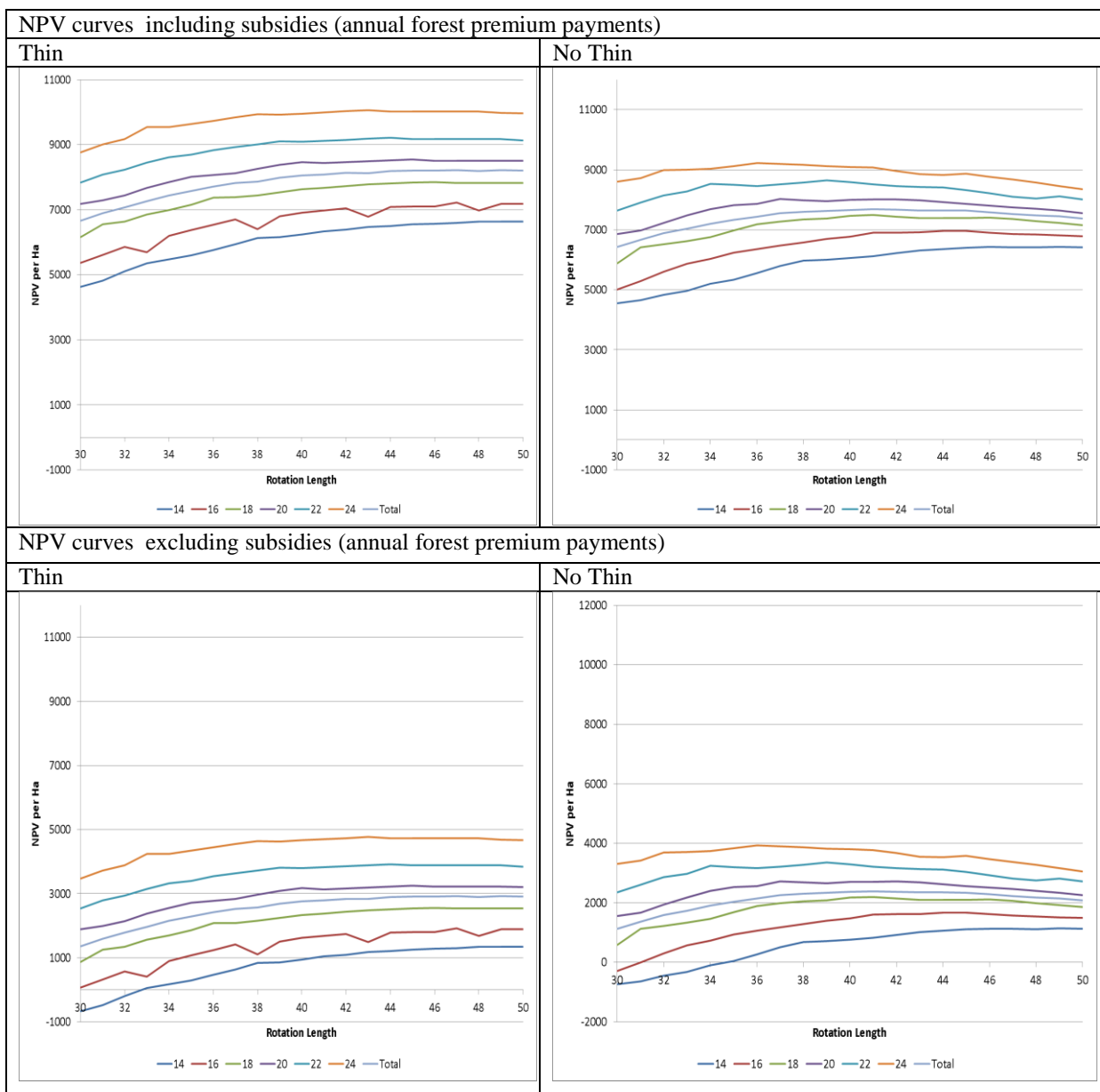
magnitude of the NPV. For comparison purposes, the ForBES max NPV rotations are presented with and without subsidies, for yield class and thin/no thin scenarios.

In focusing initially on the NPV inclusive of subsidies, a number of features are notable:

- The magnitude of the NPV is considerably higher when subsidies/premium payments are included in the calculation, unsurprising given the relative magnitude of the subsidies.
- The gaps between yield classes are much closer for the NPV including the premium than the NPV excluding the premium. Thus subsidies reduce the differential incentives, reflecting the fact that there is no explicit variation between areas other than those defined by being a less favoured area (LFA) (see Ryan et al. 2014).
- The NPV curves which include the premium are much flatter than those without premium, varying less by rotation length than for the curves without premium.
- The curves are not continuous, reflecting the fact that the Edwards and Christie (1981), growth curves increase in 5 year intervals. Although average values are imputed for the intervening years, the curves still have a non-continuous functional form illustrated as jagged, piece-wise linear curves.
- The NPV curves for the thin scenarios are flatter in general than the no thin curves, although there is more variation in the thin curves, particularly for yield class 16 where the effect of the 5 year non-linear increases are most evident.
- The thin NPV curves increase monotonically i.e. the age of maximum NPV decreases with increasing yield class.
- However, the non-monotonicity of the optimum rotation length curve for the no thin scenarios is also notable. Here, the general trend is for the optimal rotation to decrease with yield class, however, the age at which the NPV is highest increases from 37 to 39 years for yield class 22 before dropping back to 36 years for yield class 24. At first glance, this could be an anomaly, however on examining the data behind the curves, it is clear that it is caused by the flatness of the curves at this point. While the maximum NPV is achieved in year 39, from year 34 onwards, the NPV fluctuates between €8,533 and €8649. However, further inferences about earlier clearfell ages cannot be drawn in the absence of confidence intervals around the data observations. This is currently not possible as there are no standard deviation values for the FC growth curves.
- Comparing the NPV curves with subsidies to those without, it is evident that the length of the rotations is the same i.e. the point of maximum NPV is the same with and

without subsidies but the NPVs are very different. For instance, the max NPV for the yield class 24 thin scenario (with subsidies) is €10,064 and falls to €3,888 (without subsidies). A similar trend is evident in the no thin scenario where the maximum NPV for yield class 24 is €9,225 with subsidies and €3,931 without subsidies. Thus, while the inclusion or exclusion of subsidies in the calculation of max NPV has a large impact on the magnitude of the NPV, it does not affect the point in time at which the curve reaches the maximum.

Figure 5.14 NPV financial rotation curves (with and without annual subsidies) for yield class and thin/no thin scenarios



- Despite the variation between the NPVs (including and excluding premium), the optimal rotation lengths are the same. It is not clear whether this is a statistical artefact given that there are so many issues that affect the optimal rotation, or whether it will always be the case. Particularly in the higher yield class situation, it is plausible that a small change in a driver might result in a large change in the optimal rotation length, given the flatness of the NPV curve observed relative to rotation length.

Essentially this confirms that the main driver of the point at which the NPV is maximised, is the discounted timing of the clearfell. The maximum NPV is driven by volume and prices more so than subsidies. Intuitively, this makes sense as the subsidies occur only in the early part of the rotation and the sheer magnitude of the clearfell value at the end of the rotation is the strongest driver.

The financial rotation curves generated by the ForBES model provide significant additional information on the interaction of the components of the NPV and the point at which the NPV is maximised, reinforcing the usefulness of this type of financial modelling approach. In future, this information could be augmented by developing confidence intervals around the data behind the curves, allowing for even more precise modelling of the financially optimum rotation. However, it appears that the curve could be “smoothed,” the model predictions of the optimal financial rotation could be improved by the inclusion of confidence intervals. In order to achieve this, it would be necessary to introduce a stochastic component to the model. This would essentially sample observations from a normal distribution around the growth data in the FC models, to provide a standard deviation around the observations. This would in turn enable the generation of confidence intervals around the data in the growth curves. This is something that can be considered for future work in this area as the nature of the infrastructure of the ForBES model allows for modelling flexibility and the inclusion of additional parameters and data.

5.8 SUMMARY

This chapter set out to develop a forest bio-economic model to examine the financial impact of different choices on the economic return to forestry in order to provide information to farmers and policy makers on the financial optimisation of afforestation and forest management decisions. From the farmers’ perspective, they need information on the impact of the choices they make on growth, management, cost and income components. From the

forest managers or policy makers' perspective, the methodological choices examined influence both the measurement and measurement period of forest returns. All of these choices influence outcomes in relation to the optimisation of the forest rotation.

An examination of the scientific literature on forestry bio-economic models determined the range of choices and methodologies analysed and formed the basis for the specific forest management choices and valuation methodologies in the literature in developing the model. Reflecting the factors driving tree growth and the impact of management decisions on volume outcomes and building on the management choices in the literature, a number of scenarios are selected which allow for the investigation of the financially optimum rotation. These include the impact of species choice, yield class and the impact of thinning or not thinning. In addition and again building on the literature, it was decided to analyse the impact of methodological scenarios on the calculation of returns, namely, the inclusion of subsidies, the extension of the rotation length, the choice of discount rate and the choice of price indices.

The mechanism to achieve this involved developing the Teagasc Forest Bio-Economic System (ForBES) model, based on the Edwards and Christie (1981) forest growth curves. Cost curves were generated on the basis of current industry practice. Income curves were generated using long-term historical price series data appropriate for long-term projections. ForBES uses the growth, income and cost curves to generate NPV curves for one rotation by species, yield class and thin scenario. These curves are iterated for each rotation length from 30 to 50 years to determine the financially optimum rotation of maximum NPV. The sensitivity of calculation of NPV to the methodological scenarios was also examined.

Simulating the scenarios for Sitka spruce, it is clear that different objectives result in different outcomes, confirming the initial hypothesis in this chapter. There are substantial differences between the biologically optimal rotation, the reduced rotation in common usage and the financially optimal rotation as calculated by ForBES. The NPV calculation is not sensitive to the inclusion of reforestation costs or to the extension of the rotation measurement period.

However, the results are particularly sensitive to the choice of yield class, thin scenario, inclusion of subsidies, choice of discount rate and nature of price index. Specifically, better site productivity and thin versus no-thin options, result in higher NPVs and shorter rotations across all optimisations. This particular information is of benefit to (a) farmers wishing to

optimise their forest investment, (b) extension agents who provide information to farmers and (c) policy makers who need understand the drivers of afforestation in relation to the design of future afforestation incentive schemes.

Many of the BEMs reviewed as part of this research address different dimensions of forest management decision-making in great depth, however, it appears that ForBES is unique in the breadth of silvicultural and financial choices that it has the capacity to model, across the whole afforestation system. ForBES potentially has the capacity to take inputs from dynamic growth models to reflect forest management decisions taken on the basis of market demands and pricing structures, rather than on the management regimes imposed by static growth models. The prediction of long-term timber revenues is currently limited by the lack of availability of historical price data and log specifications for the timber end-products currently in demand. Future availability of this information would allow for additional analysis of the sensitivity of the optimal financial rotation to timber prices and end-product optimisation and would hugely improve the role of ForBES as a farm afforestation decision support tool. The addition of a stochastic component to the model would also enable the smoothing of the growth curves allowing for more precise predictions of the financially optimal rotation length.

The nature of the infrastructure developed in ForBES will allow us to run new scenarios and conduct sensitivity analysis as policies change over time. At present, the model currently generates outputs based only on net realisable timber volume. However ForBES has the capacity to include carbon sequestration as a model output. In addition, risk (particularly in relation to wind damage and financial markets) could be accounted for in future versions of the model. At present this model is hypothetical but it could ultimately be scaled up to the national level. This would involve weighting up the species and yield class data to be representative of farm forests at the national level.

The primary objective of this chapter was to generate forest market income streams for a range of species, management and financial choices in relation to the afforestation decision. However, the majority of afforestation in Ireland is undertaken on previously agricultural land. Learning from whole-farm models such as the Australian Farm Forest Financial Model (AFFFM), ForBES was developed to have the capacity to go beyond the modelling of forest yields and returns. The model has additional capacity to integrate biophysical and farm financial data in order to calculate the agricultural opportunity cost foregone when land is

planted. The next step is to consider the farm income that would be foregone once land is planted. This can then be incorporated into the ForBES forest income streams to fully reflect the opportunity cost of the land use change.

5.9 APPENDICES

Table 5.13 Cost Price Indices

Year	Establishment and Reforestation Cost	Maintenance Cost	Insurance Cost	Inspection Paths Cost	Roading Cost
1985	66	66	70	120	66
1986	70	70	72	110	70
1987	73	73	74	88	73
1988	75	75	76	95	75
1989	76	76	78	101	76
1990	80	80	79	101	80
1991	82	82	82	103	82
1992	85	85	84	101	85
1993	87	87	86	96	87
1994	89	89	87	96	89
1995	91	91	90	96	91
1996	93	93	91	101	93
1997	95	95	93	95	95
1998	96	96	94	91	96
1999	98	98	96	93	98
2000	100	100	100	100	100
2001	105	105	106	113	105
2002	108	108	110	111	108
2003	110	110	114	113	110
2004	111	111	117	115	111
2005	115	115	121	124	115
2006	122	122	124	133	122
2007	132	132	129	136	132
2008	138	138	137	221	138
2009	141	141	139	185	141
2010	144	144	137	162	144
2011	139	139	162	180	139
2012	142	142	178	191	142
2013	141	141	172	210	141

Table 5.14 Revenue Price Indices

Year	Premium	Thin revenue	Clearfell revenue	Once off revenue
1985	0.0	66.2	66.2	66.3
1986	0.0	68.7	68.7	69.9
1987	23.3	70.9	70.9	72.6
1988	23.3	72.4	72.4	74.9
1989	23.3	75.4	75.4	76.4
1990	36.5	77.9	77.9	79.6
1991	36.5	80.4	80.4	82.2
1992	36.5	82.9	82.9	84.9
1993	59.7	84.1	84.1	87.5
1994	59.7	86.1	86.1	88.7
1995	59.7	88.2	88.2	90.8
1996	59.7	89.6	89.6	93.1
1997	67.6	90.9	90.9	94.7
1998	67.6	93.2	93.2	96.1
1999	67.6	94.7	94.7	98.3
2000	100.0	100.0	100.0	100.0
2001	100.0	104.9	104.9	104.9
2002	100.0	109.7	109.7	109.7
2003	100.0	98.2	98.2	113.6
2004	100.0	78.3	78.3	116.0
2005	100.0	72.9	72.9	118.9
2006	146.0	75.1	75.1	123.6
2007	146.0	114.7	114.7	129.6
2008	146.0	85.7	85.7	134.9
2009	134.3	62.5	62.5	128.8
2010	134.3	137.6	137.6	127.7
2011	134.3	116.2	116.2	127.3
2012	134.3	121.4	121.4	128.0
2013	134.3	130.1	130.1	128.0

Chapter 6. INCORPORATING AGRICULTURAL OPPORTUNITY COSTS IN THE RETURNS TO FARM AFFORESTATION

6.1 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 from 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.

6.2 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 Formula 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.

6.3 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.³⁰

Table 6.1 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.³¹ 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-diverse³² 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 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

³⁰ This methodology can also be used for other tree species once the relativity of growth rates with Sitka spruce is available.

³¹ For a description of FIVE, see Ryan et al. (2013).

³² 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).

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 6.2 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 enterprise³³, as calculated on a standard output basis³⁴ i.e. specialised dairy; dairy other; tillage; cattle rearing; cattle other and sheep³⁵. 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 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

³³ Note that farms may have multiple enterprises but are categorised on the basis of the dominant enterprise.

³⁴ 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).

³⁵ Some changes have been made to system classifications over time which can make longitudinal comparisons difficult.

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 compatibility 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.

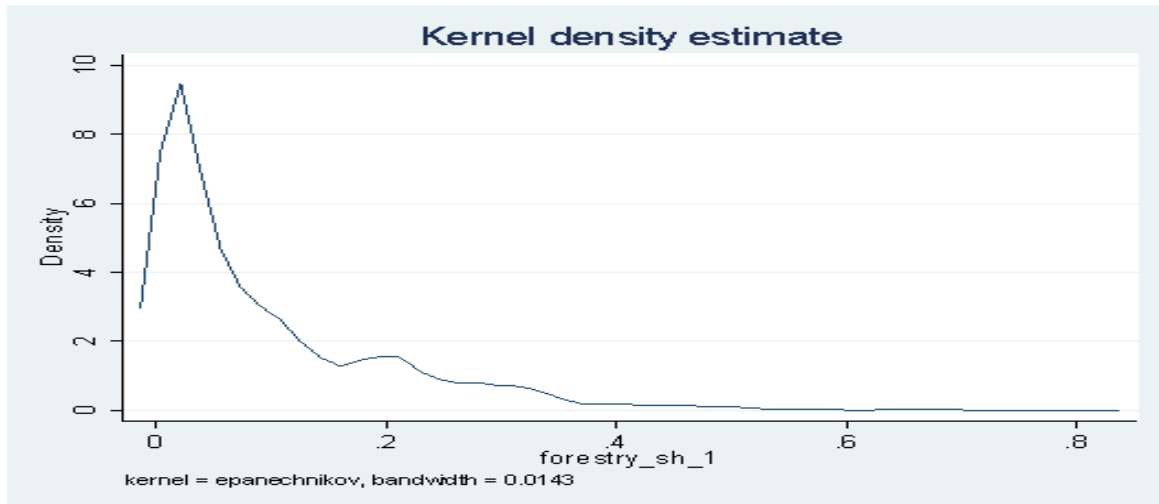
As forest market income is a multi-period income, much more so than agriculture, a temporally comparable metric is necessary. The ForBES model (Ryan et al. 2016) generates forest income for a given year, whereas there are multiple years of farm data in the NFS. Additionally, agricultural and forest inputs 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.

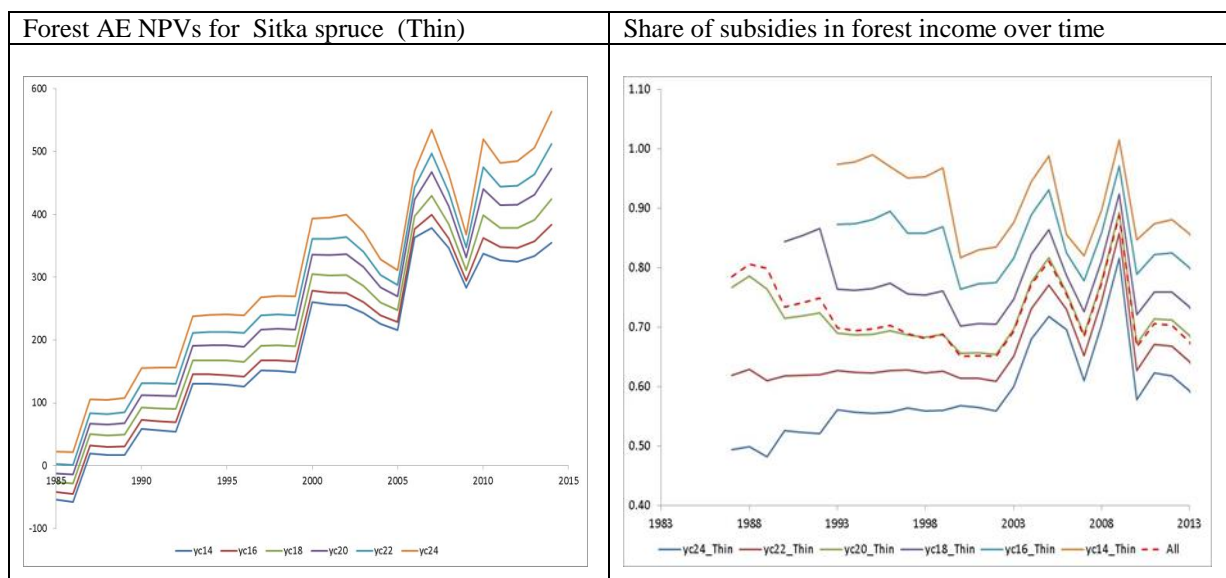
Figure 6.1 Kernel density of the distribution of farms with forests over time



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.

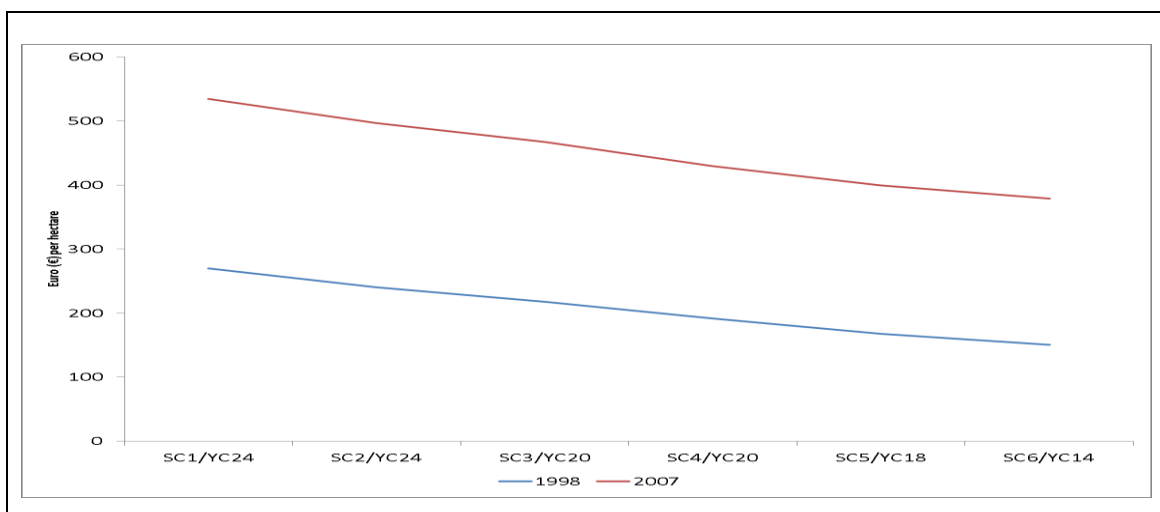
Figure 6.2 Annual Equivalised NPVs (€/ha) and Share of Subsidies in Forest Income over time



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 6.3 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 6.4 Share of agricultural subsidies in agricultural incomes measured using FFI/ha and GM/ha over time

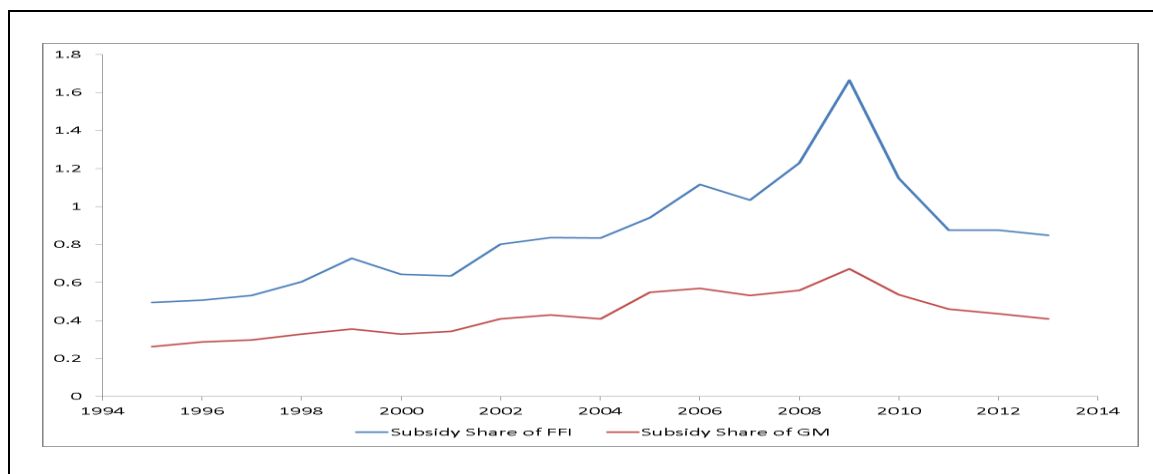


Table 6.3 presents the average livestock density across all years and all livestock systems. As expected, this confirms the strong and almost linear effect of soil code on livestock density. The best soils have a much higher stock carrying capacity than poorer soils may be steep or have impeded drainage.

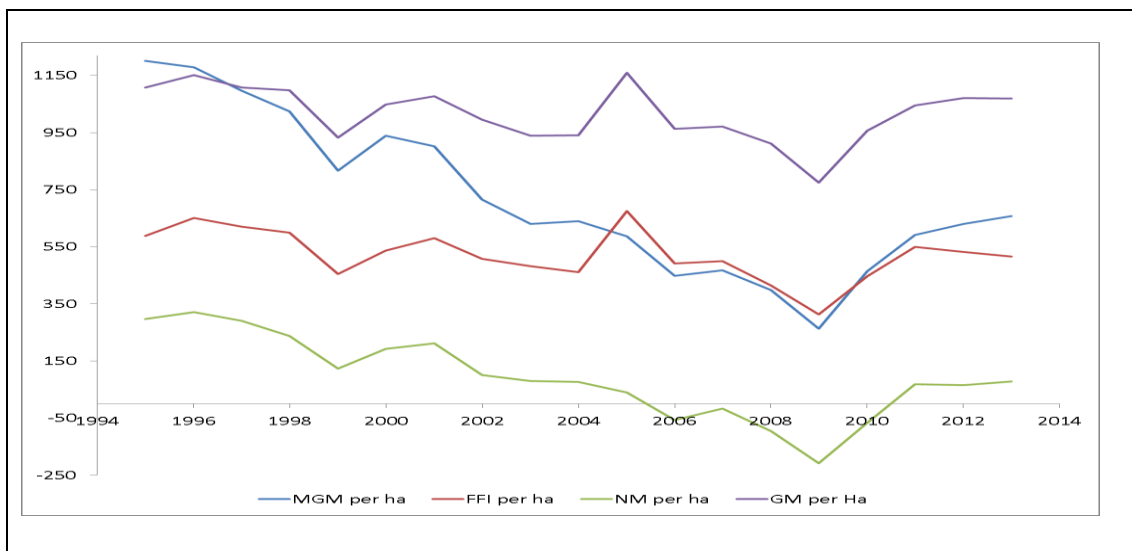
Table 6.3 Average livestock density for each soil code over time (LU ha⁻¹)

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.

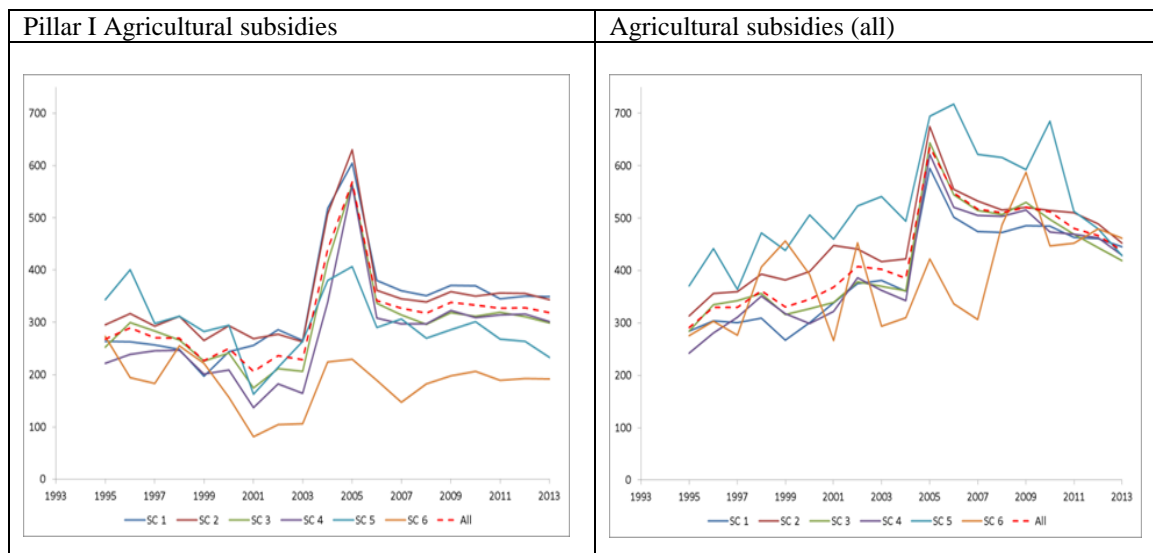
Figure 6.5 Weighted Average AE of NPV (€/ha) of agricultural income (1985 to 2013) using four agricultural income measures (CPI adjusted)



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 6.6 Agricultural subsidies and Direct payments per hectare by Soil Code (1985 to 2013)



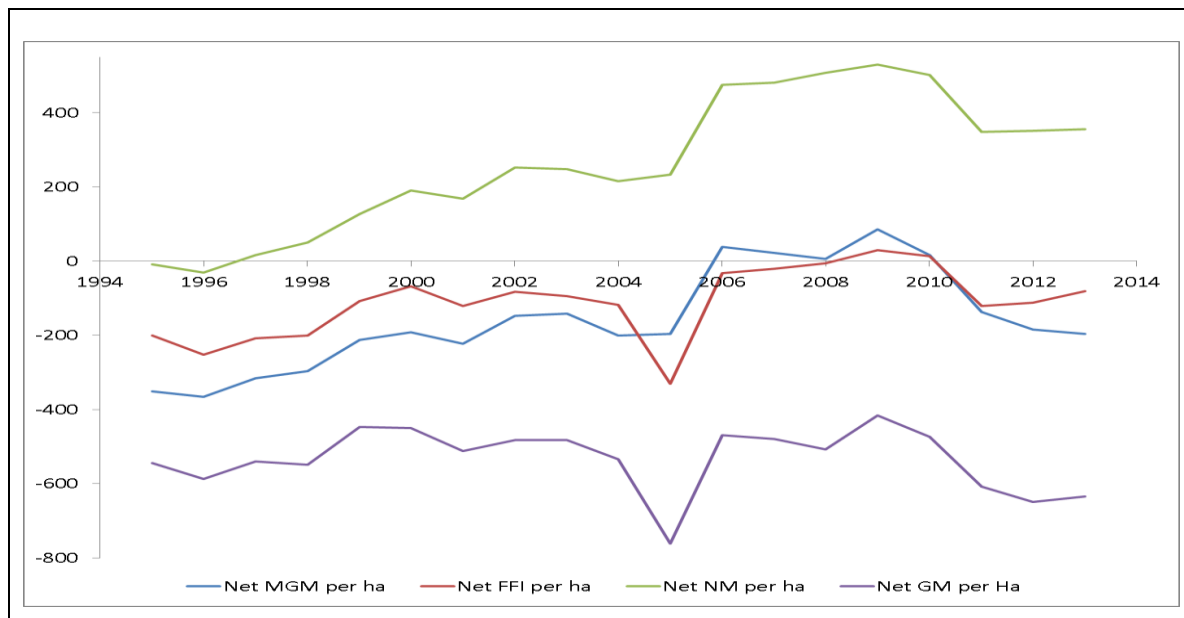
Pillar I payments of the Common Agricultural Policy (CAP) are examined separately as these are production-related prior to 2005 and are based on historical production post 2005. In general, farms on better soil classes receive higher Pillar I subsidy payments over the period³⁶. This confirms *a priori* 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.

³⁶ The spike in 2005 is again reflective of carry-over payments

6.4 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 6.7 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.

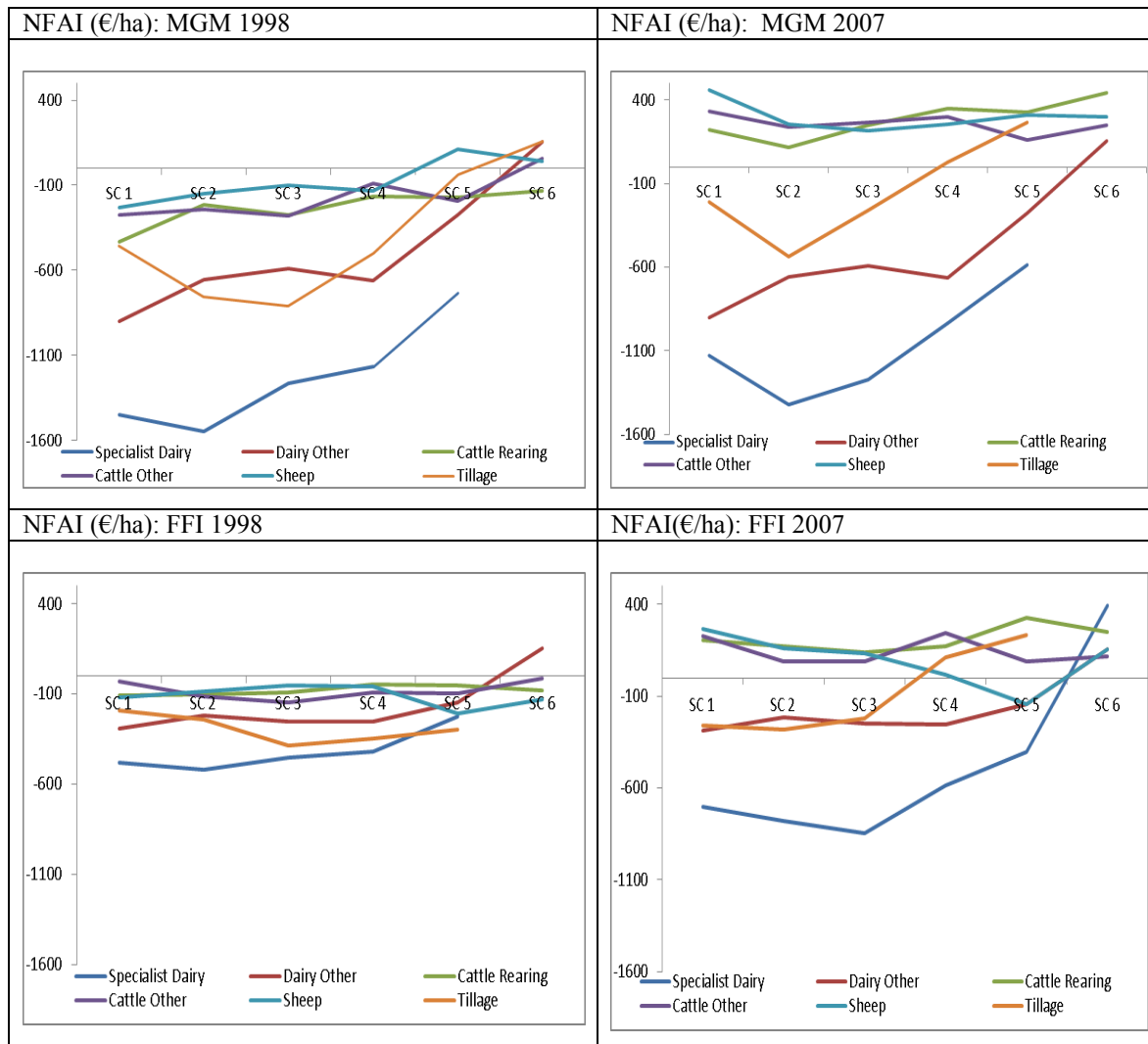
In analysing the differences between policy eras, the NFAI per ha of converting one hectare of land from agriculture to forestry for each farm system and soil class for both MGM and FFI is presented in Figure 6.8 for 1998 and 2007. While the NFS is nationally representative by farm system, the sample 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 6.8 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 $€450 \text{ ha}^{-1}$. 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 $€200 \text{ ha}^{-1}$.

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.

6.5 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 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,³⁷ 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

³⁷Many 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.

6.6 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 farming 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?

Chapter 7. LAND USE CHANGE FROM AGRICULTURE TO FORESTRY A STRUCTURAL MODEL OF THE INCOME AND LEISURE CHOICES OF FARMERS

7.1 INTRODUCTION

As a result of the failure to meet afforestation targets in many European countries, there is a growing literature on the complexity surrounding the decision to convert land from agriculture to forestry. Much of the literature looks at afforestation from a biological perspective and generally either compares biological optima for a specific forest stand or specific harvesting options, or investigates how to generate more biomass or income from forests. However, these analyses are largely conditional on forests that are already established³⁸.

In addressing the conversion of land from agriculture to forestry, linear programming approaches to examining the agricultural opportunity cost associated with farm afforestation, assume that farmers are profit-maximisers and will select the choice that provides the highest income (Edwards-Jones 2006). However, from the qualitative literature, it is clear that many farmers' objectives are broader than profit maximisation and involve making choices based on other factors (Key 2005; Key and Roberts 2009). Farm size, farm system, soil class, farmer age and intensity of farming (Howley et al. 2012 and 2015) are commonly cited as either positive or negative drivers of afforestation. It has also been reported that the loss of flexibility of land use after planting acts as a barrier to afforestation (McDonagh et al. 2010). From a behavioural perspective, there are other factors such as lifestyle and culture that influence farmer decision making in relation to land use choices. These factors are addressed in much of the qualitative and attitudinal literature. While farmers may not always be driven solely by profit maximisation, according to Becker (1993) their behavioural choices are rational in that they maximise utility in the form of a trade-off between income and leisure.

This chapter aims to go beyond biological optima, profit maximising and existing qualitative studies to look at the behavioural aspects of the decision making process in relation to farm afforestation. In this chapter, farmers' utility in relation to agriculture and forestry is examined using discrete choice methodology, where utility reflects the actual outcome of the choice and the weight given to income and time respectively. To date, it would appear that there are no other studies that quantify the parameters of a utility function for afforestation.

³⁸ See Chapter 5 for further detail

The aim of this chapter is to fill gaps in the literature by using micro-level data to build a structural afforestation choice model which considers the utility maximising decisions of farmers when presented with a range of afforestation choices.

There is an extensive literature on discrete choice studies but many studies utilise reduced form rather than structural models. In recent studies on land use change, Hynes and Garvey (2009) conducted an empirical examination of the participation decision of farmers in voluntary agri-environment schemes in Ireland and DeFrancesco et al. (2008) examined the participation decisions of Italian farmers. These studies provide information about the type of farmers participating in these schemes by using reduced form models to compare individual specific variables on the farms of participants, with individual specific variables on the farms of non-participants. The first use of the phrase “structural model” is attributed to Koopmans (1949) who held that the underlying rationale of structural modelling is that measurement cannot be done without some kind of theory. In moving from a reduced form model (characteristics of the farmers) to the behavioural theory and processes embodied in a structural model i.e. the factors that govern utility in theoretical choice models, this chapter examines the afforestation choices that are actually made by farmers relative to the choices that could have been made.

From a methodological perspective, this chapter aims to dig further to examine revealed preferences around the forestry participation choice, therefore it is necessary to estimate a behavioural model that contains choice specific attributes i.e. a choice model. Domencich and McFadden (1996) define a behavioural model as one which “represents the decision which consumers make when confronted with alternative choices”. Since the 1970s, there has been a steady growth in interest in quantitative statistical methods to study choices made by individuals (Hensher et al. 2005). In relation to both understanding how choices are made and forecasting future choice responses, a healthy literature has evolved and is largely synthesised in the reference works of Louviere et al. (2000) and Train (2003).

Choice modelling attempts to model the decision process of an individual using either revealed preferences or stated preferences made in a particular context or contexts. Typically, the approach attempts to use discrete choices where A is chosen over B in order to infer the influence of preferences j and k on utility (where j and k are mutually exclusive). It is assumed that consumers’ preferences are stable over the observed time period, i.e. the consumer will not reverse their relative preferences regarding A and B (if both are

affordable). This condition is known as the Weak Axiom of Revealed Preference (WARP) (Varian 2006).

Such choices are commonly modelled using either a conditional logit (CL) which models the attributes of the choice, or a multinomial logit (MNL) which models the attributes of the individual (farmer). Here the choices are modelled using a standard CL model (McFadden 1973) modified by Van Soest (1995) which models the expected utilities of the discrete choice. The choices are modelled in terms of the characteristics of the alternatives rather than attributes of the individuals, where the afforestation choice takes the value 1 and the choice not to afforest takes the value 0.

Logit models are the most widely used discrete choice model and are derived under the assumptions that the error terms are assumed to be Gumbel (Extreme Value Type 1)³⁹ and independently and identically distributed (IID). According to Train (2003) “the critical part of this assumption is that the unobserved factors are uncorrelated over alternatives, as well as having the same variance for all alternatives.” According to Aaberge and Colombino (2014), a potential limitation of RUM models based on the independent and identical extreme value distribution for the random component (ε), is the Independence of Irrelevant Alternatives (IIA) assumption, which imposes restrictions on the behavioural responses (see Ben Akiva and Lerman 1985). This restriction implies that the odds ratio of two alternatives j and k , does not depend on other alternatives (Haan 2006). Logit models that address preference heterogeneity by relaxing the IIA assumption and introducing correlation in the error terms, are the nested logit and mixed logit. Flannery and O’Donoghue (2013) use a mixed nested logit to account for individual heterogeneity in education participation decisions. Haan (2006) examines more general discrete choice models that relax the IID assumption and allow for heterogeneity, for example the random coefficient model (Revelt and Train 1996). Alternatively, latent class models allow for segregation into classes that share a similar structure in terms of preference and behaviour (Provencher et al. 2002; Morey et al. 2006). However, these less restrictive specifications have been shown to incur very high computational costs (Haan 2006) and in the case of using afforestation data, would have difficulty converging due to the limited number of observations of farms with forests, compared to those without forests.

³⁹³⁹ The Gumbel distribution is a particular case of the generalized extreme value distribution. The difference of two Gumbel-distributed random variables has a logistic distribution.

In the context of landowner participation in a US forest stewardship programme, Bell et al. (1994) successfully use a very similar approach to that adopted in this chapter. They estimate a random utility model to determine the probability that a landowner chooses to participate in the programme, using a measure of the landowners' income and the cost of participation as the attributes of the choice. A binary choice model is specified to represent the dichotomous decision and a logit is utilised to fit the model.

Many studies use stated preference methodologies which can be idealised, rather than actual (revealed) preferences. Stated preference studies use the choices made by individuals under experimental conditions to estimate these values, where individuals state their preferences via their choices. However, stated preferences may differ from choices made in reality. On the other hand, revealed preference studies utilise the choices already made by individuals to estimate the value they ascribe to items i.e. they reveal their preferences (and hence values or utilities), by their choices. McFadden (1974) successfully used revealed preferences (in previous transport studies) to predict the demand for the Bay Area Rapid Transit (BART) before it was built.

This chapter contributes to the literature by building a structural model based on revealed preferences, in relation to the actual choices made by a representative sample population of farmers, over a 30 year time period. To date, the theoretical parameters around the attributes of the afforestation choice, have not been presented in the framework of a structural model. The literature in other areas of public economics is drawn upon in order to understand the behavioural drivers surrounding farm afforestation. The inter-temporal nature of the conversion of land from agriculture to forestry requires that utility maximising decisions are examined within a life cycle theoretical framework. The preceding chapters in this thesis have been incrementally building the infrastructure which is necessary to incorporate the relevant methodologies to understand the complex factors determining the land use change decision in the Irish context. The next sections of this chapter investigate the utility maximisation literature to develop a theoretical framework. The generation of the variables and the estimation of the choice models, are then described and the model estimates are presented. The final component of the chapter includes discussion, model limitations and conclusions.

7.2 THEORETICAL FRAMEWORK

Random Utility Maximisation (RUM) and Discrete Choice theory

This section describes the development of a theoretical framework to fit the context of the farm afforestation choice Ben-Akiva and Lerman (1985) outline a framework whereby individuals facing a choice problem firstly determine the alternatives available to them. The individuals then evaluate the attributes of each alternative relevant to the choice under consideration and finally use a decision rule such as random utility maximisation (RUM) to select an alternative and make their choice. According to neo-classical economic theory, preferences or “utility” can be derived from one of two goods: income (and the resulting ability to consume) and leisure. Random utility theory, as it is understood today, was developed by McFadden (1973). The utility maximization rule states that an individual will select the alternative from his/her set of available alternatives that maximizes his/her utility. Thus individuals choose the alternative that gives them the highest level of utility, meaning farmer i chooses alternative j over k in repeated choices if and only if:

$$U_{ij} > U_{ik} \quad (7.1)$$

Further, the rule implies that there is a function containing attributes of alternatives and characteristics of individuals that describes an individual’s utility valuation for each alternative. The level of utility that individuals assign to each alternative j and k are not witnessed, but the discrete choice outcomes actually made by farmers are witnessed in the NFS survey data. A variant of RUM which applies specifically to the farm situation, assumes that farm household decisions are derived by maximising utility over consumption and leisure (Becker 1993). This economic approach assumes that farm households weigh up the advantages and disadvantages of different options and has been utilised to examine the impact of off-farm employment (El-Osta et al. 2004; Kimhi; 2004; Ahearn et al. 2006) and decoupled payments (Weber and Key 2012) on farmer utility. A random utility model is used by Bell et al. (1994) to determine the probability that a landowner will choose to participate in the Tennessee Forest Stewardship Programme. However, to date, farmers’ utility levels associated with the afforestation choice have not previously been estimated.

The farm household model (Becker 1993) assumes that as rational beings, farmers choose management options that provide them with the highest level of utility, subject to constraints.

Based on neo-classical economic theory, utility can be derived from one of two goods: income (and the resulting ability to consume) and leisure as in equation 7.2:

$$U_i = U(Y_i, T_i; Z_i) \quad (7.2)$$

where farmer i gains utility U_i from purchased goods (Y_i) and leisure time (T_i). The utility function U has the property that an alternative is chosen only if its utility is greater than the utility of all other alternatives in the individual's choice set. Thus farmers maximise their utility subject to constraints on time, income and farm production. The farm-specific characteristics in Z_i , indirectly provide farmers with utility through income or leisure time. For example, farmers with productive soil types are presumed to derive (*ceteris paribus*), a greater amount of utility from income (and therefore consumption) than those who do not have productive soil types. Similarly, individual-specific characteristics in Z_i are expected to influence farmers' utility levels indirectly through income or leisure. For example, younger farmers may associate an increase in on-farm income with higher utility levels than older farmers because they have a young family to provide for, whereas older farmers may place a higher value on utility from leisure. RUM provides a framework in which the decisions of individuals, over a finite set of alternatives, can be understood in a consistent and meaningful way and analysed probabilistically, to facilitate forecasting (Murphy et al. 2014).

Life cycle analysis

The theoretical framework for the choice model is developed around life cycle choice theory, based on the underlying assumption that people make rational, consistent, inter-temporal plans and that they act as if they are maximizing a utility function over the course of their life. Although the classic life cycle theoretical framework has been in existence for many years, it continues to provide a framework in which economists think about inter-temporal issues. According to Deaton (2005) the theory is still largely consistent with the theory of consumer choice and has "a generality that accounts for much of its durability."

The life cycle approach was first used to explain the decision to participate in higher education (Mincer 1958; Becker 1964; Ben Porath 1967). These studies identify the link between the life cycle of earnings and an individual's investment in human capital, so that the investment decision in human capital is based on expected returns and costs of that investment. Life cycle models have also been applied successfully to models of labour supply (Heckman and MaCurdy 1980). This chapter adapts a life cycle model which has previously

been utilised by Flannery and O'Donoghue (2013) who look at education participation and labour choices. The framework is modified to incorporate the variables used to explain the afforestation decision i.e. an individual (farmer) i chooses alternative j in choice setting t , if and only if:

$$U_{itj} > U_{itk} \text{ for all } k \neq j \quad (7.3)$$

assuming that farmers maximise lifetime utility derived from the consumption of goods and leisure, subject to constraints which vary with the choice to continue farming all the land, or afforest a portion of the land.

Factors that influence life cycle utility

In order to estimate the model, it is necessary to incorporate the following economic and non-economic factors, using a life cycle perspective:

- the relative productivity of the land for agriculture and forestry and consequent income;
- the long term nature of the land use change and the consequent reduction in land value due to reduced flexibility of use;
- inherent lifestyle preferences in relation to farming intensity and hours worked in agriculture or forestry.

The objective is to assess the relative income from both agricultural and forest enterprises on specific farms with specific environmental conditions over comparable periods. The responses from a Teagasc NFS Supplementary Survey in 2012 which contained questions in relation to farm afforestation, indicate that the source of the income (either agriculture or forestry) also affects utility as 84% of farmers will “never” plant, even if forest income is potentially higher than agricultural income. Thus it is expected that income from agriculture is more highly valued than income from forestry. This suggests that while farmers value income, they also value the utility they get from farming, possibly over and above the utility they get from income.

A measure of land value is included as a proxy for long term wealth in the models as this has not previously been investigated. The expectation is that this will provide some insight into the long term nature and reduced flexibility of land use as the decision to afforest is permanent and irreversible (except in particular circumstances at the discretion of the Minister) (Irish Statute Book 2014). Farmers see the permanence of the planting decision as a

barrier to afforestation (McDonagh et al. 2010) and expect farmers to place a high value on the land itself and flexibility in relation to use. The attachment to land in Ireland is evidenced by the fact that on average, less than 1% of total land area changes hands on an annual basis (Ganly 2009).

The reduction in working hours associated with the afforestation of farmland may result in farmers making a decision to trade-off between income and leisure. While much of the literature suggests that farmers should behave rationally to maximise profit, there is also a considerable literature suggesting that farmers like to farm and may choose to maximise their utility by remaining in farming even if they lose money (Key and Roberts 2009).

The idea that costs may be incurred by individuals making specific choices is common in public policy economics. For instance, the choice to work involves a fixed cost incurred in travelling to work (Cogan 1980). The literature reviewed and the analysis conducted so far in this thesis, suggest that the afforestation choice involves potentially overcoming attitudinal or mindset prejudices in deciding to plant any land at all. For example, it is likely that the decision to plant up to 5% of the land of the farm involves an initial hurdle that is not a factor in the decision to plant between 5% and 10%. This is accounted for by estimating an additional “fixed cost of planting” model, in which the explanatory variable accounts for the fixed cost associated with making the initial planting choice.

In relation to farm and farmer characteristics that may affect utility from an economic perspective, we utilise a range of farm characteristics from farm size, farm system, or share of a particular system, stocking density, whether the farm already has forestry, whether the farm is in REPS or has a Teagasc extension contract, as independent variables in the choice models. From the analysis in the previous chapters, we expect farm size to have a positive impact on both income and land value as larger farms tend to be located on better soils and are thus more intensive (except in the case of commonages). We have already seen in chapter 6 that farm system has a large impact on income and hypothesise that livestock density may also affect the income component of utility. Previous studies show that agri-environment scheme (REPS) participation can involve additional work to comply with scheme requirements (Murphy et al. 2014), whereas we expect farmers with extension contracts to be more efficient as a result of knowledge transfer programmes and thus have higher incomes.

Additionally, characteristics that relate specifically to the farmer such as age, and off-farm employment may impact directly on the leisure component of utility. We also hypothesise that farm size, farm system and stocking density may all have an effect on leisure as well as on income. Larger farms tend to be located on better soils and may thus be easier to work, however intensive dairy systems or high stocking densities may result in an increase in hours worked. We also hypothesise that land value may also impact on leisure as high value land tends to be associated with better quality land which may require fewer hours worked, whereas lower value land tends to be associated with smaller farms and may be more difficult to farm, requiring more hours worked on a per hectare basis.

In general, it is hypothesised here that the coefficients on income and wealth are likely to be positive, while the coefficient on hours worked is likely to be negative. However we expect to observe preference heterogeneity. Therefore taste shifters are included to estimate the effects of having children, good or poor soil and off-farm income. However, conditional logit models assume preference homogeneity, therefore it is necessary to test the robustness of the results by comparing two sample populations. This is achieved by comparing the coefficients of the cohorts of farms (in the 2012 NFS Supplementary Survey) that “might plant” against the cohort of farms that will “never plant.”

The population is also disaggregated on the basis of whether a farm is economically viable, in order to examine whether there are changes in the preferences for income. An economically viable farm is defined as having the capacity to remunerate family labour on the farm at the average agricultural wage and the capacity to provide an additional 5% return on non-land assets (Frawley et al. 2000). Using this definition, non-viable farmers could potentially earn more by working as agricultural contractors or investing the value of their assets. However a review of the literature suggests that it is often the case that farmers continue farming, even when they are losing money (Key and Roberts 2009).

7.3 METHODOLOGY

The literature to date on the afforestation decision has focused either on the attitudes of farmers or on empirical reduced form models which relate the decision to farm and farmer characteristics. In order to look at behaviour, there is a need to understand the attributes of the choices that farmers face in relation to planting a forest or continuing with their current farm system. This chapter develops a structural model of behaviour that examines the parameters

associated with the choice attributes, rather than the farmer attributes, while the next chapter (Chapter 8) examines the farm and farmer attributes.

Within the statistical model, the primary objective is to utilise explanatory variables that determine the choices that farmers make in relation to afforestation. These choices relate to how the income, land value and hours worked associated with different alternative land-uses, impact on farmer decision making. A conditional logit (CL) is utilised to fit the model, thus, in the context of a change in land use from agriculture to forestry, the conditional logit probability of being chosen from a set of i alternatives by an individual n is derived in equation 7.4

$$P_{ni} = \frac{\exp(\beta x_{ni})}{\sum_{j=1}^J \exp(\beta x_{nj})} \quad (7.4)$$

where x_n represents the choice attributes (income, land value and hours worked) associated with each of the alternative land use choices faced by individual n . Taking the inter-temporal and irreversible nature of the conversion to forestry into account, two distinct components of farm income are examined: the NPV of the agricultural or forest income streams and the farm wealth or asset value (as represented by the land value). In order to estimate the conditional logit model, it is necessary to generate actual and counterfactual data for each choice. The actual choices made are observed in the NFS dataset but counterfactuals must be simulated for the missing data i.e. the unobserved choices available to farmers. Similar difficulty arises in the field of labour supply economics in relation to unobserved wage rates for those who are not working.

In using the conditional logit in this analysis, the author is cognisant of the limitations and follows the recommendations of Train (2003), who points out that once the model is correctly specified,⁴⁰ the IIA property can be seen as an “ideal rather than a restriction,” to provide a “good representation of reality”.

Simulation of counterfactuals

Behavioural microsimulation methodologies are being used more and more to understand the impact of policy changes on behaviour by simulating counterfactual data (Aaberge and

⁴⁰ (the error terms are random)

Colombino 2014). The literature reviewed in this thesis shows that the afforestation decision is essentially behavioural, although the policy focus to date has been limited to incentivisation through financial drivers. The aim here is to (a) simulate unobserved forest income for farms without forests and (b) to simulate unobserved agricultural income for farms with forests. This provides choice specific life cycle income attributes.

A description of the methodology employed to simulate unobserved wage rates is detailed by Aaberge and Colombino (2014). A similar approach which is based also on analysis conducted by Van Soest in 1995, was recently used in a land-use context by Murphy et al. (2014) to generate both actual and counterfactual observations for participants and non-participants in an agri-environment scheme using farm-level data. This analysis adopts a similar approach to the aforementioned studies in that it allows for the comparison of individuals with counterfactual versions of themselves that differ only with regard to their afforestation participation. The approach is similar to the labour supply literature in that a linear land return price is employed. However as the model is estimating preferences for farm forestry, where the entire sample already has a price, the variant of the methodology adopted here is simplified by not having to incorporate the selection issues observed in labour supply issues, where counter-factual prices need to be simulated for non-participants.

The simulation of counterfactual observations for farm and forest income streams, also addresses the problem of selection bias which would arise if farms with forests are compared with farms without forests, due to the loop of causality between the choice to afforest and the individual and farm specific variables that describe the choice.

7.4 DATA AND STRUCTURE OF THE MODEL

In a conditional logit, there are n choices for i individuals, each with choice specific variables that are a function of the income, hours worked and land value associated with the choice. The actual choices made by farmers in relation to the decision to afforest or not, in a given year, are observed in the farm level micro-data in the Teagasc National Farm Survey (NFS) longitudinal database (1985 to 2013). In order to reduce model complexity and to facilitate per hectare relativities, it was decided to focus on the share of total land, expressed in 5% categories, which a farmer could assign to forestry. Thus, it is assumed that each farmer faces 11 alternatives each year, i.e. to plant 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, up to 50% of their

farm-land. The maximum afforestation area chosen is 50% as this reflects the largest area afforested by any farmer in the longitudinal dataset.

It is further assumed that farmers base this decision on the effect this change in land use would have on three attributes or factors, i.e. net income, the perceived value of the farm-land and the hours worked. In order to understand the effect of entering forestry on hours worked and land value, two fixed effects models of the observations in the NFS panel dataset are specified using Cobb Douglas functions. Hours worked is modelled against the farm (total land base) and farmer characteristics (including share of land in forestry). Land value is modelled against the characteristics of the farm as a whole. From these results, the influence of forestry share on hours worked and land values is derived, holding all other variables constant i.e. the only structural changes modelled are the increases in forestry share.

Thus five explanatory variables of interest are derived, namely forest subsidy income, forest market income, agricultural market gross margin, hours worked on-farm and self-reported land value. Each of these varies, depending on the proportion of land in forestry, thus the number of hectares in either agriculture or forestry is varied for each choice. The counterfactual income streams are then derived by simulating the “per hectare income” from agriculture or forestry and multiplying by the number of hectares associated with each of the 11 choices, for each farm in the dataset and for each year in the study period. Annual counterfactual agricultural incomes are simulated using the NFS panel dataset and annual counterfactual forest incomes are simulated using the ForSubs and ForBES models. Annual counterfactual values are also simulated for hours worked and land value using the panel data model estimates.

In addition, taste shifter values are generated by collating farm and farmer characteristics such as farm size, soil class, share of farm in different enterprises, age, presence of children and off-farm income, for each farm in the NFS dataset.

Simulation of forestry counterfactuals

Forest subsidies are generated using the Teagasc ForSubs (Forest Subsidies) model as described in Chapter 2, which simulates policy changes in afforestation grants and premiums since 1981, based on year of participation in a given afforestation scheme. Forest market income streams are generated using the Teagasc ForBES (Forest Bio-Economic System) model as described in Chapter 5. The ForBES model is essentially a simulation framework

which links static forest yield models and timber prices to the Teagasc National Farm Survey dataset. For the purpose of this study, ForBES utilises a cost benefit analysis (CBA) framework to generate the forest income stream that arises when changing land use from an agricultural enterprise to the most commonly planted conifer Sitka spruce for one rotation, up to the time of first clearfell (reforestation costs are not included). The model generates yield, cost and income streams across a range of species and soil types.

Simulation of agricultural counterfactuals

The agricultural market gross margin (MGM) which is defined as gross output minus direct costs (as described in detail in Chapter 6) is derived for each farm, using the NFS longitudinal dataset. The forest income streams also include an opportunity cost for agricultural income foregone. The assumption is that farmers entering forestry could accommodate forestry on the farm without having to increase their stocking rate, therefore they would have the opportunity to reduce average land use equally across all their enterprises, rather than selecting their lowest gross margin enterprise.

Discrete choice models

Discrete choice models are based on the random utility theory assumption that utility contains a deterministic element, V and a random element ε which are assumed to be additive. The information in the random (error) term is unobservable to the researcher but the random utility maximisation rule states that the probability of a farmer choosing his actual afforestation participation alternative is equal to the probability that the difference in the unobserved source of utility of the actual alternative, compared to the counterfactual alternative, is less than the difference in the observed sources of utility associated with both.

$$Pr(Y_{ij} = 1|C) = Pr(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}) \quad (7.5)$$

Estimates of the residual (unobserved) component (ε) of the conditional logit are generated by drawing random numbers such that the residuals ε_{ij} and ε_{ik} have a Gumbel distribution. Underpinning the estimation of the residual is the relationship:

$$x_i \beta + \varepsilon_i > x_j \beta + \varepsilon_j \quad (7.6)$$

for all $j \neq i$, where j is the original choice. This enables the random selection of the residual value which maximises the value of utility ($x_i\beta + \varepsilon$) for each choice in the dataset, thus satisfying the requirement in relation to the random nature of the error terms (Train 2003).

Although the different income sources are simulated separately (agricultural income, forest market income and forest subsidies), they are amalgamated into a single income variable. As afforestation entails an inter-temporal decision involving costs and benefits spread over a forest rotation (approx 40 years), the ForBES model is utilised to generate life cycle net revenue streams for each of the 11 planting choices, using the annual (actual and counterfactual) agricultural and forest incomes. The income streams are first projected forward for the rotation lengths appropriate for the species and yield class, using the relevant price indices for each year and then discounted to present day NPVs.⁴¹

As wealth over time is also a variable of interest, it is necessary to also examine a monetary total for the life cycle. These values represent (a) the life cycle income and leisure status of farms with forest(s) if they had not participated in afforestation and (b) the life cycle income and leisure status of non-participants if they had decided to participate in afforestation schemes, respectively. The discount rate employed is 5% which is the standard rate applied to forest investments in Ireland (Clinch 1999).

7.5 RESULTS

The model inputs for the simulation of counterfactual choice attributes and the parameter estimates of the CL discrete choice models are presented initially.

Panel Data Models: On Farm Hours and Land Value per Hectare

The NFS collects data on the number of hours worked (on and off farm) annually and on the annual perceived (self-assessed) value of the farm-land. In Table 7.1, the model coefficients for the random effects panel data models necessary to impute counterfactual choice attributes for hours worked and land value are reported (taking logs to remove the scale effects).

⁴¹ Chapters 5 and 6 of this thesis presented the annual equivalised NPV in order to enable a comparison across yield classes and with annual agricultural income streams. Here, it is more appropriate to present results in terms of NPV of income in examining discounted income streams over the forest life cycle.

Table 7.1 Model Estimates, On-Farm Hours and Land Value per hectare

Dependent Variable	Logged (On-Farm Hours Worked)		Logged (Land Value ha^{-1}) ⁴²	
	Coefficient	SE	Coefficient	SE
New forest planting			-0.0785**	0.030339
Land Value/ha ¹ (t-1)	-0.0348***	0.004763	0.0237***	0.000768
Farm Size	0.0006***	0.000194	-0.0076***	0.000306
Farm Size Squared	-0.000001***	3.79E-07	0.000008***	7.22E-07
Age	-0.0063***	0.000222		
Age Squared	-0.000003***	1.49E-07		
Has Off Farm Employment	-0.2557***	0.006749		
Spouse Has Off Farm Employment	0.0366***	0.006504		
Share of Tillage Area	-0.0913***	0.02453	-0.0057	0.034153
Share of Dairy Forage	0.3095***	0.0208	-0.2921***	0.029395
Share of Sheep Forage	0.0464**	0.019508	-0.0915***	0.027302
Sheep Number of Livestock Units	0.0003	0.000195	-0.0006**	0.000254
Cattle Number of Livestock Units	0.001***	0.000144	0.0002	0.000196
Dairy Number of Livestock Units	-0.0011***	0.000227	0.0049***	0.000309
Teagasc Client	-0.0048	0.004633		
Has REPS payment	0.0201***	0.005827		
Unpaid labour	0.4311***	0.006392		
Forestry Share	-0.2406*	0.130063	-0.0022	0.080673
Forestry Share Squared	0.3546	0.318835		
Constant	7.202518	0.023046	-0.81892	0.020557
Share of Variance due to Fixed Effect	0.70104273		0.607808	
R ²	0.3284		0.5214	
N	35333		27219	

*** significant at 1% level; * significant at 10% level

As expected, on-farm hours worked increases with farm size and is higher for dairy enterprises and higher stocked farms. On-farm hours decreases as land value increases; as hypothesised, land with a high value requires less work to farm. As might be expected, hours worked is also lower for older farmers and those with off-farm employment. Participation in the REPS results in increased hours of work, a factor which was noted in a study of agri-environment scheme participation (Murphy et al. 2014). The coefficient on the share of land under forestry is negative and positive in the square (albeit the square is not significant), indicating a small reduction in labour hours as a result of planting forestry. The coefficients on farm size (positive) and farm size squared (negative) show that hours worked increases with increasing farm size but at a reducing rate. The age and age squared coefficients (both negative) show that the reduction in hours worked accelerates as farmers get older as they are less likely to realise the gains.

In the land value model, only those factors that affect land value are included. There is evidence of multicollinearity in the model as there are high correlations among predictor values such as livestock, causing the signs to change. However, the R² value can be deemed

⁴² In the Land Value Model, the land value per hectare explanatory variable is logged and lagged, reflecting the logged dependent variable.

to be reasonable as multicollinearity doesn't affect the overall fit of the model. In addition, a high degree of correlation between certain independent variables can be irrelevant in relation to how well the model estimates other parameters (Wooldridge 2009). In this case, the most important information here is that (conditional on the lagged value of land), the coefficient on new forest planting is significant and negative, indicating that afforestation reduces farmers' (self-reported) perceptions of the value of the planted land.

This is consistent with *a priori* expectations based on the loss of flexibility of land use imposed by the legal requirement to replant forests once the timber is harvested. Although the land value is self-assessed, it is nevertheless, a reliable indication of land value. In a comparison of the annual NFS land values with annual agricultural land sales official statistics, a recent Irish study found that while the NFS values are below the official sales figures, the trend over time is almost exactly the same (O'Donoghue et al. 2015).

The on-farm hours and land value information detailed in Table 7.1 facilitates the estimation of the hours worked and reported land value associated with each of the 11 alternative forest share choices.

Choice Models

In each of the models presented, there are 11 potential choices derived by varying the share of forestry for each farm from 0 to 50% of total farm size. Therefore for each farm in the model, there are 11 rows representing each of the forestry (share) choices. This generates a dataset of over 30,000 observations per choice. Initially the results of two restricted discrete choice models are presented. The first is a basic model incorporating the three economically relevant choice attributes, income, wealth (land value) and labour and a second model which includes the fixed cost of planting. Model parameters from two restricted CL models are reported in Table 7.2.

A basic model of the attributes of the afforestation choice is presented, along with a variant of this model which incorporates the fixed or opportunity cost of afforestation. These coefficients reflect the marginal utility with respect to the attributes. The choice attributes are initially examined, with and without the fixed cost of planting, before further investigating preference heterogeneity. In both restricted models, the coefficients are significant and reflect what one would expect, namely that the first derivative of utility increases in income and wealth

Table 7.2 Restricted Models

Basic Model			
Choice	Coefficient	Std. Err.	P>z
NPV Ag Income	5.61E-06	4.14E-07	0
NPV Forest Income	1.73E-06	1.31E-07	0
Hours Worked On Farm	0.043815	0.000876	0
NPV Ag Income x Hours Worked On Farm	-2.3E-09	1.3E-10	0
Land Value per Hectare	0.004031	0.000074	0
Pseudo R ²	0.7504		
Fixed Cost of Planting Model			
NPV Ag Income	4.83E-06	3.78E-07	0
NPV Forest Income	1.4E-06	1.23E-07	0
Hours Worked On Farm	0.031672	0.000891	0
NPV Ag Income x Hours Worked On Farm	-1.8E-09	1.18E-10	0
Land Value per Hectare	0.002972	7.45E-05	0
Fixed Cost of Planting a Forest	-0.93339	0.034254	0
Pseudo R ²	0.7564		

It is clear that across the 11 forestry share choices, if income increases for any alternative, there is a higher probability of that alternative being chosen. Similarly for land value, if any of the 11 alternatives shows an increase in land value, there is a higher probability of that alternative being chosen. In the case of hours worked, the effect is positive, reflecting the increase in farm income, consequent on an increase in farming intensity and the utility that farmers get from farming. However when hours worked is interacted with agricultural income, the effect is opposite, indicating that while farmers prefer higher incomes, they also value their leisure time and utility decreases as hours worked on-farm increases. In other words, farmers prefer to generate the same agricultural income with less hours worked.

The value of the coefficient for agricultural income is greater than the coefficient for forest income by a factor of three, indicating that the utility derived from agricultural income is three times higher than the utility derived from forestry. Thus in relation to income, while farmers have a preference for more income, they derive a higher utility from agricultural income. This is consistent with estimates for the utility of income and hours worked in relation to farmer participation in agri-environment schemes (REPS) in Ireland. Murphy et al. (2014) find that farmers associate additional agricultural income and REPS subsidies with utility, and associate additional on-farm work hours with disutility, indicating that they would participate in REPS if their income increased but their hours worked didn't increase.

In relation to land value, higher utility is derived from greater land wealth as this generally reflects more productive and profitable farming. If afforestation results in a decrease in land value or hours worked, this leads to a decrease in utility. In relation to the magnitude of the coefficients, it is not possible to compare them directly as the different variables have different scales. However, the coefficients on both land value and hours worked are strongly positive.

In relation to the afforestation choice, farmers associate afforestation with lack of flexibility and consequent loss in value due to the permanent nature of the conversion of land to forestry. There is also strong evidence that quite simply, farmers prefer to farm. Farmers derive a large proportion of utility from farming activity. Factors that diminish agricultural activity result in dis-utility. This is particularly evident in a year when very few farmers in the dataset afforest land, as the model is picking up the strong dis-utility that non-planters associate with afforestation. In summary, the preferences for land value and hours worked dominate the other variables, reflecting conclusions in the literature in relation to non-pecuniary benefits of farming (Howley et al. 2015; Key and Roberts 2009) and preferences for more flexible uses of land (Duesberg 2013), resulting in low preferences for forestry.

The basic model does not account for the fixed cost of planting and is thus estimated on the basis that there is no change in utility between the decision to plant any land and the decision in relation to the amount to plant. The inclusion of the fixed cost of planting in the second model does not give rise to a qualitative difference in the conclusions as there is no change in sign and all the parameters fall within the confidence limits (except for land value which falls slightly outside). The inclusion of the fixed cost of planting does however, result in a decrease in each of the parameters of the utility function with a negative coefficient on the fixed cost itself. This indicates that there is indeed a hurdle to be overcome in the initial planting decision.

Both restricted model results are consistent with economic theory and uphold the hypotheses with regards to average preferences for income, wealth and leisure. It would appear that this is the first time that the parameters of the utility function for the afforestation decision have been estimated. The inclusion of the fixed cost of planting also confirms the results of a previous qualitative study which examined the barriers to afforestation in Ireland (McDonagh et al. 2010). The largest barriers to afforestation in this study are the desire to keep land for

agriculture and the irreversibility of afforestation. These “hurdles” have not been confirmed in a quantitative study until now.

The restricted models are relatively simple and imply that the average participation decision of a farmer in forestry is determined by a limited number of factors. However, the literature suggests that the participation decision is more complex and heterogeneous and may be influenced by a range of factors. Two different methods of uncovering this heterogeneity are explored i.e. the incorporation of taste shifters and the comparison of different cohorts.

Taste shifter model

The “taste shifters” or farm specific characteristics are first interacted with choice specific variables to account for differential preferences for different farm types. In the conditional logit, the attributes (x) must vary across the choices as they fall out of the model by themselves, so they are interacted with taste shifters to gain additional information. For example, interacting farmer age with income and leisure variables could provide additional information on whether older farmers have a higher preference for income or leisure. These taste shifters such as farm system, farm size, age and children are incorporated into a second choice model (Table 7.3) and interacted with the “NPV income” variable.

Despite the increase in complexity in this model, the high pseudo R^2 value reflects the high proportion of the total variability of the outcome accounted for in the model. It would appear that the preference not to plant is so strong that the inclusion of the taste shifters in the unrestricted model, results in only marginal changes in relation to the explanatory variable estimates in the restricted fixed cost of planting model. Again this is consistent with the qualitative literature.

The coefficients (except for share of dairy and age squared) are significant and most are positive, indicating a preference for greater income. Again, the most consistently positive explanatory variable in all the analyses conducted in this thesis is farm size. This is also the experience of other studies in the literature that have included farm size as a variable (Duesberg 2013; Howley 2015). For farms with children⁴³, the negative coefficient indicates that these farmers may place a higher weight on other factors such as leisure.

⁴³ These data refer to farms with children of school-going age

Table 7.3 Taste Shifter Model

	Coefficient	Std. Err.	z	P>z
NPV Ag Income x Has Children	-0.000000604	0.000000292	-2.07	0.04
NPV Ag Income x Best Soil	-0.000000842	0.000000348	-2.42	0.02
NPV Ag Income x Worst Soil	0.000003630	0.000001270	2.85	0.00
NPV Ag Income x Share of Dairy Forage	0.000000257	0.000001030	0.25	0.80
NPV Ag Income x Share of Cattle Forage	0.000008530	0.000001040	8.16	0.00
NPV Ag Income x Share of Sheep Forage	0.000001890	0.000001050	1.81	0.07
NPV Ag Income x Share of Tillage Area	0.000003820	0.000001150	3.32	0.00
NPV Ag Income x UAA	0.000000017	0.000000003	5.14	0.00
NPV Ag Income x Age of Farmer	-0.000000114	0.000000045	-2.53	0.01
NPV Ag Income x Age of Farmer Squared	0.000000001	0.000000000	1.45	0.15
NPV Ag Income x Off Farm Employment	0.000001050	0.000000641	1.64	0.10
NPV Ag Income	0.000006340	0.000001730	3.67	0.00
NPV Forest Income	0.000001850	0.000000133	13.93	0.00
Hours Worked On Farm	0.031393700	0.000978300	32.09	0.00
NPV Ag Income x Hours Worked On Farm	-0.000000002	0.000000000	-10.67	0.00
Land Value per hectare	0.003038300	0.000077400	39.24	0.00
Fixed Effect of Planting	-0.884388900	0.034539700	-25.60	0.00
Pseudo R^2	0.7593			

It appears that for farms with poor soils, the choice to increase income is stronger than for farms on good soils, possibly indicating a greater need for income on these farms. Thus it would appear that farmers with higher incomes may be less motivated to increase income than those with lower incomes. This finding is further investigated in Chapter 8. The interaction of income and age is negative in this model, indicating that as farmers get older, they may not place as high a value on income and are likely to place a higher value on working fewer hours. Farmers with off-farm employment place a higher value on income as they may not be economically viable on the basis of agricultural income alone.

Overall, only minor changes arise when choice attributes are inter-acted with the taste shifters and there is little difference in the pseudo R^2 between the models. Thus it would appear that the inclusion of the taste shifters in the model gives little additional information on preferences for income. The inference here is that farmers follow rational choices, as the patterns are similar to those reported by Becker (1993), but only at the margins. It is also

likely that socio-economic and cultural factors have a strong role to play in the choices made by farmers.

Cohort comparisons

The second method of uncovering heterogeneous preferences is to examine if there are underlying differences in preferences between different cohorts of farmers. The population is initially disaggregated to see if there is a difference in preferences for income between those farmers who “might” plant and those who will “never” plant. In addition, the population is also disaggregated on the basis of economically viable and non-viable farms. Two regressions are estimated with confidence intervals around the β parameters. The results are presented in Table 7.4.

Table 7.4 Cohort Comparison Models

	Might Plant				Never Plant			
	Coefficient	Std. Err.	z	P>z	Coefficient	Std. Err.	z	P>z
NPV Ag Income	0.000030600	0.0000120	2.54	0.01	0.000030100	0.0000076	3.93	0.00
NPV Forest Income	0.000005860	0.0000027	2.16	0.03	0.000000951	0.0000009	1.09	0.28
Hours Worked On Farm	0.009100800	0.0123143	0.74	0.46	0.020240000	0.0074483	2.72	0.01
NPV Ag Income x Hours Worked	-0.000000009	0.0000000	-2.70	0.01	-0.000000009	0.0000000	-4.05	0.00
Land Value per hectare	0.008749600	0.0017900	4.89	0.00	0.007661200	0.0008903	8.61	0.00
Pseudo R ²	0.6778				0.7753			
	Viable				Non-Viable			
	Coefficient	Std. Err.	z	P>z	Coefficient	Std. Err.	z	P>z
NPV Ag Income	0.000005190	0.0000004	12.78	0.00	0.000023500	0.0000016	14.97	0.00
NPV Forest Income	0.000001770	0.0000002	11.49	0.00	0.000001660	0.0000002	6.93	0.00
Hours Worked On Farm	0.048895400	0.0011066	44.18	0.00	0.036917900	0.0014678	25.15	0.00
NPV Ag Income x Hours Worked	-0.000000002	0.0000000	-17.41	0.00	-0.000000008	0.0000000	-15.11	0.00
Land Value per hectare	0.003466000	0.0000974	35.59	0.00	0.004585800	0.0001151	39.85	0.00
Pseudo R ²	0.742				0.7652			

Overall, the results of these models are very similar to the earlier restricted models with consistently high pseudo R² values, explaining a high proportion of the variability of the outcome. Firstly, comparing the might plant cohort with the never plant cohort, there is no qualitative difference between the parameter estimates. The estimates are all similar in sign and magnitude i.e. they are positive in income, wealth and hours worked and negative in hours worked interacted with NPV of agricultural income. As there is no statistical difference

in the preferences for income between the might and never plant cohorts, it is likely that the difference between these cohorts is attitudinal. In addition, there is no significant difference in the preference for income between any of the might plant and the never plant parameters (as they all fall within the confidence intervals).

Comparing the viability cohorts shows similar results in that the signs and magnitudes of the coefficients are not dissimilar between the viable and non-viable cohorts. However, the parameter estimates (except for forest income) are statistically different, albeit still being consistent with economic theory. Otherwise there is little difference between the viability cohorts other than the change in the preference for income between viable and non-viable and this is already captured by disaggregating the population on the basis of income. It is not surprising that the viability cohorts are statistically different, as they are essentially two different economic populations.

Previous chapters examined forest and agricultural income streams over time. The focus here is on life cycle utility i.e. how the weights that farmers place on different components of income influence their choice to convert land to forestry, or to maintain it in its current agricultural enterprise, in a given year. Utility is about human behaviour and not just income. The analysis in this chapter shows that farmers place a high weight on income and land value (wealth) and agricultural activity (hours worked). It is also evident that farmers place a higher weight on income derived from agriculture, than income derived from forestry.

The issue that this chapter set out to illuminate relates to the apparent conundrum in Irish forest policy whereby, despite generous afforestation incentives (which in many cases appear higher than agricultural incomes), the afforestation rate has dropped back to less than a third of the area planted in the 1990s. An examination of the underlying trends in the forest and agricultural income streams generated shows that in real terms, forest subsidies increased strongly over the period and timber prices reflected the economic situation as prices rose dramatically at the height of the construction boom and dropped back equally dramatically once Ireland went into recession (Upton et al. 2013). In real terms there is a strong downward trend in agricultural incomes as input prices rose and output prices remained relatively stable (Hynes and Hennessy 2012). However, in recent years, trends in agricultural incomes have been strongly positive on average (Hennessy et al. 2015). Perhaps one of the most significant factors over the period examined, is the upward trend in land value as there was a dramatic increase in land prices, particularly over the period 1992 to 2007 (Breen et al. 2010). These

trends in aggregate may influence farmers to choose to maintain the flexibility of their land over time, rather than make a long-term (permanent) afforestation decision.

Another interesting feature of trends in farmer planting over the period examined is the high proportion of dairy farmers observed in the NFS dataset who planted land in the 1980s. At this time, farmers who wanted to increase dairy quota had to acquire additional land. Many dairy farmers harvested the quota and then planted the attached land. However, in recent years, it is livestock farmers (particularly cattle farmers) who plan to plant in future (Ryan and Kinsella 2008).

7.6 DISCUSSION

The objective of this chapter was to develop a greater understanding of the behavioural factors that influence that choice. A choice model was estimated to measure preferences based on the theory of utility maximisation, where farmers make a trade-off between income, leisure and wealth. In estimating the model, data were collected on actual choices and choice specific attributes in order to simulate counter-factual attributes.

The results show that the coefficients of the choice models developed in this analysis are robust and are consistent with economic theory. Utility increases with the NPV of agricultural income, wealth (land value) and hours worked on the farm. When hours worked is interacted with agricultural income however, utility decreases. What these preferences illustrate is that farmers prefer choices that give them more income and/or wealth and have a negative preference for non-agricultural activities in relation to hours worked. The average preferences are statistically significant and consistent with economic theory, reflecting the underlying preference for farming. Although in cases where the NPV of forest income is higher than the NPV of agricultural income and requires less labour per hectare on average, the preference for forestry is at the expense of a fall in wealth due to the decline in land value and hours worked. The inference here is that this is due to the inflexibility of forestry as a land use. Thus, on balance, many farmers prefer to farm than to afforest land, even if the income from forestry is higher. There is solid evidence that the gain in (forest) income is not sufficient to off-set the decrease in agricultural income, perceived decline in wealth and loss of utility derived from farming.

Limitations of the model

This analysis has focused on average preferences in the population as generated using the conditional logit. While some preference heterogeneity is accounted for by the inclusion of taste shifters in the analysis, it is possible that additional underlying preference groups exist in the population. However, the consideration of more complex models is not appropriate as the low probability of planting poses difficulties for more computationally complex models. The mixed logit in particular, is very sensitive to missing data or to small sample size (due to the low probability of uptake of afforestation). Other methods such as the use of latent classes are unlikely to add additional information, as the explanatory power of the models is already very high and the results are consistent for all specifications run on the dataset. There is no evidence that the might/never plant or the viable/non-viable cohorts have different utility functions as the coefficients on the models have the same sign and are similar in magnitude, thus any minor differences are not likely to be qualitative.

While the Hausman and MacFadden test for the validity of the IIA assumption (Greene 2003) was rejected, Train (2003) points out that once the unobserved portion of utility is random, the IIA property can be seen as “an ideal rather than a restriction” to provide a “good representation of reality.”

The minor changes in utility observed as a result of the interaction of the choice attributes with taste shifters are likely to reflect the small cohort of farmers (around one per cent) who plant in any given year (whereas 17% of farms have forests). The magnitude of the coefficients on land value and hours worked, also create difficulties for extending the model.

The model could be criticised on the basis that the estimates could be biased as they are not based on a randomised control trial (RCT) (Rubin 1974), which affects the relative value of the parameters which in turn is important for simulations. The use of farm characteristics in developing the choice attributes could give rise to endogeneity due to the possible impact on the β s of the effect of soil class on both agricultural income and the actual choice made. However, while soil class affects all the explanatory variables to some degree, it is not soil class but income that drives the decision.

In many models, the main source of endogeneity is ability bias. It is not unusual for estimates to be biased in the socio-economic literature – what is more important is the level of bias. It is felt that if the estimates generated in this study are biased, the level of bias is limited by (a) a

stochastic element to the level of farm gross margin (in relation to management ability and capacity for hard work) and (b) as most farmers employ forestry contractors to undertake forest establishment and management, farmers are largely exogenous to the afforestation process. However the overall qualitative conclusions are so robust that they are unlikely to change, even if the estimates are biased.

In this study only the afforestation choices that farmers make in any given year is examined. An examination of the likelihood of planting at some point in the future (might ever plant), could provide a broader population and consequent valuable additional information, but changes in policy environments over time pose modelling difficulties for this approach. The level of utility that individuals assign to each alternative j and k , is not witnessed, but the discrete choice outcomes actually made by farmers are. Despite the limitations, the model coefficients are significant, the level of the elasticities is strong and the findings are consistent with economic theory as well as with the qualitative literature.

7.7 CONCLUSIONS

In explaining the importance of positive non-pecuniary benefits of farming to farmers, Key and Roberts (2009) give the example of farmers who continue to farm despite the fact that they appear to earn less on-farm than they could earn in an alternative off-farm occupation. It would appear from the results of this thesis that these cultural or attitudinal values are deeply held and can outweigh the greater pecuniary benefits sometimes offered by afforestation. Howley et al. (2012) refer to these “apparently irrational” decisions but find that Irish farmers derive utility from a range of non-pecuniary life style benefits associated with farming.

This chapter shows that in fact farmers act rationally in maximising their utility from farming in a manner that is consistent with theory, however they are not necessarily profit maximising. This analysis is a novel contribution to the literature which progresses the field of study by estimating the parameters of a utility function for farm afforestation for the first time. There are limitations to the methodology and it could be improved in the future by extracting more information on the levels of utility, but the qualitative conclusions are unambiguous: farmers derive utility from agricultural income, land value and time spent farming – they like to farm.

In the US, a stated preference analysis (using discrete choice (CL) methodology), in which forest landowners were asked to participate in a Forest Stewardship Programme in Tennessee,

found that a negative attitude regarding the goals of the programme can outweigh the benefits (including financial gains), such that the individual will not participate, regardless of the cost-share offered in the survey (Bell et al. 1994). Personal characteristics analysed include occupation and education and the results showed that farmers and more educated individuals are expected to be more likely to participate in the programme. A more extreme view was taken by Scottish farmers. The Mindspace (2010) survey reported that for one third of farmers who hadn't planted, there was "nothing that would persuade them to plant.

There is a common thread which runs through the literature on the Irish afforestation decision (Frawley and Leavy 2001; O'Leary et al. 2000; McDonagh et al. 2010; Ní Dhubháin and Gardiner 1994; Duesberg et al. 2013; Upton et al. 2013) Howley et al. 2012) – and that is that farmers want to farm and are reluctant to plant land that they can use for food production.. This is consistent with recent qualitative literature. In particular, Duesberg et al. (2014) found that only a quarter of farmers want to 'maximise' profit, half want a 'satisfying' rather than maximum profit and the remainder are 'hobby' farmers.

In aggregating the findings from this analysis with other quantitative studies and with the qualitative literature, it would appear that the permanent nature of the conversion from agriculture to forestry and the desire to maintain the farming life and lifestyle, are both strong barriers to afforestation. The permanence of the farm afforestation decision (in the Irish case) is a matter for the legislature and is unlikely to change in the short term. This chapter provides additional information about farmers' average utility preferences. However, a further investigation of the characteristics of farmers at the individual farm level is warranted. Are there differences between farmers who have and those who haven't planted? Are there obvious income or lifestyle objectives or patterns within the cohort of farmers who overcame the initial hurdle? Achieving a greater insight into the characteristics of those individual farmers who have and those who haven't planted, should provide a better understanding of the drivers of afforestation and how these might be used to incentivise further planting.

In the context of trying to understand how to achieve an increase in afforestation rates, this analysis provides an appreciation of the challenges involved in increasing the uptake of afforestation incentive schemes. The concept of a "compensating differential" in labour economics literature, recognises the additional income that a worker must be offered as compensation to accept a less pleasant job. This analysis clearly shows that financial incentives will influence some farmers but for the majority of farmers, financial incentives

alone are not sufficient to overcome the attitudinal “hurdle” or barrier that many farmers associate with undertaking afforestation. For many years, forest and agricultural incentives were mutually exclusive. In recent years, changes to agri-environment schemes and SFP have been more favourable towards farm afforestation. However, incentives to date have been independent of other decision making at farm level. In the past, many dairy farmers overcame this hurdle and planted land in order to increase dairy quotas. On the basis that the primary motivation of farmers is to farm, the integration of afforestation incentives with farm management decisions could generate more success.

Chapter 8. HETEROGENEOUS ECONOMIC AND BEHAVIOURAL DRIVERS OF THE FARM AFFORESTATION DECISION

8.1 INTRODUCTION

The conversion of land from agriculture to forest is an important policy objective across many EU countries as it assists in fulfilling EU objectives such as greenhouse gas mitigation, biodiversity enhancement and ecosystem service provision (EU Commission 2013). However, the analysis in earlier chapters shows that the conversion involves a complex decision-making process and the influencing factors can be difficult to isolate. So far, this thesis has examined average values for the farm population. It is clear that farmers act rationally to maximise utility in relation to income, wealth and hours spent farming. However, it is likely that underlying heterogeneity exists in relation to farm and farmer characteristics that colour farmers' attitudes towards afforestation.

Much has been written about the diversity of landowners attitudes towards forestry. Beach et al. (2005) identify four factors driving decision-making among forest owners: owner characteristics and preferences; soil type and plot size; policy variables that affect the forest investment decision; and costs and returns from forestry and alternative enterprises. Their analysis refers to both afforestation and forest management but shows that while country specific studies differ in the relative importance of these factors, there is strong commonality around the drivers of the afforestation decision.

This thesis has already addressed many of these drivers. In Chapter 2, Irish forest policy is assessed before taking an overview of the effect of soil class and other environmental factors on the spatial distribution of afforestation on private land in Chapter 3. Chapter 4 addresses the relativity of agricultural and forest policies (subsidies) in relation to forest investment decision on farms, while Chapter 5 generates forest income streams for a range of productivity classes. Chapter 6 calculates the average agricultural opportunity cost by farm system and productivity and goes beyond farm and farmer characteristics to examine farmer behaviour by estimating average farmer preferences for alternative planting options. However, the results so far are limited by the focus on average values.

In reality, 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.” The farming population is notoriously heterogeneous and approaches which utilise averages do not take account of both farm and farmer efficiencies at the individual farm level (Hennessy and Thorne 2005). In order to understand economic motivations fully, further investigation at farm level is required to analyse the environmental and economic characteristics across the distribution of farms. In doing so, it is necessary to expand the analysis to look at forest returns and agricultural opportunity costs for individual farms with individual environmental characteristics such as soil class, farm system, farm size and livestock density.

Moreover, 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) further highlights the importance of the socio-cultural nature of farming as the primary motivating factor for farmers ...”farming becomes a way of life”. These characterisations of farmers highlight the range of motivations and the heterogeneity of farm and farmer characteristics that could influence the afforestation decision. In this context, an examination of the characteristics of individual farmers who plant and those who don’t plant, will allow for to the observation of differences between these cohorts, ultimately providing additional information about the heterogeneous farm and farmer characteristics that influence land conversion.

This chapter examines the farm level and behavioural characteristics that influence this inter-temporal land use change by examining the farm afforestation decision on individual farms, across the distribution of farms within the Teagasc National Farm Survey (NFS) database which is representative of farms nationally, by farm system. The NFS is not representative of small farms but represents 95% of the Standard Output from agriculture and also represents 3.714 million hectares or 81.3% of total Utilisable Agricultural Area (UAA)⁴⁴ (Hennessy and Moran 2015). The analysis focuses primarily on the complexity of the afforestation decision

⁴⁴ Of the total land area of 6.98 million ha, 1.5 million is classified as non-agricultural/forest land; 1.15 million ha is composed of rock, peat, bog and other unclassified land; and the remaining 4.34 million ha is classified as grassland (Farrelly and Gallagher 2015b).

at individual farm level and the relative importance of financial drivers and socio-cultural barriers. Specifically, the analysis explores (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.

A theoretical framework to suit the context of the afforestation decision based on international literature is initially defined and existing frameworks are adapted to suit the temporal factors involved in the decision making process around land conversion. Next, a pooled dataset of farm level micro data is utilised to generate agricultural life-cycle income streams for each farm in the NFS distribution. Information from the ForBES and ForSubs models is used to generate average forest life-cycle income streams for the farms that planted, based on the farm soil classification. These income streams are then used to simulate counterfactual income streams for each farm i.e. agricultural income streams are simulated for farms with forests and forest income streams for simulated for farms without forests. This allows for the assessment of the relativity of forest and agricultural income streams in relation to specific farm characteristics such as soil class, farm system and size as well as farmer characteristics such as age, hours worked on the farm and off-farm income.

Summary statistics are generated to analyse the characteristics of farms and farmers whose forest income (on a per hectare annual basis) is greater than their agricultural income. Regression models are estimated using net present value (NPV) to incorporate the life-cycle financial attributes in terms of relative income streams of planting/not planting. Farmers who have planted are characterised according to the level of farming intensity after planting. The characteristics of those who might plant in future are analysed and these variables are used to estimate binary logit models. These models examine the characteristics of those farms that have higher forest income streams. Ultimately, conclusions are drawn in relation to the range of motivations of different types of farms and farmers around the afforestation decision.

8.2 THEORETICAL FRAMEWORK

From Chapter 3, it is evident that the physical and environmental characteristics of a farm have a large influence on the planting decision. Land quality is also a factor, in that farmers are more likely to plant land that is unproductive or difficult for agriculture but may be more

productive under forest (Ni Dhubhain and Gardiner 1994; Duesberg et al. 2012 and 2013). Previous studies have also highlighted the overall size of the farm as a determinant of the likelihood of planting (Beach et al. 2005; Ryan and Kinsella 2008; Howley 2012; Upton 2013) as farms with spare capacity are more likely to afforest land. These studies also indicate that most farmers plant only a relatively small portion of their farms (DAFM (2013a) report that the average area planted is 9 ha). The literature also shows that many farmers simply wish to continue farming and display a negative cultural bias towards planting land (Watkins et al. 1996; Beach 2005; Howley 2012; Duesberg et al. 2013; Lawrence and Dandy 2014).

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) and efficiency of management and on the agricultural subsidies available (e.g. Less Favoured Area payments, Single Farm Payment, agri-environment (AE) scheme payments). On the forest side, the availability of afforestation subsidies (grants and annual premium payments) makes forestry a financially attractive enterprise for many farmers but particularly those engaged in extensive livestock rearing (Breen et al. 2010; Upton et al. 2013). For this reason, this chapter will focus on livestock enterprises.

It is evident in the previous chapter, that while financial gain is important, it may not be the core motivation for farming. There is a growing literature on the psychology of farmers' decision-making (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.

Post afforestation stocking density changes on livestock farms

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.

It is hypothesised here 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 (hectare for hectare), thus reducing livestock density or livestock units per hectare (LU/ha). These farms essentially use the afforestation income to subsidise the loss of agricultural income. They may not gain or lose much in terms of income, but their farm working hours are reduced as a consequence of afforestation. On intensive farms, farmers may increase stock numbers on the reduced grazing area, resulting in an increase in costs and hours worked but 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. Specifically, three distinct hypotheses are explored:

- The conversion of agricultural land to forestry is a straight-forward land use substitution decision
- There is a relationship between the relative incomes from agriculture and forestry and the likelihood of planting
- The cultural beliefs associated with the decision are not affected by financial factors.

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 decision. 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) and is similar to the life-cycle methodology employed in Chapter 7, although this chapter differs from the previous chapter in that it focuses initially on the financial drivers of the farm afforestation, rather than the behavioural decision. 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 (FFI ha⁻¹), intensity of farming measured as livestock units (LU ha⁻¹), farm size and farmer age to be significant in relation to afforestation. In chapter 7, we say that these variables are all significant in relation to the utility derived from farming and forestry. These variables allow for the exploration of how the productivity of farms dictates the financial potential for either agriculture or forestry and also allows for the characterisation of farms with forests on the basis of subsequent livestock density change.

In the context of examining the characteristics of farms with forests and those who might plant in future, additional independent values are added to the models in this chapter. Specifically, these relate to region or location of the farm and the dominant soil type of the farm. The analysis in Chapter 3 shows that both of these factors are likely to have a large influence on the probability of planting. With this information, conclusions are drawn as to the drivers of afforestation for farmers who “might plant” in future.

8.3 METHODOLOGY

In planting land, farmers forego the agricultural market income and farm subsidies relating to that area of land and are incentivised to do this by the forest market income and forest subsidies available for that soil type. For the purpose of this analysis, it is assumed that a farmer who afforests land would reduce average land use equally across all their enterprises, rather than selecting their lowest gross margin enterprise. In reality, farmers often plant areas of land that are marginal for agricultural production, that are outlying or fragmented parcels and areas that are steep or difficult to manage. 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 (see Chapter 6 for further discussion).

The purpose of this chapter is therefore to relate the forest planting decision and other contemporaneous farm decisions to the heterogeneous characteristics of farms. In summary, a number of drivers are identified in the literature, that are relevant to the forest planting decision:

- Change in farming intensity after planting
- Financial incentives

- Quality of land
- Opportunity cost of planting
- Irreversibility of afforestation decision
- Socio-cultural attitudes towards afforestation.
- Net Impact of Afforestation Decision

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 chapter 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 chapter 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 will ultimately allow for the generation of a binary variable for farms that would have a higher income stream from forestry than from agriculture, namely $For > Ag$ (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 ($Ag > For$). Forest income is comprised of market and subsidy income. From the examination of forest subsidies in Chapter 4 and the examination of the relativity of forest market and subsidy income in Chapter 6, it is evident that the subsidies are the most variable component of forest income, whereas forest market income is dictated largely by soil class.

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.

Chapter 6 focused on the agricultural opportunity cost in order to assess the magnitude of the opportunity cost for different systems and soil types. Values for net farm afforestation income (NFAI) were generated by deducting the annual opportunity cost from the forest income stream and the opportunity cost was generated using two different income measures. The level of the agricultural income stream/opportunity cost was found to be very sensitive to the measure used, particularly in relation to the treatment of overhead costs and to variations in subsidies in different policy periods. The analysis in this chapter builds on previous chapters, to test the significance of the different measures used in generating the relative agricultural and forest income streams.

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 ($NPV_0 \text{ ha}_j^{-1}$ (equation 8.1)). All amounts are expressed on a per hectare basis and discounted at a discount rate (r).

$$\begin{aligned}
 NPV_0 \text{ ha}_j^{-1} &= \left(\left(\sum_{t=0}^{n_j} \frac{\text{ForestNM} \text{ ha}_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{\text{FarmOverheadCosts} \text{ ha}_j^{-1}}{(1+r)^t} \right) \right. \\
 &\quad \left. + \sum_{t=0}^{n_j} \frac{\text{ForestSubsidy} \text{ ha}_j^{-1}}{(1+r)^t} \right) \\
 &\quad - \left(\left(\sum_{t=0}^{n_j} \frac{\text{GM} \text{ ha}_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{\text{FarmOverheadCosts} \text{ ha}_j^{-1}}{(1+r)^t} \right) \right) \\
 &\quad \left. + \sum_{t=0}^{n_j} \frac{\text{FarmSubsidy} \text{ ha}_j^{-1}}{(1+r)^t} \right)
 \end{aligned}
 \tag{8.1}$$

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, NPV_0 (GM+Subs-OH) simplifies to NPV_1 (GM+Subs) as presented in equation 8.2.

$$\begin{aligned}
NPV \text{ 1 } ha_j^{-1} &= \sum_{t=0}^n \frac{ForestNM \ ha_j^{-1}}{(1+r)^t} \\
&+ \sum_{t=0}^{n_j} \frac{ForestrySubsidy \ ha_j^{-1}}{(1+r)^t} \\
&- \left(\sum_{t=0}^{n_j} \frac{GM \ ha_j^{-1}}{(1+r)^t} + \sum_{t=0}^{n_j} \frac{FarmSubsidy \ ha_j^{-1}}{(1+r)^t} \right)
\end{aligned}
\tag{8.2}$$

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. In relation to area based payments, the Disadvantaged Area Scheme (DAS) 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.

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 tiered REPS payments were highest for initial hectares and reduced (on a per hectare basis) farm size increased. Thus larger REPS farmers are more likely to have planted as they only stood to lose the lowest tier of REPS payments (per hectare). 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 consider a version of the net present value, NPV2 (GM) which ignores farm level subsidies, can also be considered.

$$NPV 2 \ ha_j^{-1} = \sum_{t=0}^{n_j} \frac{ForestNM \ ha_j^{-1}}{(1+r)^t} + \sum_{t=0}^{n_j} \frac{ForestSubsidy \ ha_j^{-1}}{(1+r)^t} - \sum_{t=0}^{n_j} \frac{GM \ ha_j^{-1}}{(1+r)^t} \quad (8.3)$$

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 (described in Chapter 4) 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. 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 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 which, along with up to 20% of another conifer species, represents the most common composition of afforested land over the period (DAFM 2013a).

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 (as described in Chapter 7) 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).

8.4 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 desire 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 chapter, 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.

As the annual survey primarily collects farm rather than forest data, some data cleaning was required to prepare the dataset. The farm survey records data in relation to farm forests in terms of hectares of land planted along with forest subsidy payments, however, there are some instances, where farms have forest hectares in time t and time $t + 2$, but not in time $t + 1$. Given the irreversibility of forest planting, the data are cleaned by imputing forest hectares for missing years.

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. In order to incorporate these into the analysis, only the set of farms that were contained in the survey in 2012, can be considered in this analysis.

Agricultural market income and subsidies

Actual farm micro data (described below) are used to calculate farm incomes per hectare. As detailed in Chapter 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 8.1). 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). 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 For > Ag NPV1 (which includes agricultural subsidy payments) and For > Ag NPV2 (which represents only market gross margin).

Table 8.1 Relativity of agriculture and forest incomes contingent on “has forest”

	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.

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. It would appear from Table 8.1 that the calculation of NPV is sensitive to the inclusion of subsidies as the percentage of farms with higher forest incomes drops from 40% (NPV2) to 25% when agricultural subsidies are explicitly taken into account (NPV1). However, this may not be statistically significant.

Summary Statistics 2: Farms with and without Forests

In examining the characteristics of the farms with and without forests as presented in Table 8.2, 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 8.2 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 ⁴⁵	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 ⁴⁶	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 value⁴⁷ 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.

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.

⁴⁵ Agricultural income stream greater than Forest income stream – No forest on farm

⁴⁶ Forest income greater than Agricultural income – Has Forest

⁴⁷ Each year NFS survey farms are asked to value their land

As previously discussed, 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 8.3). 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 8.3 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 8.4. 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 8.4 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.

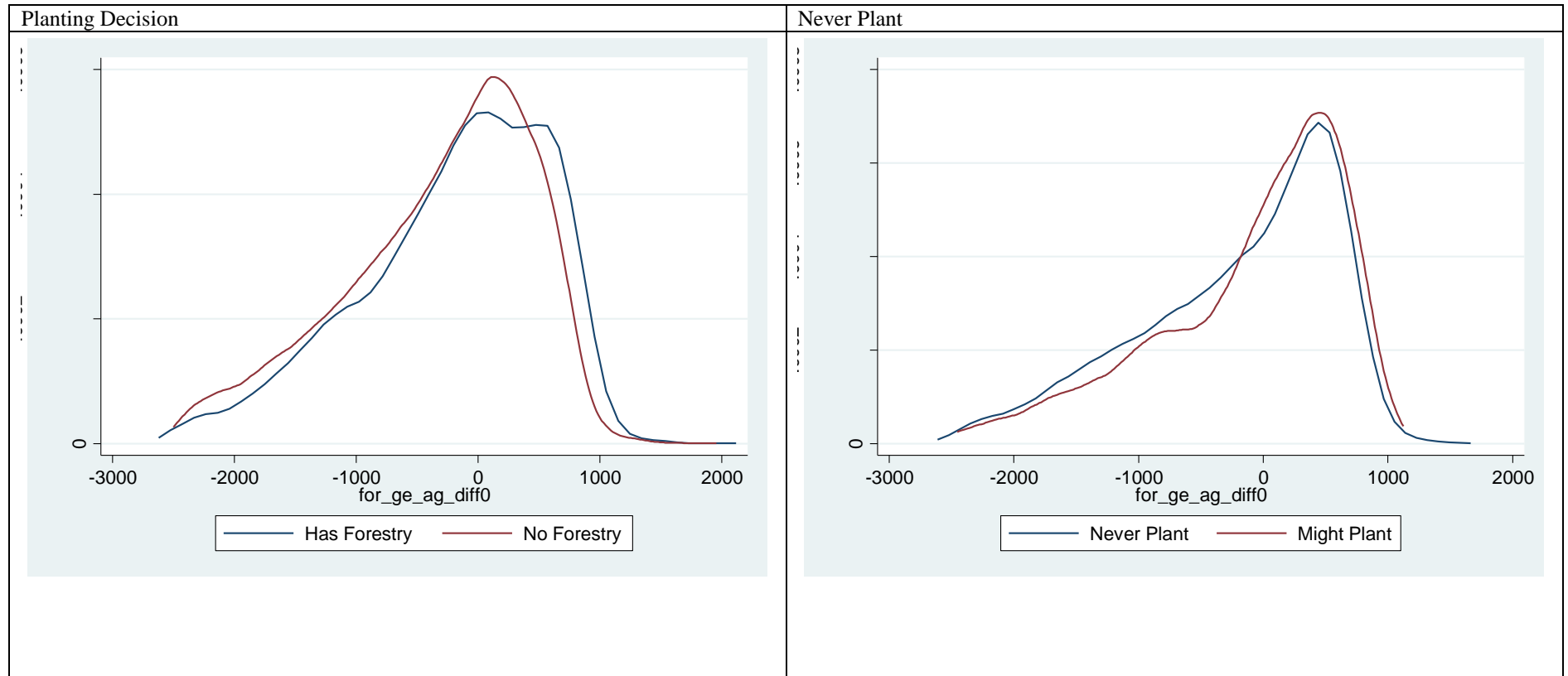
The characteristics of the farms and farmers that might plant in the future (depending on the financial incentives offered) are particularly interesting for both policy makers and extension agencies. These farms represent just under 16% of the farm population. Those with higher agricultural income streams 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 8.1. 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 8.1 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).

8.5 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) (Table 8.5). 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. Again, this is consistent with all of the Irish and international literature. 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.

Table 8.5 Models of farms with forests (farm GM with and without subsidies)

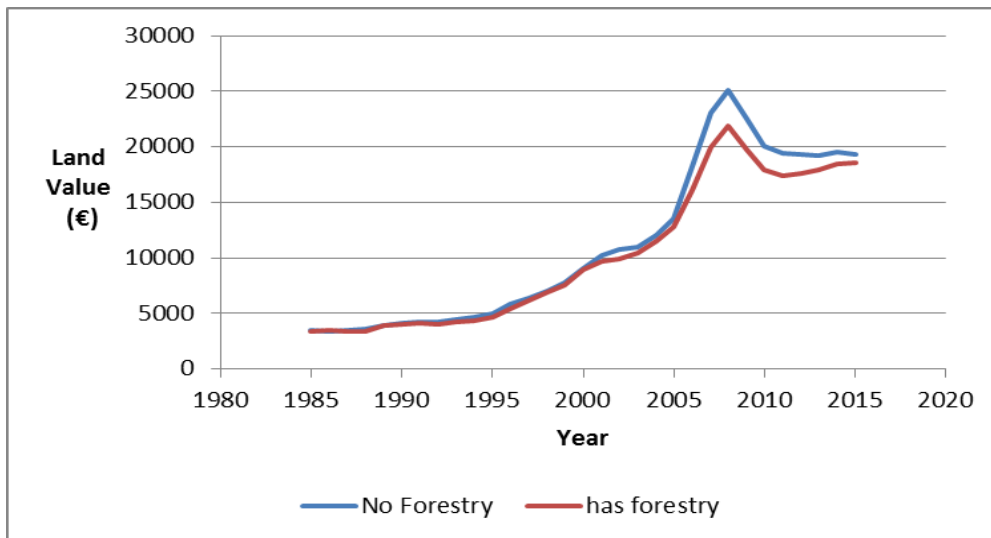
has forest	For>Ag NPV2 (MGM)		For>Ag NPV1 (GM incl. subs)	
	Coefficient	SE	Coefficient	SE
Income: For>Ag	0.2998***	0.0456	0.5885***	0.0491
Land Value ha ⁻¹ (logged)	0.6351***	0.0392	0.6795***	0.0396
Family Farm Income ha ⁻¹	-0.0004***	0.0001	-0.0001	0.0001
Dairy Stocking Rate	0.00002	0.0000	-0.0001**	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
⁴⁸ 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	
Pseudo R ²			0.0779	

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

This initially appears to be counter-intuitive and contradictory of findings in Chapter 7 which show that farmers decrease their self-assessed land value after planting. However, it must be borne in mind that this model represents the presence of forestry on farms over the 30 year time-frame. In this context, an examination of the raw data is presented in is illustrated in Figure 8.2 which shows that farms that plant have slightly lower average land values at the point of planting and reduce their land value after planting. This is consistent with the analysis in Chapter 7. Essentially what is being captured in this model is a temporal effect as there are more forests now than in the past and land values are higher now than in the past. 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.

⁴⁸ Region 1 (dropped) Border: Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan.
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; egion 8 – Galway, Mayo, Roscommon.

Figure 8.2 Average land values over time for farms with and without forests



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.

Fundamental Choices about Planting

Farms that might consider afforestation in the future are considered in Figure 8.6. 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 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. This could be explained by restrictions on planting midland peats and on poorer high elevation sites (below yield class 14). In addition, it is evident from Chapter 3 that the potential for further afforestation in large areas of the southwest, is restricted due to environmental regulations.

Table 8.6 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. This is consistent with the analysis in Chapter 6. It would also appear that the relative importance of other farm and farmer characteristics has changed over time, possibly reflecting changing economic and policy environments. Again

the analysis in Chapter 6 highlights the impact that changes in the magnitude of the opportunity cost could potentially have on the feasibility of afforestation in any given year.

Consequences of planting – change in farming intensity in year of planting

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. The analysis on the relativity of agricultural and forest subsidies in Chapter 4 shows that the 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 have the following options:

- Become more intensive – carry the same number of livestock on a reduced land area thereby increasing the number of livestock units (LU) ha⁻¹;
- Maintain the same stocking density - reduce the number of livestock to match the reduced land area; or
- Become less intensive – reduce the stock numbers further to farm at a lower stocking density than before planting.

An examination of the stocking density in the year of planting for all farms with forests in the NFS 2012 Supplementary survey dataset shows that the average stocking rate reduces from 1.44 to 1.37 LU ha⁻¹ (year before planting versus year of planting). Table 8.7 categorises farms on the basis of change in livestock density in the planting year.

Table 8.7 Stocking Rate Change in year of planting

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

Just under one third of farms had no change in livestock density in the year of planting. A quarter of farms increase stocking rate while the largest proportion of farms (43%), reduce livestock density in the year of planting. The farm characteristics are further examined in relation to the three stocking density change categories and are presented in Table 8.8.

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.

Table 8.8 Average characteristics of farms with new forests by 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

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 part of a wider lifestyle objectives.

8.6 CONCLUSIONS

The analysis in earlier chapters provides a greater understanding of the complexity of the farm afforestation decision. It is evident that the market component of income fluctuates with soil type and over time. In addition, the share of subsidies in agricultural income varies with different policy periods. However, farmers behave rationally in maximising their average utility in relation to income, wealth and time spent farming.

The analysis in this chapter goes deeper to unpick the complexity of land conversion at individual farm level by examining the individual characteristics of the farms and the farmers who are likely or unlikely to afforest land. Using a pooled dataset of farm level micro-data, forest and agricultural income streams are generated and a life-cycle theoretical framework is employed to analyse the relative importance of agricultural and forest financial drivers in the decision-making process at farm level.

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 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).

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, 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. The analysis in Chapter 6 confirms that the farmers with the highest net farm afforestation income (NFAI) are likely to be livestock farmers on medium quality soils. 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. This may be a time-related issue as Chapters 4 and 6 showed that it is possible that afforestation in earlier policy periods could have resulted in substantial loss of farm subsidies.

In addition to the financial drivers, for many farmers the afforestation decision involves a wider complex of contemporaneous multi-enterprise farm decisions which necessitates the consideration of farm livestock density as a consequence of planting. On a higher level, this involves lifestyle decisions about the future direction of the farm business.

There is a growing recognition that farmers are motivated by a range of socio-economic factors and that financial gain may not be their core motivation for farming. The low uptake of policy incentives for both woodland creation and woodland management in the UK was examined by Lawrence and Dandy (2014) who find that insufficient financial incentives, the long term nature of the investment and socio-cultural factors, all act as barriers to uptake. They conclude that socio-cultural factors have a larger role in the afforestation land use change decision than previously acknowledged. This thesis 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 (2005) recognised 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. These farms would benefit financially from afforestation as they have the lowest farm income/ha, the smallest average farm size, the lowest livestock numbers and are the oldest farmers on average. However, it was not previously evident that these farmers will never consider forestry, regardless of the level of the financial incentive.

On a more positive note, this thesis also identifies a cohort of large, younger farmers who might plant, if the income from forestry is greater than the agricultural income. Of the farmers who might plant, those farms with higher forest income streams are the farms that are most likely to consider forestry. The results indicate that these farmers are likely to have larger farms and may have off-farm income but are also less aware of the permanence of the planting decision. However, the thesis results also indicate that this is not a homogeneous group, although the farms display common characteristics around decisions to optimise their land and time resources and ultimately their lifestyles.

The objective of this chapter 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. The analysis clearly demonstrates the heterogeneous nature of the livestock farming population but suggests possible typologies of farmers who might plant on the basis of their long-term motivations, as revealed by the changes they make in relation to their level of agricultural intensity in the year of planting. 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.

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 chapter 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.

Chapter 9. CONCLUSIONS

9.1 INTRODUCTION

There has been much discussion in Irish land use policy circles in recent years as to how to reverse the decline in afforestation. The benefits of afforestation are well recognised by policy makers, particularly in relation to the development of an effective timber processing sector and the provision of a range of forest ecosystem services. In recent years, the ability of forests to sequester carbon and the consequent potential to mitigate greenhouse gas emissions from agriculture and forest harvesting, has brought the incentivisation of further afforestation up the policy agenda.

In countries where agriculture is the dominant land use, policy makers need more information about the motivation for planting and the incentives required for farmers to make a choice between agriculture and forestry. While there are large volumes of literature that deal with either agriculture or forestry as a land use, there is a dearth of literature that examines the factors involved in the land use change from agriculture to forestry, within the same framework.

The objective of this thesis was to critically and holistically examine the factors that add to the complexity of an inter-temporal land use change such as farm afforestation, with a view to gaining a deeper understanding of the relativity and impact of the economic, bio-physical and behavioural factors. The analysis was undertaken in the policy context of the period 1985 to 2013.

The effect of agricultural and forest policy incentives on annual afforestation rates was addressed initially. In examining the economic factors in depth, market and subsidy components of potential forest income and the opportunity cost of the agricultural income foregone were disaggregated. From a biophysical perspective, this thesis focused on the effect of soil type on forest productivity and the economic implications of planting on different soil types. The incorporation of a spatial component allows for the inclusion of soil type as an explanatory variable in this analysis thus facilitating an examination of the physical context of afforestation patterns over time. In particular, apart from the Australian research undertaken by Herbohn et al. (2009), Bateman's (2005) Welsh land use change study and Upton's (2013) Irish study, there is little literature that specifically incorporates the

biophysical context (i.e. soil type) of proposed forests in relation to projections of potential forest yield that incorporate the opportunity cost of the superseded agricultural enterprise.

This thesis goes beyond these studies by utilising micro-data from a longitudinal farm survey database to examine the effect of soil type on the agricultural opportunity cost, the forest returns and the consequent net economic returns arising from the afforestation of farmland at the individual farm level. While the attractiveness of forest subsidies is noted as a factor in the afforestation decision, the comprehensive nature of the longitudinal micro-data also facilitates a comparison of the relative importance of both agricultural and forest subsidies over time, a factor which has not previously been examined in the Irish context.

The behavioural aspect of the afforestation decision was examined by estimating a choice model to examine the utility maximising behaviour of farmers in relation to afforestation. In addition, the complexity posed by the heterogeneity of farmers' attitudes was addressed by examining individual farm and farmer characteristics across the distribution of the farming population in relation to their attitudes towards afforestation.

9.2 SUMMARY OF THESIS FINDINGS

There are complex motivations surrounding the decision to plant or not to plant. In the earlier chapters it is evident that the rate of farm afforestation changes significantly over time, as farmers respond to a variety of incentives and disincentives to afforest. These include agricultural commodity prices, changes in the value of the forest premium payments, agricultural policy reforms and developments in land markets.

In reviewing the policy environment for both agriculture and forestry in Chapter 2, it is evident that the policy conflicts between agricultural and forestry incentives add to policy complexity. However, from the literature there are clear indications that factors such as soil type, financial drivers, having a productivist mindset and/or a desire to stay farming, or a negative cultural attitude towards forestry, all have an impact on whether farmers will even consider afforestation.

Chapter 3 examines the relationship between the biophysical, economic and policy drivers of farm afforestation. It is clear that fundamental to understanding the land use change is the influence of the physical characteristics of the land, particularly soil quality. 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, as evidenced by the proportion of poorer quality soils having a major effect on afforestation rates. The relative profitability of land conversion was found to have a significant effect but its influence on planting rates was relatively small. This chapter highlights a policy conflict between environmental and forest policies in that conservation policies have impacted negatively on land conversion and limitations on land availability may have a large bearing on low afforestation rates in some areas.

In addition, this chapter highlights the importance of land availability in policy development and of potential conflicts between policies with similar goals. If agricultural expansion results in increased profitability of competing agricultural enterprises, either through increased intensification or the expansion of more profitable enterprises, commercial forestry may lose competitiveness as a land-use option. However, if agricultural intensification occurs only on the best quality land this could result in the availability of marginal land for alternative uses (Feehan and O'Connor 2009). This chapter concludes that in developing targets for forest expansion, policy makers should account for conflicting land use policies, the availability of land and the impact of changes to the profitability of alternative land uses if realistic targets are to be developed. In relation to its contribution to the literature, the integration of forest and agricultural economic data with spatial data in Chapter 3 provides the basis for future econo-spatial analyses.

Chapter 4 uncovers more information on the apparent conflict between agricultural and forest policies. A detailed examination of the cattle and forestry subsidies available to farmers who may have considered forestry over the time period has not previously been undertaken in the Irish literature. This analysis shows that for much of the period reviewed, cattle subsidies were higher than forestry subsidies, particularly in MSH areas and for more intensive farms. In essence, the (subsidy) opportunity cost of undertaking forestry is higher for intensive farms than for less intensive farms, in terms of the income foregone from agricultural subsidies.

O'Connor and Kearney (1993) report that "other things being equal, the expected returns from forestry must show a premium over the returns from land before landholders will seriously consider the forestry option". Overall it is evident that increases in forestry subsidies only served to maintain the relativity with cattle subsidies, rather than providing forestry with a financial advantage over cattle farming during that period. This thesis adds to the Irish literature by revealing that the subsidy component of the opportunity cost of farm

afforestation may have been greater than was previously recognised. This finding may also have relevance in other EU countries with similar agricultural incentives.

The primary objective of Chapter 5 was to generate forest market income streams for farm afforestation choices. This information is a necessary step in considering a land use change from agriculture to forestry. This particular information is of benefit to (a) farmers wishing to optimise their forest investment, (b) extension agents who provide information to farmers and (c) policy makers who need understand the drivers of afforestation in relation to the design of future afforestation incentive schemes. The need for such information is highlighted by Ní Dhubháin and Greene (2009) who report that “the low level of knowledge, among owners, of aspects of the silvicultural management, call into question whether the timber production targets that form the basis of the financial support scheme in Ireland will be met”.

This was achieved through the development of the Teagasc Forest Bio-Economic System (ForBES) model, which is based on the FC growth curves published by Edwards and Christie (1981). ForBES generates growth, income and cost curves to generate NPV curves for one rotation by species, yield class and thin scenario. Simulating the scenarios for Sitka spruce, it is evident that different objectives result in different outcomes, confirming the initial hypothesis. Substantial differences are evident between the biologically optimal rotation, the reduced rotation in common usage and the financially optimal rotation as calculated by ForBES, reinforcing the usefulness of this type of financial modelling approach.

The model output shows that the calculation of NPV is not sensitive to the inclusion of reforestation costs or to the extension of the rotation measurement period. However, the results are particularly sensitive to the choice of yield class, thin scenario, inclusion of subsidies, choice of discount rate and nature of price index. Specifically, better site productivity and thin versus no-thin options result in higher NPVs and shorter rotations across all optimisations. The development of the ForBES model provides a frame-work for future integrated analysis of agricultural and forestry parameters, particularly in relation to the modelling of carbon sequestration from forests planted on previously agricultural land. To our knowledge, there are no comparable farm-level afforestation models in existence.

Chapter 6 decomposes agricultural and forest incomes into their market and subsidy components to assess the relativity of market income and subsidies. This chapter also examined the role of soil class as a driver in both market and subsidy income, before

calculating the annual agricultural opportunity cost associated with the afforestation of one hectare in each year of the dataset for each farm system. The results show that there is significant variability between systems, years and soil classes. 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 evident in this chapter, as over the period examined, there are large variations in relation to system, subsidies, soil type and overhead costs as a result of policy changes and price volatility. Essentially farmers are confronted by a trade-off in which the parameters change from year to year. This chapter contributes to the literature by revealing a 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 and shows clearly, that the opportunity cost is not a flat rate per hectare but is very much about the system opportunity cost. The effect of soil type is reflected in both the opportunity cost of the agricultural income foregone and the productivity of the forest. To the best of our knowledge, analysis of this depth in relation to the opportunity cost of planting agricultural land has not previously been undertaken. While the previous chapters examined forest and agricultural income streams over time, Chapter 7 examines life cycle utility by estimating a choice model to examine farmers' preferences in relation to life-cycle income, long term land value and hours worked. The coefficients of the choice model are robust and are consistent with economic theory. The average preferences are statistically significant and consistent with economic theory, reflecting the underlying preference for farming. Utility increases with NPV of income and land value (wealth) and agricultural activity (hours worked), reflecting the high weight farmers place on these attributes. When hours worked is interacted with agricultural income however, utility decreases. In addition, in cases where the NPV of forest income is higher than the NPV of agricultural income and requires less labour per hectare on average, the preference for forestry is at the expense of a fall in wealth due to the decline in land value and hours worked, as a result of a more inflexible non-agricultural land use activity.

Thus, on balance, many farmers prefer to farm than to afforest land, even if the income from forestry is higher and there is solid evidence that the gain in (forest) income is not sufficient

to off-set the decrease in agricultural income, perceived decline in wealth and loss of utility derived from farming. This thesis confirms that in fact farmers act rationally in maximising their utility from farming in a manner that is consistent with theory, however they are not necessarily profit maximising. Only minor changes arise when choice attributes are interacted with taste shifters, giving little additional information on preferences for income. It is possible to infer from this that farmers follow rational choices as the patterns are similar to those reported by Becker (1993), but only at the margins. The behavioural analysis in this chapter also highlights that socio-economic and cultural factors are likely to have a strong role to play in the choices made by many farmers. The estimation of the parameters of a discrete choice model in the land use context is a novel but effective use of this methodology, which to our knowledge has not previously been used in the land use context. In Chapter 8, the final analytical chapter, a complex distributional analysis is undertaken across a dataset of over 35,000 observations to unpick the complexity of land conversion at individual farm level by examining the individual characteristics of the farms and the farmers who are likely or unlikely to afforest land. Forest and agricultural income streams are generated and a life-cycle theoretical framework is employed to analyse the relative importance of agricultural and forest financial drivers in the decision-making process at farm level. Changes in farming intensity in the year of planting were observed in the dataset. The analysis shows that the relativity of agricultural and forest incomes over the period analysed, has a large impact on the afforestation decision and is not sensitive to different methods of calculation of the income streams. Farms with higher forest income streams ($For > Ag$) are significantly more likely to have afforested land and to consider forestry in the future.

There is a high proportion of older farmers for whom negative cultural attitudes are stronger than financial drivers, even though these farms would benefit financially from afforestation. A cohort of large, younger farmers is identified, who might plant if the forest income is greater than the agricultural income. Of the farmers who might plant, those farms with higher forest income streams are the farms that are most likely to consider forestry.

Chapter 8 also specifically comments on the relationship between farm size and land value in relation to the probability of planting. Model results show that as hypothesised, farm size is significant and positive for both NPV calculation methods. Again, this is consistent with all of the Irish and international literature. 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. What is being captured in this model is a temporal effect as there are more forests now than in the past and land values are higher now than in the past, therefore there is a greater weight on land value. This finding is thus consistent with findings in Chapter 7.

In addition to the financial drivers, the afforestation decision involves a wider complex of contemporaneous multi-enterprise farm decisions for many farmers. For example, the land use change decision necessitates the consideration of farm livestock density as a consequence of planting. On a higher level, this involves lifestyle decisions about the future direction of the farm business. The analytical power of the ForBES model allows for analysis of farm and farmer characteristics at individual farm level, providing a depth of information for policy makers, that was previously unavailable. This information can thus form the basis of more targeted promotional and extension programmes.

9.3 OVERALL CONCLUSIONS

This thesis provides additional information about farmers' average utility preferences and the heterogeneity of the farming population. In the context of trying to understand how to achieve an increase in afforestation rates, the thesis further provides an appreciation of the challenges involved in increasing the uptake of afforestation incentive schemes. While the findings reported here relate to the challenges surrounding farm afforestation in Ireland, these findings may also have relevance in other countries which face similar challenges. The literature clearly points to a growing recognition that farmers are motivated by socio-economic factors to a greater extent than was previously acknowledged and financial gain may not be their core motivation for farming (Lawrence and Dandy 2014). For many, negative cultural or attitudinal values are deeply held and can outweigh the greater pecuniary benefits sometimes offered by afforestation. One approach to potentially overcome the attitudinal "hurdle" associated with afforestation, is the concept of the "compensating differential" in labour economics literature (Carpenter et al. 2015), which refers to the additional income that a worker must be offered as compensation to undertake less desirable tasks.

Another hurdle is presented by the long-term nature of afforestation and the high level of awareness of the irreversibility. In relation to other long-term investments such as pensions, policy makers are increasingly looking to behavioural economics for solutions to overcome

the decline in personal pensions (Tapia and Yermo 2007). In recent years, the Pensions Commission in the UK introduced pension options which include voluntary opt out clauses and find that the high level of inertia prevails after long term decisions are made. The Pensions Commission found that auto enrolment pension schemes with the right to opt out have much higher participation rates (Pensions Commission (2004). However, opt out rates in UK pensions are less than 12% in recent years (O’Loughlin 2015).

Effecting behavioural change can be a complex, time consuming process, particularly if adoption of a practice is voluntary. Vanclay and Lawrence (1995) find that when changes or innovations are unproven, and/or “contrary to accepted farming ways”, adoption of new technologies/practices can be lower than anticipated.

Vanclay (2004) states that different farmers have “different priorities, different understandings, different values and different ways of working”. This is consistent with the research findings in this thesis which suggest that due to the underlying heterogeneity of the farming population, a “one rule for all” approach is likely to have limited success and that a more targeted approach, informed by qualitative research, may be necessary to improve the uptake of farm afforestation in future. The usefulness of a segmentation approach for agricultural policy is highlighted in studies undertaken by Pike (2008, 2011) for Defra in the UK, who reports that this approach provides a deeper understanding of farmer motivation, which is critical to the design of long-lasting policy solutions.

To date, afforestation incentives have been independent of other decision making at farm level. In the past, many dairy farmers overcame this hurdle and planted land in order to increase dairy quotas. On the basis that the primary motivation of farmers is to farm, the integration of afforestation incentives with farm management decisions could generate more success. The role of extension in this context is also important. Bell et al. (1994) suggest that indirect (extension) as well as direct (financial) incentives can lead to better uptake of forest programmes. It is suggested 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. On the basis of the information generated by this thesis and drawing from the behavioural literature, a suite of policy options is presented here in relation to incentivising behavioural change around the farm afforestation decision.

General contribution of thesis to the literature

The overall contribution of this thesis to the literature can be summarised as follows:

- The holistic and comprehensive manner in which the land use change from agriculture to forestry is examined, has not previously been attempted in the literature.
- The use of discrete choice analysis is novel in the land use context and confirms that in the afforestation context, farmers maximise utility in relation to income and leisure according to economic theory.
- The distributional analysis provides clear evidence that while profit maximisation is a significant driver of the afforestation decision, there are other (and perhaps stronger) drivers at play, which should be taken into account by policy makers.
- On the basis of the behavioural economics literature, this thesis further presents novel ways to go beyond purely financial incentives to achieve an increase in farm afforestation.
- The thesis presents new information on livestock density changes at farm level in the year of planting which appear to be indicative of lifestyle choices. There is thus potential for future policy-makers to take whole farm planning into account in designing policies.
- The ForBES model has the capacity to generate large quantities of information for use in the forestry extension context.

9.4 INFORMATION FOR POLICY MAKERS AND POLICY OPTIONS

In the context of trying to understand how to achieve an increase in afforestation rates, this analysis gives us an appreciation of the breadth of the challenges involved in increasing the uptake of afforestation incentive schemes. Drawing from economic theory, this section presents potential options to mitigate these challenges.

Providing Environmental Public Goods

There are important public policy drivers for increasing the carbon sequestered in forests to counter-balance GHG emissions from agriculture. From an environmental economics point of view, the marginal benefit to a farmer from planting is less than the marginal benefit to the state. There is therefore, a rationale for Pigouvian transfers to farmers, to motivate them to provide this environmental public good.

Requirement to re-forest (permanence)

Given farmers' preferences to farm and their concern about inter-generational attachment to the land, the permanence of the decision to afforest can prove to be quite a significant barrier to planting (McDonagh et al. 2010). This barrier is compounded by the high level of awareness of the potential irreversibility of the decision. The attachment to land in Ireland is evidenced by the fact that on average less than 1% of the total land area changes hands in any given year (Ganly 2009). However, on an annual basis, more land is sold than is afforested.

Behavioural economics examines why people's actions deviate from the predictions of standard economic theory. If there is a large gap between what we do and what we should do, it is necessary to encourage or "nudge" this behaviour. Policy makers are increasingly looking to behavioural economics for solutions to overcome barriers associated with other long-term investments, such as the decline in personal pensions (Tapia and Yermo 2007). Nudge theory suggests consumer behaviour can be influenced by small suggestions and positive reinforcements (Thaler & Sunstein 2008). The most popular nudge to do with pensions is auto-enrolment, which takes advantage of peoples' inertia. Under the nudge principle, workers are automatically enrolled in the scheme and actively have to opt out if they do not want to join.

In recent years, the UK introduced voluntary opt-out pension clauses and find that auto enrolment pension schemes (with the right to opt-out) have much higher participation rates (Pensions Commission 2004). The Pensions Commission also find that a high level of inertia prevails after long term decisions are made. In general, opt-out rates in the UK are in the region of 1 in 10 in recent years (O'Loughlin 2015a). Drawing on lessons from behavioural economics applied to pensions, there are merits to considering the relaxing of the reforestation requirement. The possibility of an element of land use reversion on future afforestation, could potentially reduce the barrier to planting in the first instance. There is already an element of discretion allowed in relation to reforestation and it is a matter of policy how this is implemented. Current reforestation policy is based on a general requirement to replant harvested areas but some exceptions are made in practice (e.g. for bog restoration in Special Areas of Conservation). In general, replanting of an alternative site is also allowed. However given the high cost associated with forest removal, there are likely to be strong disincentives to reverting the land to agriculture. This cost builds on natural inertia

which suggests that (similarly to the pensions scenario) once a long term (land use) decision is made, there is a relatively low chance of change in any case.

As a corollary to this, increased forestry-related land use change, could reduce the socio-cultural barriers to afforestation, in the same way that initial agri-environmental scheme participation in the 1990s reduced the general antipathy towards agri-environmental programmes, significantly changing attitudes and participation levels (Murphy et al. 2014).

Overcoming inertia

For many farmers, negative cultural or attitudinal values are deeply held and can outweigh the greater pecuniary benefits sometimes offered by afforestation. Therefore monetary compensation for income foregone may not be sufficient to incentivise the change to a less preferred land use option. An approach to potentially overcome the attitudinal “hurdle” associated with, in the first instance, considering afforestation, is the concept of the “compensating differential” in labour economics literature (Carpenter et al. 2015), which refers to the additional income that a worker must be offered as compensation to undertake less desirable tasks.

Scheme Design – Timing of Payment

The long-term nature of the economic return from forestry is contrary to the preference for income now, rather than later. At present initial establishment costs and loss of income (for 15 years) are compensated however the return on investment arises primarily through harvesting at potentially over 40 years from planting. While in theory, the timing of payments does not matter, in reality farmers cannot easily borrow against future income. Bacon (2004) suggests that the State should have an option or right to purchase the timber in the plantation from year 10 at a price that would equate to the final timber value. Similarly financial incentives by institutional investors could potentially pay farmers a bond for future planting rights, incorporating a greater degree of income front-loading, say in exchange for a share of future harvesting income.

Risk management

Consideration could be given to the establishment of a state insurance scheme for forestry. State provision is justified on the basis of insurance market failures in the forestry sector. In order for insurance markets to exist efficiently, the following elements are necessary:

- Independent probabilities
- Probability of event occurring is less than one
- Known probabilities
- No adverse selection
- No moral hazard
- Low transaction costs.

The availability of timber insurance in some countries demonstrates that the reduction of transaction costs by the government or by landowner associations is a possibility, and that this can assist the growth of the timber insurance business (Zhang and Stengler 2014). Following devastating losses caused by two winter storms in 1999 and 2009, proposals for legislation and a timber insurance programme have been made in France. However Brunette and Couture (2008) suggest that governments should not provide direct compensation for forest damage as this would reduce incentives for risk management. They suggest that it is more appropriate for governments to offer aid to landowners who protect their assets through insurance. The question of whether governments might make insurance mandatory for private forest owners, thus reducing risk for insurers and lowering premium prices, is more controversial. So far, no country has adopted this approach (Zhang and Stengler 2014).

Linking Afforestation and Agricultural Land Use Decisions

Effecting behavioural change can be a complex, time consuming process, particularly if adoption of a practice is voluntary. Vanclay and Lawrence (1995) find that when changes or innovations are unproven, and/or “contrary to accepted farming ways”, adoption of new technologies/practices can be lower than anticipated. Vanclay (2004) states that different farmers have “different priorities, different understandings, different values and different ways of working”. This is consistent with the findings of this thesis which suggest that due to the underlying heterogeneity of the farming population, a “one rule for all” approach is likely to have limited success and that a more targeted approach, informed by qualitative research, may be necessary to improve the uptake of farm afforestation in future.

The analysis of other farm decisions that are contemporaneous with the planting decision illustrates that the afforestation decision seems to be part of a wider farm management decision and suggests that farmers may be more likely to plant if afforestation is linked to things they want to do on their farm. For example, from 1984 until 2006, dairy farmers who wanted to expand, had to buy land that had a quota to produce milk in order to increase milk production. In the early years, before quotas were ring-fenced, farmers bought and afforested land away from the home farm in order to acquire the attached dairy quota. During this period, dairy farmers, although having higher incomes from agriculture than from forestry, were responsible for a high proportion of annual afforestation.

For many years, forest and agricultural subsidies were mutually exclusive. In recent years, changes to agri-environment schemes and direct payments have been favourable towards farm afforestation. However, incentives to date have been independent of other decision making at farm level, although the recent COFORD (2016) report on land availability recognises the merits of a whole farm incentives approach. Linking forestry and agricultural incentives around actions such as the facilitation of land mobility and succession or the protection of watercourses using riparian buffer zones can provide for “win-win” outcomes. Current policy objectives in relation to agricultural expansion and the need to limit GHG emissions, present perhaps the greatest potential win-win in relation to motivating the carbon linkage between agriculture and forestry.

Linking Carbon Neutrality Objectives

Even with the adoption of the range of options available in the carbon mitigation toolkit, (such as the displacement of fossil fuels with wood biomass or improvements in the efficiency of food production utilising genetic technologies), it will be difficult for Ireland to meet its GHG reduction commitments from 2020 onwards. Previous “emissions gaps” forced the Irish government to spend €100 million on carbon credits between 2007 and 2012, however the reduction in emissions as a result of the economic downturn has meant that there has been no further requirement to buy credits to date (Matthews 2015).

Clearly, there is a need to deal with the impending emissions gap and given that one of the primary motivations of farm afforestation is carbon sequestration, there is merit in explicitly motivating the linkage between expansion activities that generate carbon emissions such as dairy expansion and measures that mitigate these carbon emissions such as afforestation.

In 2015, Teagasc made a pre-budget proposal to government that linked a reduction in the tax-payable to expanding dairy farmers on the increase in value of their herd if it was offset by afforestation (either on their own land or other farmers' land) (Connolly et al. 2015). This would utilise the stock relief policy lever within the tax code. For the expansion to be carbon neutral, research suggests that 1 hectare of forest would need to be planted for every 5 additional livestock units. This incentive of reduced tax associated with increasing stock values through stock relief, has already been introduced as an incentive for behavioural change for young farmers and partnerships. It could also be considered for afforestation associated with carbon neutral dairy expansion.

Linking afforestation with water quality objectives

A longitudinal study of fresh-water quality using Environmental Protection Agency (EPA) “Q⁴⁹” values which examines land use changes such as agricultural intensity, afforestation and septic tank density shows that over time, forestry is associated with “Good” Water Quality (O’Donoghue et al. 2015). While planting and harvesting operations can have a negative impact on water quality at a point in time, reduce Water Quality at a point in time, the association with good water quality is essentially due to the low level of disturbance over time as there are long periods of inactivity.

In the whole farm context, riparian buffer strips can assist in meeting Water Framework Directive targets by soaking up nutrients that can be lost to water during the application of chemical fertilisers or organic manure. According to ADAS (2011), buffer strips additionally restrict direct livestock access to watercourses; intercept surface runoff from agricultural land before it reaches the watercourse, therefore acting as a sediment trap and filter for nutrients; increase carbon sequestration (Newell Price et al. 2011). However, to date there has been poor uptake of riparian buffers in AE Schemes (DAFM 2014b). In this regard, there is potential to link forest buffer strips with water quality objectives. The spatial analysis in Chapter 3 of this thesis provides an analytical framework for possible future targeting of such measures to optimise efficiencies in relation to targeting areas in most need of forest buffers, but also to target areas that are most likely to plant in relation to their economic and environmental farm context.

⁴⁹ Scale of water quality from poor (=1) to Very Good (=5)

Extension

The role of extension in the context of incentivising afforestation is highlighted by Bell et al. (1994) who report that indirect (extension) as well as direct (financial) incentives can lead to better uptake of forest programmes. 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. Additionally, there is merit in the promotion of farm afforestation as an on-farm pension fund. Some challenges exist in relation to taxation of clearfell returns and inter-action with non-contributory State pension schemes, however these could also potentially be addressed using taxation levers.

Establishment costs of second and subsequent rotations

In addition, providing for re-establishment costs for second and subsequent rotations would widen the financial gap between reforestation and reverting the land to agricultural use, thereby reducing farmer concerns in relation to the cost of reforestation.

Differential Land Availability

An additional 510,000 ha of afforestation would be required to achieve the 18% forest cover target by mid-century (COFORD 2016). The analysis presented in this paper shows that soil type is an important physical driver of (a) the economic return to afforestation and (b) the agricultural opportunity cost of farm afforestation and that fibre and sequestration demands can be optimised on land which is not necessary economically attractive for agriculture. Farrelly & Gallagher (2016) identify a total of 423,000ha of wet grassland and unimproved land that occurs on the margins of productive agricultural land and in marginal agricultural areas, that is productive for forestry. However, this research also shows that under the current policy incentives, a large proportion of farmers are not prepared to consider afforestation.

In light of the conflicting demands on land use and common objectives around the provision of ecosystem services such as carbon sequestration, fibre for timber processing and renewable energy, as well as the provision of biodiversity and good quality air and water, there is merit in developing long term integrated land use policies. The concept of Functional Land Management (Schulte et al. 2014) recognises the differential capacity of different soils and environmental conditions to sustainably intensify land-based production of food, fibre

and ecosystem services. However, long term land use policies and objectives should be designed to span multiple CAP periods. For example, the initial afforestation “hurdle” could be reduced if farmers were confident that planting land would not disadvantage them in relation to future agricultural schemes i.e. if a commitment was given in relation to the continuity of the social benefits generated by farmers who plant.

9.5 CAVEATS

Although forest cover in Ireland has almost doubled in the last twenty years and approximately 17% of farms have forests, only about one % of farms in the NFS afforest land annually. Although there are a total of 250 farms with forests in the NFS longitudinal dataset, the small sample size (relative to farms without forests) is a limitation of this research.

The agricultural and forest income streams generated in this thesis are pre-tax income streams as the NFS does not contain tax information. However, this means that the tax-free element of forest subsidy payments is not taken into account in this analysis.

The discrete choice model focuses on average preferences in the population as generated using the conditional logit. While some preference heterogeneity is accounted for by the inclusion of taste shifters in the analysis, it is possible that different underlying preference groups exist in the population. However, the consideration of more complex models is not appropriate as the low probability of planting poses difficulties for more computationally complex models. The mixed logit in particular is very sensitive to missing data or low probability of uptake. Other methods such as the use of latent classes are unlikely to add additional information, as the explanatory power of the models is already very high and the results are consistent for all specifications run on the dataset. There is no evidence that the might/never plant or the viable/non-viable cohorts have different utility functions as the coefficients on the models have the same sign and are similar in magnitude, thus any minor differences are not likely to be qualitative.

In many models, the main source of endogeneity is ability bias. It is not unusual for estimates to be biased in the socio-economic literature – what is more important is the level of bias. It is felt that if the estimates generated in this study are biased, the level of bias is limited by (a) a stochastic element to the level of farm gross margin (in relation to management ability and capacity for hard work and (b) as most farmers employ forestry contractors to undertake forest establishment and management, farmers are largely exogenous to the afforestation

process. However the overall qualitative conclusions are so robust that they are unlikely to change, even if the estimates are biased.

This thesis pulls together the many strands of the farm afforestation conundrum which allows us to undertake deeper analyses than before. Despite the limitations, the model coefficients are significant, the level of the elasticities is strong and the findings are consistent with economic theory as well as with the qualitative literature.

9.6 NEXT STEPS

The ForBES model is based on static growth curves but the coding could be adapted to read dynamic yield models. The inclusion of a stochastic component to take changes in costs, prices and risks into account and the modelling of carbon sequestration would significantly improve the accuracy of forest income predictions. In addition, incorporating the recent geo-referencing of the NFS dataset would allow for inclusion of spatial forest yield classes the basis of actual soil type, rather than the approximations used in this study.

In this research only the afforestation choices that farmers make in any given year are examined. An examination of the likelihood of planting at some point in the future (might ever plant), could provide a broader population and consequent valuable additional information, but changes in policy environments over time pose modelling difficulties for this approach.

The analytical infrastructure developed in this thesis provides the potential for broader analysis of policy questions. For instance, the challenges of carbon neutrality, sustainable agricultural intensification and afforestation are inextricably linked. Future work could include modelling carbon at the farm level in order to (a) incorporate carbon as a farm level objective with other income and lifestyle objectives (b) linking with other policy incentives such as pensions and tax relief i.e. linking agricultural stock relief to afforestation in the context of dairy expansion or domestic offsetting (c) provide potential solutions for the design of the next CAP. The infrastructure developed in this thesis could also accommodate mixed methods approaches such as those adopted by Defra in England (Pike 2008, 2011) and Scotland (Barnes 2012) which combine qualitative data with farm level micro data.

In the context of the 2014-2020 afforestation programme, which provides subsidies for both farmer and non-farmer afforestation (DAFM 2015b), current (as yet unpublished Teagasc

research) suggests that although the land market is limited, more farmers are willing to sell land than to afforest land. This is likely to lead to up-front payments to farmers for timber harvesting rights – an area that will require economic analysis.

The infrastructure developed also provides potential to look at estimating an economic value for the wider value chain i.e. timber production and added value products. Using an input output framework, analysis could be undertaken to examine the effect of planting in different locations and where the added value is generated.

The recently published report on land availability for afforestation (COFORD 2016) and the accompanying report on site classification for afforestation (Farrelly and Gallagher 2015) highlight issues in relation to policy conflicts, site productivity and socio-economic factors that limit land availability for afforestation. There is scope for significant synergies between the analysis in this thesis and these reports, in the context of future research in the wider Functional Land Management (Schulte et al. 2014) framework.

This thesis comprehensively addresses the private benefits to farmers accruing from afforestation. Herbohn et al. (2009) also only examined private benefits, however the studies undertaken by Clinch (1999) and Bateman et al. (2005) examine the public benefits from afforestation. Forest expansion is considered desirable for the provision of ecosystem services, particularly in relation to the ability of forests to sequester carbon (Nijnik and Bizikova 2008) and rural economic diversification (Kanowski 2010). However, this requires the replacement of an existing land-use. Traditionally, afforestation occurs on sub-marginal land but this is increasingly valued for biodiversity and recreation (Buckley et al. 2009; Bullock et al. 2012), which may be impacted negatively by afforestation (Buscardo et al. 2008). Such areas are therefore becoming less available for land conversion in general, including for afforestation. Detailed knowledge of the economic and environmental trade-offs involved in the afforestation of agricultural land is essential for sound decision making, to ensure that unforeseen consequences do not arise from attempts to improve a given service (Rodríguez et al. 2006). As services are not linear in nature, a decline in the provision of one service may not be proportionate to the increase in provision of another. These so called “ecological thresholds” are fundamental in understanding ecosystem services. Once a threshold is breached, either as a result of natural processes or anthropogenic disturbance, an ecosystem and the services which it provides revert from one stable state to another (Huggett 2005).

Long-term climate mitigation and adaptation strategies must address the multiple economic and environmental goals in an integrated way, as the value that is put on different ES from forest may differ between interest groups, resulting in very different perspectives on forest management. This thesis provides the economic component in relation to economic trade-offs and the ForBES model developed in this research has the capacity to be adapted to model carbon sequestration to provide information on the environmental trade-offs. Thus this thesis is already being used as the base information to facilitate modelling of trade-offs for the provision of carbon sequestration and biodiversity ecosystem services.

While past and current policies have focused on the incentivisation of afforestation by providing for additional private benefits for forest owners, the increasing urgency around natural resource efficiency and climate change mitigation are likely to become more important drivers of land use policy in the near future. This thesis provides a much needed and previously unavailable framework in which to facilitate the assessment and evaluation of the wider social benefits/costs arising from afforestation of agricultural land.

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