The potential availability of land for afforestation in the Republic of Ireland

Niall Farrelly[a*] and Gerhardt Gallagher[b]

Abstract

The Irish Government reiterated its commitment to expand the productive forest area to 18% of the land area by 2046 (DAFM 2014) in order to maintain a sustainable processing sector with its many additional benefits. The process of increasing afforestation rates may also offer significant scope to mitigate greenhouse gas (GHG) emissions, especially from agriculture, which is expected to expand production to cater for increased demand for food and fibre. The challenges of managing multiple conflicting land use objectives (aimed at both increasing food and fibre production as well as trying to maintain conservation values) and their effect on land availability for forestry expansion are examined in this paper. An assessment was made of the land resource available for afforestation and the related opportunities and constraints are discussed. Results indicate that 4.65 million ha of land in Ireland are potentially suitable for forestry; of this 896,880 ha are subject to national and EU designations where existing habitat conservation is prioritised. Of the remaining 3.75 M ha, 2.42 M ha are classed as productive agricultural land, likely to be the main focus of agricultural expansion. The remaining 1.3 M ha, classed as being marginal for agriculture, shows significant scope for afforestation. To assist in the achievement of forestry targets, it may be necessary to consider all sources of land, including a significant area currently under-utilised (unenclosed land), more than a third of the target planting area (c. 178,000 ha), as well as the development of native woodlands that may also fulfil conservation and carbon sequestration objectives.

Keywords: *Land use, afforestation targets, conservation, agricultural land use.*

Introduction

Opportunities and challenges to forestry expansion

Forestry expansion has re-emerged at the top of the land use agenda in Ireland, driven by two contemporary challenges: (1) the need to produce enough fibre to create a sustainable processing sector and (2) the sustainability of agricultural intensification and the achievement of a carbon neutral agricultural sector by 2050 (Schulte et al. 2013, O'Brien et al. 2014). Reflecting these challenges Government policy has reiterated its commitment to expand the productive forest area to approximately 1.25 million ha or 18% of the land area (DAFM 2014). This would require annual afforestation targets of 16,000 ha yr^{-1} to 2046. Whether such planting rates are possible is very uncertain, particularly given the recent decline in afforestation from 23,000

[a] Teagasc, Mellows Centre, Athenry, Co. Galway.
[b] 53 Upper Beechwood Avenue, Ranelagh, Dublin 6.
[*] Corresponding author: niall.farrelly@teagasc.ie

ha yr^{-1} in 1995 to just over 6,200 ha in 2013; significant efforts will be necessary to stimulate land-use change and increased forestry expansion. While the availability of funding for forestry expansion and recent budgetary constraints undoubtedly have had a significant impact on the expansion of new forest planting, the availability of land will ultimately limit forestry expansion, owing to the array of competing land uses, including planned expansion in the agricultural sector and constraints posed by conservation policies and objectives. Since 4.9 million ha are currently in agricultural use (CSO 2012), future forestry expansion will disproportionally depend on a change in land use from agriculture to forestry. The quality of land is a defining aspect in the decision-making process by farmers (Ní Dhubháin and Gardiner 1994, Howley et al. 2012). Land marginal to economic agriculture represents a viable prospect for such land use and many landowners (18,000 since 1980 (Ní Dhubháin et al. 2010)) have availed of incentives such as grant and premium payments to convert agricultural land to forestry. Where land is of better quality and suitable for a wide range of agricultural enterprises, such as in livestock, tillage and horticulture, forestry becomes a less attractive option since returns in forestry are often lower than in competing agricultural enterprises (Upton et al. 2013). The issue of personal choice also influences the outcome. Farmers, for various reasons of lifestyle choice, lack of familiarity with forestry, family tradition, or the perception that "good land" should remain in agriculture, sometimes do not consider forestry as a land-use option.

Despite these challenges there is still an interest among policy makers in a continued expansion of the forest resource with the aim of developing a more sustainable sector that provides many additional benefits (i.e. production of raw material, expansion of the processing sector, recreation, etc.). One of the main drivers of forestry expansion in Ireland over the last number of years has been the capacity of post 1990 "Kyoto" forests to sequester carbon. Including fossil fuel substitution, the sequestration potential for forestry is estimated to be 4.2 Mt CO_2 equivalent yr^{-1} by 2030 (Schulte et al. 2013). Recently the aim to achieve a carbon neutral agricultural sector by 2050 in Ireland has received much attention (Schulte et al. 2013). If this is to be achieved, it is likely to require a mosaic of solutions. These include an increase in carbon sequestration capacity by accelerating new forest planting above current levels (as well as correcting an unbalanced age-profile within the forest estate), advanced mitigation strategies, technology advancements and restrictions on production. The potential for increased sequestration through accelerated new afforestation shows considerable scope. While increased forest sequestration does not reduce national emissions, its full compensatory effect is disproportionally dependent on a balanced age structure so the achievement of higher planting rates is vital, at least over the next two decades.

Although creating a carbon neutral agricultural sector by 2050 in Ireland could be partially achieved by increased forest carbon sequestration and changes to the carbon

accounting procedures, this may ultimately result in a competition for land for use in agriculture, or to help meet other environmental objectives. There is a high probability of additional land resources being required to support increased agricultural output, particularly following the phasing-out of EU milk quota by 2015 (Schulte et. al. 2014). However, policy makers are increasingly viewing forestry as an integrated land-use option, which will assist in the overall achievement of food and fibre security and support the sustainable intensification of the agricultural sector by helping to offset carbon emissions.

The knowledge gap

To help achieve current Government targets of 18% forest cover (DAFM 2014), an urgent acceleration of the afforestation programme is necessary, requiring the planting of 490,000 ha of new forests by 2046. Currently the afforestation programme is largely focused on encouraging the private sector to convert less productive agricultural land into forestry. To date, information on the availability of land resources to facilitate forestry expansion has not been available. There is a need to examine all current information to characterise the nature and extent of land availability and suitability for afforestation and quantify the various land use types and their potential suitability for forestry using soils and related spatial datasets. This information could then be used to assess the opportunities and constraints for forestry expansion. Similar research in Scotland, which has succeeded in identifying these opportunities and constraints, was carried out by the Woodland Expansion Advisory Group (WEAG) (Sing et al. 2013).

Certain constraints may limit or preclude forestry expansion or land use change for any particular parcel of land. It has been suggested that conservation policies related to habitats or species have reduced annual afforestation rates and discouraged applications in relevant areas (Collier et al. 2002). These include EU habitats (92/43/EEC) and birds (79/409/EEC) directives, in which conservation of existing habitats is prioritised. In addition, there are restrictions on the planting of coniferous forestry in acid sensitive catchments. Constraints relating to the types of land that can be planted, and its productive capacity, are likely to influence the potential area made available for forestry expansion. Land deemed suitable to receive financial support under the afforestation scheme must be capable of growth rates equivalent to a minimum of yield class 14 for Sitka spruce (*Picea sitchensis* (Bong.) Carr.) (Forest Service 2012). Other constraints on the types of land include restrictions on the amount of unenclosed land that can be planted (lands generally used for extensive grazing, on which agricultural productivity is low currently) and will further reduce the potential pool of land for afforestation (Farrelly and Gallagher 2013). All these constraints, together with the predicted expansion in agriculture (e.g. the diary sector which expects to expand milk production by 50%), may result in considerably less land becoming available for

future forestry expansion. This paper aims to provide information on the barriers to land availability for forestry in Ireland, which may ultimately limit the expansion of forest cover and the achievement of multi-sectorial goals. This expansion may result in an increase in competition for land with agriculture and necessitate a re-appraisal of the current administrative constraints on new forestry planting.

Objective

The overall objective of this study is to provide information on the potential availability of land for afforestation, and assess if limitations to land availability will ultimately constrain the expansion of the forestry area. The study seeks to identify the most likely areas to have potential for forestry expansion, given the increased importance of multiple land use objectives like agricultural expansion and conservation.

Data and methods

Spatial analysis techniques were used in this study to assess land-use using a Geographic Information Systems (GIS) and a series of the most up-to-date spatial datasets available on land-related activities (Table 1). The total administrative area of the Republic of Ireland (6,989 M ha) was derived from a boundary shape file map of the Republic of Ireland representing the terrestrial land area. The base map was converted to an ESRITM grid file raster map containing 6.989 × 108 pixel cells each representing a land area of 10 × 10 m. For certain datasets (e.g. energy utilities, road and railway infrastructure and buildings) a buffering technique was incorporated to allow for setback distances in which forests cannot be planted as per Irish Forest Service guidelines (Anon 2012). These setback distances ranged from 5 to 30 m either side of a road or building. Other datasets used included a shapefile of all forests in public and private ownership (correct up to 2008), land cover datasets (Loftus et al. 2002, Fealy et al. 2006), datasets relating to national and EU designations (e.g. NHA's, SAC's SPA's) and datasets related to water quality (potentially acid sensitive catchments and fishery sensitive areas), a soils and land use capability map for agriculture (Gardiner and Radford 1980) and a national forest productivity map (Farrelly et al. 2011). The GIS analysis method was similar to the approach used in Scotland by Sing et al. (2013) to evaluate the potential of land for tree planting and combines features from multiple datasets, and uses this information as the basis to classify land into the four categories based on opportunities and constraints for afforestation, as outlined below.

1: Land biophysically unavailable for forestry expansion

Land was designated as being biophysically unavailable for forestry expansion if it was composed of one or more of the following: existing forest cover, water, urban areas, energy utilities, road and rail infrastructure and buildings (Table 3; Figure 1a-e).

Table 1: *Sources of various data available on land use and related information used in the study.*

Data type	Data source	Year	Format	Primary processing unit (resolution m^{-2})
Administration boundary				
Republic of Ireland boundary	Ordnance Survey Ireland	2006	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Forestry				
Forestry parcels data	Forest Service	2008	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Woodland cover	Ordnance Survey	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Forest productivity data	Teagasc	2011	ESRI™ grid	ESRI™ Grid (10 × 10)
Water				
Water features	Navtech™ dataset	2011	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Lakes, ponds, reservoirs, river banks and centres	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Urban areas				
Towns/urban areas/retail/amenity/beach/golf courses	Navtech™ dataset	2011	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Towns/military	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Utilities				
Electricity pylons - ESB	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 30 m setback
Railway infrastructure				
Industrial and passenger rail	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 20 m setback
Road infrastructure				
Major and secondary Highways	Navtech™ dataset	2011	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 20 m setback
Streets, fourth class roads	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 20 m, 5 m setback
Buildings				
Houses, once-off units	An Post Geo Directory	2006	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 30 m setback
Other buildings	Ordnance Survey Ireland	2005	ESRI™ shapefile	ESRI™ Grid (10 × 10) + 30 m setback
Landcover data				
Landcover/habitat maps	Teagasc	2005	ESRI™ grid	ESRI™ Grid (10 × 10)
Environmental/conservation				
Special Areas of Conservation (Nature 2000 network)	NPWS data	2012	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Special Protected Areas (Natura 2000 network)	NPWS data			
Natural Heritage areas (NHA)	NPWS data			
Freshwater pearl mussel catchments (+ 6 km buffers)	Forest Service	2012	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Potentially acid sensitive catchments	Forest Service	2012	ESRI™ shapefile	ESRI™ Grid (10 × 10)
Agricultural land use data				
Soil association & Land Capability map for Agriculture	Teagasc	1980	ESRI™ grid	ESRI™ Grid (10 × 10)
Agricultural land use data (National Farm Survey)	Teagasc	2012	Summary statistics	n/a

2. Land biologically unsuitable for forestry expansion

Land was considered biologically unsuitable for forestry expansion if it included land incapable of producing a forest crop, such as intact raised bogs, fens, sand dunes, coastal complexes, salt marshes, rock outcrops and karst areas (Loftus et al. 2002) (Figure 1f). Areas deemed unproductive for forestry were also included here and were derived from a map of forest productivity of Sitka spruce in Ireland (Farrelly et al. 2011). Forest productivity is measured by the yield class (YC) system (Edwards and Christie 1981) and is the potential of a site in terms of the mean annual volume increment per hectare of a stand on that site up to a reference age. All land below the minimum needed for an afforestation grant aid, as per Forest Service requirements (YC 14 for Sitka spruce), was also classified as having no potential for afforestation.

3. Land affected by national and EU designations and policies

Land subject to national and EU designations and policies that may impose constraints to afforestation were calculated from a series of datasets of nature conservation designations and water quality objectives (Figure 1g; Table 1). These lands were not subject to category 1 or 2 constraints and were biologically suitable for afforestation, but were designated for protection under EU habitats (92/43/EEC) and birds (79/409/EEC) directives and other national conservation policies (e.g. natural heritage areas and nature reserves)[3]. Areas subject to specific water quality guidelines were also included using a dataset of potentially acid sensitive water catchments provided by the Irish Forest Service. Areas classed as being category 3 have limited scope for afforestation. Some areas in this category may be considered eligible for planting subject to specific conditions compatible with environmental guidelines or with specific approval by the Forest Service. For example, in potentially acid sensitive areas, commercial planting can be approved following the outcome of a laboratory test, while the native woodland establishment scheme is permitted without major restriction (see Anon 2012).

4. Land most likely to have potential for forestry expansion

This includes all lands likely to have potential for forestry expansion not in categories 1 to 3 Table 4). These areas are likely to have most potential for forestry expansion. Fishery sensitive areas are included here as, applications for afforestation grant aid are permissible subject to appropriate measures (which may be locally applicable to particular afforestation applications) together with adherence to the codes of best forestry practice. The land area within category 4 was then classified into productive agricultural land and marginal agricultural land according to Gardiner and Radford's

[3] Other areas outside of the main environmental constraint areas may have constraints for afforestation and subject to directives for water, habitat, birds, etc. These are not considered here but may be locally applicable to particular afforestation applications.

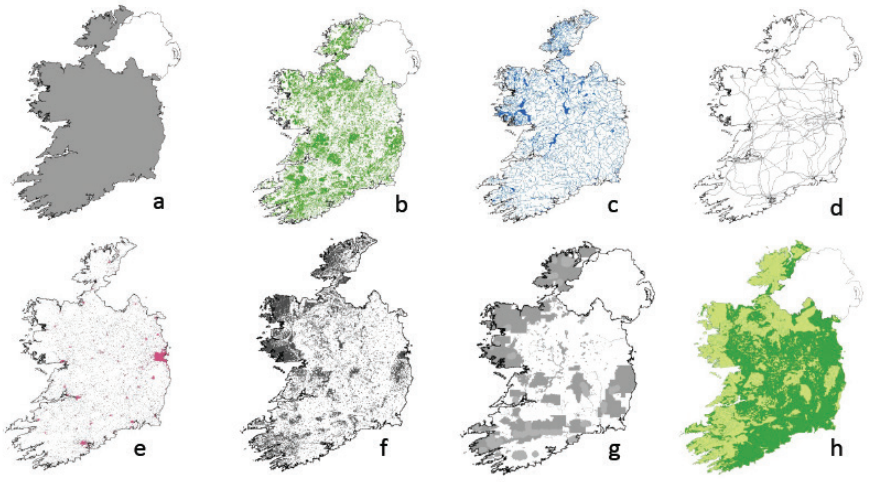

Figure 1: *Map resources used to derive the area potentially suitable for afforestation. Clockwise, (a) terrestrial land area –in grey; (b) forest cover; (c) water bodies; (d) road, rail and energy utilities; (e) urban; (f) unplantable/unproductive areas; (g) environmental constraint areas; (h) agricultural usage category (light green marginal agricultural land, dark green -productive agricultural land).*

(1980) map of soil suitability for agriculture, as described below.

Classification of productive agricultural land

Productive agricultural land was classed as having a wide usage range (class 1, 2 and 3, Table 2). Soils were deemed suitable for tillage and grassland according to Gardiner and Radford's (1980) land use potential of Irish soils, supplemented by data on the range of agricultural systems from the Teagasc National Farm Survey (Moran 2014). Generally, soils in this category were fertile, well drained and occur from the lowlands up to 150 m in elevation. Some small areas of poorer soils are often present due to the resolution limitations of the datasets used.

Classification of marginal agricultural land

Marginal agricultural land is land classed as having a limited usage range (class 4, 5, and 6, Table 2). These soils are moderately suitable for permanent pasture and not suited to tillage and are marginal for agricultural use (Gardiner and Radford 1980, Moran 2014). These soils have poor to moderate fertility and vary from well to poorly drained, occuring at higher elevations on steep slopes of mountain and hill sides or in drumlin areas. Peat soils are also present and the proportion of higher quality tillage land is low.

Assessment of potential forest productivity

The productivity assessment used here utilises data from Farrelly et al. (2011)

and land must have been capable of achieving a minimum growth rate[4] of YC 14. Forest productivity was divided into four categories; moderate, good, very good and excellent. Such categories represented the yield class bands 14-18, 18-22, 22-26 and 26+, respectively.

Trends in planting on agricultural land and national and EU designated areas

Datasets of forest cover provided by the Irish Forest Service covering all forests (both public and private) planted up to 2008 were used, to assess historical planting patterns on productive and marginal agricultural land and the land cover types planted. The level of planting on national and EU designated areas, classified here as category 3 constraint areas were also assessed. This may allow some inferences as to the likelihood of planting occurring on certain categories of agricultural lands, land-cover types and in national and EU designated areas.

Results

Area potentially suitable for afforestation

The outcomes of our analysis of land deemed most likely to have potential for afforestation are presented in Table 3 and Figure 2. An area of 1.49 M ha, 21.3% of the land area of Ireland, was classified as having category 1 constraints, being biophysically unavailable for afforestation (classified as forest, urban, water, road and rail, electricity utilities and buildings). Of the remaining 5.49 M ha, 12.2% (850,238 ha) are considered biologically unsuitable for afforestation (category 2). A further 12.8% (897,121 ha) of land was affected by national and EU designations and policies (category 3). The remaining land area with most potential for afforestation (category 4) covered 3.75 million ha or 54% of the area of the Republic of Ireland. While this land was deemed most likely to have potential for afforestation, taking the constraints mentioned above into account, it was not necessarily unconstrained for forestry expansion. Land cover characteristics show that nearly 95% of this land (3.57 M ha) was classified as grassland (dry grassland including tillage land, wet and reclaimed grassland) (Table 2). There were also smaller areas of other land-cover types typically associated with unenclosed land, including industrial cutover peat lands, heathland (with shallow peat and mineral soils) and flushed areas of bog not part of category 2 or 3 lands that showed acceptable YCs for afforestation (178,996 ha).

Potential forest productivity

The bulk of the area with most potential for afforestation (category 4 land; Tables 4 and 5) was grassland with 2.8 million ha showing very good to excellent potential for

[4] The pre-requisite for afforestation grant aid is based on the Forest Service requirement that the land must be capable of achieving a minimum growth rate of YC 14 for Sitka spruce with a standard application of fertiliser (e.g. 350 kg ha^{-1} GRP) at the time of establishment or from a split application (for full details see Anon, 2011).

Table 2: *Productive and marginal agricultural land in Ireland was classified by Gardiner and Radford (1980) into six soil suitability classes based on their potential for various agricultural systems.*

Use-range	Soil suitability class	Suitable agricultural systems
Productive agricultural land	1	Suitable for tillage, pasture, meadow and forestry
	2	Moderately suitable for tillage, pasture and widely suitable for forestry
	3	Moderate to poorly suitable for tillage; limited to moderately suitable for pasture, meadow and forestry
Marginal agricultural land	4	Poorly suitable for tillage; moderate to poorly suitable for pasture and meadow; moderately suitable for forestry
	5	Unsuitable for cultivation, meadow or intensive grazing; moderately suitable for forestry and extensive grazing
	6	Unsuitable for cultivation, meadow or intensive grazing; certain areas may be suitable for forestry

forest production with YCs in the 22 to 26+ range, the remainder of grassland shows good levels of production, having YCs ranging from 18 to 22. Of the area classed as unenclosed land, occupying 178,996 ha, 42% of the area (74,397 ha) showed good to excellent levels of potential production ranging from YC 18 to 26+, with the remainder of the area showing moderate levels ranging from YC 14 to 18 (104,600 ha).

Agricultural usage

The information gathered on agricultural use indicated that 65% of the land likely to have potential for afforestation (2.45 M ha) was classified as productive agricultural land (making it suitable for almost all agricultural enterprises). Almost all this area was identified as being suitable for tillage and grassland (2.42 M ha). Smaller areas of reclaimed and wet grassland were also present in this category representing <5% of the area. According to unpublished data from the Teagasc National Farm Survey in 2013, livestock-based enterprises predominated on these lands. The main enterprises were: cattle non-dairy (42%), dairy (25%), tillage (12%), sheep (12%) and mixed livestock (5%) (Figure 3). Farming of this category was profitable with average farm income calculated at €30,761 per annum per household in 2013 (Moran 2014). A small amount of poorer land (24,647 ha) on the margins of productive land, composed mostly of mineral soils with shrub heath, cutaway peat lands, flushed bogs, etc., are

Table 3: *Potential availability of land for forestry expansion in the Republic of Ireland.*

Category	Land use	Total area (ha)	% Ireland	Total per category
1: Land biophysically unavailable for forestry expansion	Forest	735,511	10.5%	1.49 M ha
	Other woodland	16,720	0.2%	(21.3%)
	Scrub	27,543	0.4%	
	Water	171,368	2.5%	
	Urban	160,966	2.3%	
	ESB	29,554	0.4%	
	Rail	8,115	0.1%	
	Public roads	118,684	1.7%	
	Buildings	223,467	3.2%	
2: Land biologically unsuitable for forestry expansion	Bare rock and outcrops	230,432	3.3%	0.85 M ha
	Coastal sands	5,928	0.1%	(12%)
	Raised bogs and fens	107,907	1.5%	
	Salt marsh	352	0.0%	
	Deep peat	298,014	4.3%	
	Heathland	61,985	0.9%	
	Unproductive	145,620	2.1%	
3: Land affected by National and EU designations and policies	Area designated for protection of hen harrier	54,399	0.8%	0.90 M ha (13%)
	National designations (Natura 2000 sites, NHA and Nature reserves)	180,632	2.6%	
	Fresh water pearl mussel (6 km priority catchment area)	362,507	5.2%	
	Fresh water pearl mussel (catchment)	146,522	2.1%	
	Potentially acid sensitive	153,061	2.2%	
4: Land most likely to have potential for forestry expansion	Non-fishery sensitive	3,259,524	46.6%	3.75 M ha
	- of which fishery sensitive	(490,894) [a]	7.0%	(54%)
Total land area		6,989,537	100%	

[a] Application of appropriate screening of forestry applications in fishery sensitive areas may be locally applicable.

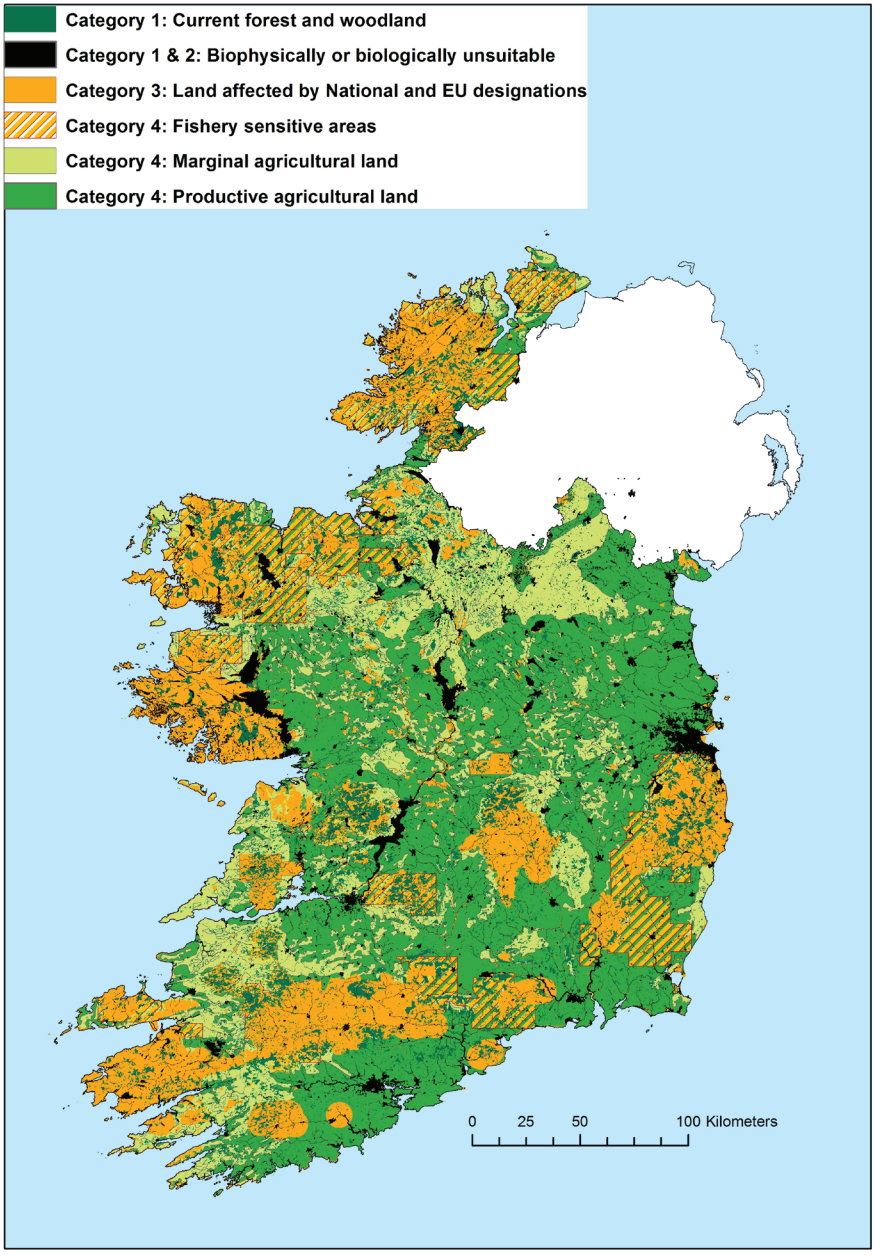

Figure 2: *Classification of Ireland's land area into four categories in relation to availability for forestry expansion and the area of productive and marginal agricultural land with most potential for forestry expansion.*

also classified here owing to the resolution of datasets used in the analysis.

The area of marginal land with potential for afforestation covered 1.3 M ha. Grassland (dry/improved, reclaimed and wet) was the dominant land cover occupying 88% of the area (1.15 M ha). Farming enterprises were predominately cattle (49%) and sheep (27%) systems, with lower levels of dairy (18%), and mixed livestock (4%) systems (Figure 3). The proportion of land in tillage in this category was very low (2%) primarily because the land was either too wet or the terrain too steep to make this enterprise economic. Overall, the profitability of farming enterprises on marginal land was lower than on productive agricultural land with average farm income of

Table 4: *The area of land most likely to have potential for forestry expansion (category 4) in Ireland, classified as productive and marginal agricultural land, with associated land cover and soil characteristics.*

Land cover	**Productive agric. land** (ha)	**Marginal agric. land** (ha)	**Total area** (ha)
Tillage and grassland	2,217,782		2,217,782
Dry/improved grassland		804,836	804,836
Reclaimed grassland	118,299	186,500	304,799
Wet grassland	87,785	156,219	244,004
Cutover peat industrial	6,663	55,819	62,482
Shallow peat with shrub heath		42,602	42,602
Mineral Soils with shrub heath	13,589	21,489	35,078
Flushed blanket bog	2,055	28,236	30,292
Cutover peat other	199	1,955	2,154
Bare soil/peat	2,059	4,158	6,217
Unclassified	82	90	172
Other			
Total	2,448,513	1,301,905	3,750,419

Table 5: *The potential productivity (yield class) of land most likely to have potential for forestry expansion (category 4).*

Land cover category **Yield class range** (m^3 ha^{-1} yr^{-1})	**Moderate 14-18**	**Good 18-22**	**Very good 22-26**	**Excellent 26+**	**Total**
			Area (ha)		
Grassland	47,008	723,575	2,340,861	459,979	3,571,422
Other	104,600	37,534	27,119	9,745	178,996
Total	151,608	761,108	2,367,979	469,724	3,750,419

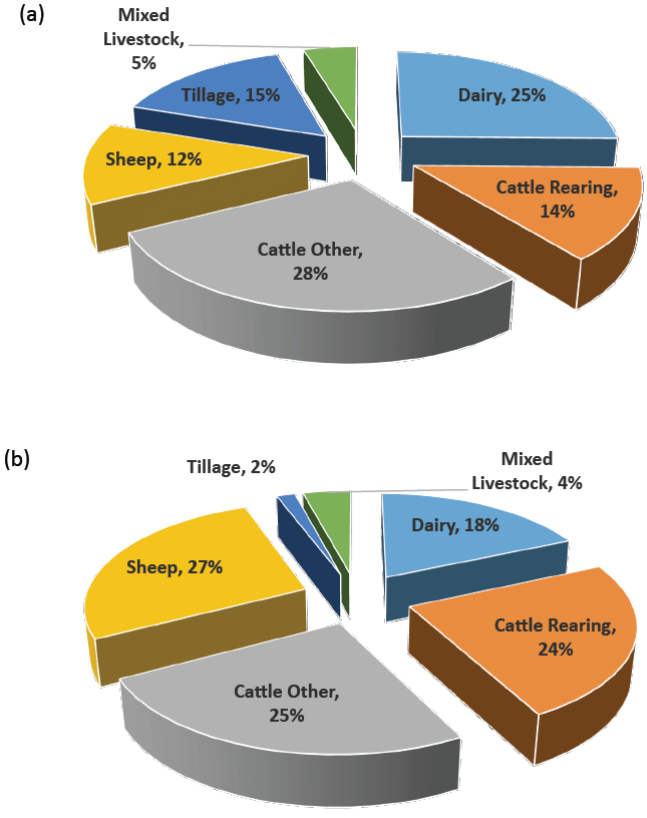

Figure 3: *The range of agricultural enterprises on (a) productive agricultural land and (b) marginal agricultural land. Note the decline in tillage and diary and increase in cattle and sheep enterprises on marginal land (data courtesy of National Farm Survey, Teagasc – Moran 2014).*

€17,006 per annum per household. A significant area of land thought to be unenclosed land (154,350 ha) was identified within this category, not likely to be the focus of future increased agricultural production or conservation objectives, being composed of cutover bogs, shallow peat/mineral soils with heath shrub vegetation, bogs with flushed vegetation, and bare soil/peat are deemed suitable for afforestation.

Historical planting in relation to land use

Over two thirds of all forests planted (532,000 ha) have been located on marginal agricultural land - a legacy of historical forest policy (Figure 4). The trend in recent afforestation (1989-2006) shows the same pattern, with 67% (122,345 ha) occurring on marginal agricultural land. Of marginal land planted, the area previously under grass represented 56% (68,426 ha). While lower levels of planting occurred on productive

agricultural land during the period, the bulk (80%) of this planting occurred on grassland (49,520 ha), indicating the better quality of sites in this category. Indeed, the proportion of grassland being planted has increased year on year since 1989, reaching a maximum in 2000, only to decline in line with overall planting over the period 2000-2006. The average area of grassland planted was 6,000 ha per annum out of an average of 10,000 ha of the total afforestation per year in Ireland during the same period (Figure 5).

Limited afforestation has taken place in areas subject to national and EU designations and policies, comprising a total of 3,084 ha over the 5 year period 2007-2012 (source Forest Service DAFM). This is equivalent to 600 ha yr^{-1}. As these areas are subject to application of appropriate screening and certain qualifying criteria, this low figure is not unexpected. However given the area of lands classed in category 3 (Land affected by national and EU designations and policies) as being suitably productive (i.e. 0.897 million ha), the planting rates mentioned represent a very small area.

Discussion

The analysis presented has identified 3.75 M ha of land likely to have potential for afforestation. The bulk of this land, some 2.42 M ha, is productive agricultural land. Farming enterprises here are typically livestock based and show relatively good profit margins. It is likely that this land will be the focus of agricultural intensification and may see opportunities for farmers to change enterprises in line with demand for certain commodities (i.e. milk and grain). Agricultural output on this type of land is forecasted to increase in response to Food Harvest 2020 measures (DAFF 2010), perhaps leading to expansion in dairying, tillage and beef systems. Increased consolidation of agricultural holdings is also expected. There

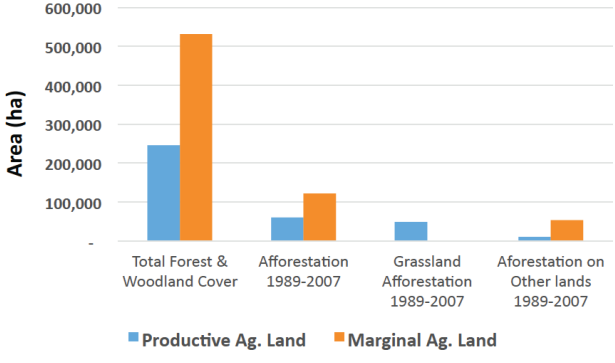

Figure 4: *The total forest and woodland cover in Ireland, planted on either marginal or productive agricultural land. Also shown is the area afforested from 1989-2007, together with the area of grassland and other lands afforested over the same period.*

will be limited opportunities for afforestation in these areas as the availability of this productive agricultural land is highly dependent on the performance of competing agricultural enterprises. It is likely that substantial increases in incentives would be necessary to encourage land-use change to forestry. Even with such incentives it is unclear whether this land would become available in significant quantity as other issues such as social circumstances, the perceived permanent nature of forestry establishment and devaluations in land price may ultimately limit uptake. In the short term, it may be possible to afforest those small areas of poorer soils occurring on the margins of productive land or where individual farming circumstances dictate.

There will be greater opportunities to establish forests on land classified as marginal or poorer quality or with a limited capability for agriculture. The results indicated good levels of potential forest production could be achieved on much of this land including the non-grassland areas. The returns from farming on this type of land have been much lower, as indicated by the Teagasc National Farm Survey data (Moran 2014). Typical farming enterprises carried out on marginal agricultural land include sheep and beef systems. These systems may be less profitable than other enterprises. Forestry may be a viable alternative on such land, particularly since wetter soils are more difficult to manage (Upton et al. 2013). Indeed, an analysis of traditional planting patterns confirms that these lands are more likely to be planted; the lower profitability associated with farming suggests that these lands should become more readily available for forestry. However, a significant proportion of this potentially available land was classified as grassland (1.146 M ha), of which 341,290 ha were probably limited to summer grazing with inherent problems of machine trafficability and animal poaching (wet and reclaimed grasslands) and higher management requirements, thereby rendering it more readily available for forestry. As considerable portions of this type have already been planted, the question of whether land in this category will remain more tightly held in agriculture remains to be seen. The key issue is whether lower quality grasslands can be utilised in more profitable livestock enterprises (e.g. dairying) following the removal of milk quotas in 2015. Availability for forestry may depend on whether these lands can be brought back into production through drainage and reclamation works at a reasonable cost. While it can be concluded that economics and land quality undoubtedly play a large part of the rationale behind land a change in land use, it is not the only factor that governs a farmer's choice of forestry as a land use option. The other issues that may influence the decision include the landowner's lifestyle choice, age and social circumstances (Ní Dhubháin et al. 1994, Duesberg et al. 2013) may ultimately constrain the availability of land for afforestation. These issues are beyond the scope of this paper.

The figures presented here show the challenge required to increase the forest area in Ireland, which might arise due to the over-dependence on land use change from agriculture to forestry. Therefore, it may be necessary to consider all potential sources including land that is not currently the focus of agricultural production. Thus, the 178,996 ha of unenclosed land that shows adequate levels of production potential should be considered. This may be easier to source for forest planting because of lower levels of farming activity and low profitability, so should be the focus of an overall plan aimed at achieving afforestation targets. Whether all or part of this area may be suitable for forestry could be assessed using further criteria or site classification methods to assist in quantifying their full potential (see Farrelly and Gallagher 2015 in this journal). It is reasonable to assume that afforestation of land affected by national and EU designations and policies will be limited in availability and will continue at the current modest rates (c. 600 ha yr^{-1}) or expand slightly into the future. However, given the scale of land classed as suitably productive, the planting rates mentioned here represents a very small area of the total. It may be necessary, therefore, to begin a new initiative to examine alternative models of afforestation (e.g. native woodlands), subject to specific requirements relating to conservation and carbon sequestration objectives, to assist in the achievement of targets.

Conclusion

The achievement of the forestry policy target of 1.25 M ha of forestry will be challenging, exceptionally so in the current time frame (2046) because of the situation regarding land availability. As productive agricultural land will continue

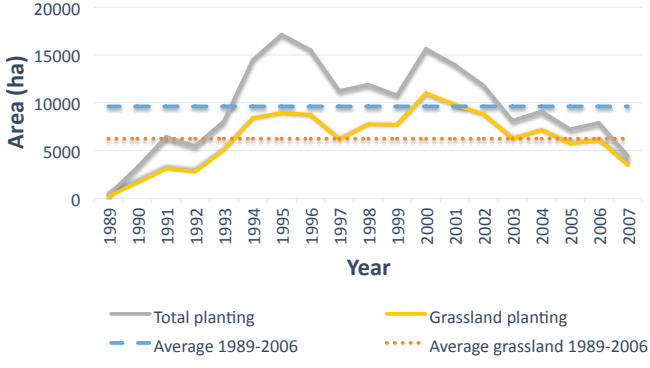

Figure 5: *Area of grassland (dry, wet and reclaimed) planted in relation to the total amount of forests planted over the period 1989-2006 –with the average area of grassland and total area planted for the same period.*

to be the focus of food production it may be prudent to focus on opportunities for afforestation on the 1.3 M ha of marginal agricultural. However the availability of wet and reclaimed grassland areas for forestry remains uncertain as these may become the focus of increased interest for agriculture if proposed new methods of management and drainage make such areas easier to manage. For many farmers on smaller holdings, forestry may represent an attractive potential alternative to unprofitable farming systems. However, despite having a significant proportion of marginal land, forest planting in certain counties is still relatively low (e.g. the northern counties of Cavan and Monaghan). Land that is considered of limited agricultural use may in fact be considered well suited to its current enterprise, so the availability of such land for conversion to forestry should not be automatically assumed. Efforts and incentives may need to be increased to encourage the conversion of more of this type of land to forestry. Given the significant area of productive unenclosed land, and its importance in the achievement of overall planting targets, its potential should be fully investigated.

Given the constraints on land use affecting its availability for afforestation, the impacts of other objectives inadvertently restricting land availability also need to be considered and evaluated. This work is the first detailed analysis of land availability for forestry in the last 25 years (since Bulfin's 1987 study), so it may be prudent, particularly in the context of target shortfall risk, to perform a bi-annual evaluation of land sources potentially available for forestry to take account of land becoming unavailable through planting or other land use designations, to monitor progress and to facilitate planning.

Finally the findings do point to a requirement for consideration of new initiatives, notably:

a) how the marginal areas in better farming regions might be brought into forestry and if compatible farm/forest systems could be developed;

b) mechanisms that might entice lower quality farmland, in areas traditionally with low afforestation rates, into afforestation;

c) new mechanisms for classifying and accessing suitable unenclosed land, including industrial cut over peat (e.g. Farrelly and Gallagher 2015 classification);

d) development of environmentally sustainable approaches for the establishment of forests on poor quality sites with low productivity potential;

e) mechanisms to encourage the implementation of alternative management objectives, such as carbon sequestration.

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