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Contemporary forest loss in Ireland; quantifying rare deforestation events in a fragmented forest landscape

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ABSTRACT

Accurate quantification of forest loss is required to meet international reporting requirements, even in countries where deforestation rates are low. In Ireland, recent evidence has suggested the rate of gross annual deforestation is increasing. However, no spatially explicit data on the extent and character of contemporary deforestation exists. Here, we quantify deforestation in a region where forest loss is rare. Deforestation estimates derived from wall-to-wall photointerpretation, official records (e.g. felling licences), the CORINE land-use/land cover changes dataset and a combined approach (hereafter termed “the Deforestation Map”) are compared in two regions in Ireland for the period 2000 to 2012. Deforestation area based on the Deforestation Map (1497 ha) was greater than estimates derived from using photo-interpretation (730 ha), official records (908 ha) and CORINE (139 ha) alone. Independent accuracy assessment highlighted high errors of omission for photo-interpretation (68.9%), official records (66.7%) and CORINE (91.84%) estimates compared to the Deforestation Map (20%). No general increase in the deforestation rate during the study period was recorded, despite regional variations. Post deforestation land-use transitions were principally to wetland, grassland and settlement although the magnitude and proportion of change varied regionally. Gross annual deforestation was higher in older broadleaf forests than in conifer plantation forests, a surprising finding considering the small area and conservation status of many broadleaf forests in Ireland. For countries with small forest area and/or low rates of deforestation, the use of methodologies employed herein can provide a valuable record of forest loss and be used to validate sample-based or remotely sensed deforestation estimates.

1. Introduction

The conversion of forest land to non-forest land contributes 6–17% of global anthropogenic CO_2 emissions to the atmosphere (Van der Werf et al., 2009) and is a principal driver of human-induced climate change (Ashton, Tyrrell, Spalding, & Gentry, 2012; Bonan, 2008). Due to high rates of deforestation, efforts have focused on the large-scale assessment of forest cover loss in tropical regions (Achard et al., 2007; Asner et al., 2010; Hansen et al., 2008). Quantification of changes in forest land-use in countries with low forest cover and/or where deforestation is rare is nonetheless required to meet international reporting obligations (Leckie, Gillis, & Wulder, 2002; Levy & Milne, 2004; UNFCCC, 1997). Tracking patterns of forest land-use on local and regional scales can also inform biodiversity conservation and ecosystem services management (Pettorelli et al., 2005; Turner et al., 2003; Zhao et al., 2004).

Changes in the extent of forest cover are often quantified using a range of automated and semi-automated satellite-based remote sensing approaches (Hansen et al., 2008; Portillo-Quintero et al., 2012; Potapov et al., 2012). Although they have been successfully used to provide accurate estimates of deforestation, automated satellite-based approaches have limitations based on image resolution and classification inaccuracies (Lister, Lister, & Alexander, 2014). While such issues can be overcome using products such as higher resolution imagery, LiDAR and object-based image analysis, these tools can require advanced expertise and resource investment not always available to regional or national reporting organisations (Lister et al., 2014). Furthermore, while automated satellite-based remote sensing can be effectively used to identify forest *cover* loss (e.g. Hansen et al., 2013), identifying changes in forest *land-use* can be problematic, particularly in countries where the principal silvicultural method is clear-cutting followed by replanting. Clear-cutting is generally associated with a marked

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change in backscatter signal (Bucha & Stibig, 2008), but differentiating clear-cutting forest management operations from permanent land-use change may require ground survey or manual photo-interpretation of imagery.

Manual interpretation of high resolution aerial photography and satellite imagery has been shown to offer an accurate and cost effective alternative to automated approaches to identifying regional land-use changes (Lister et al., 2014; Nowak & Greenfield, 2012). Detecting land-use change using manual photo-interpretation is generally carried out via interpreting a statistical sample of imagery of defined area (known as a photo-plot) (e.g. Ecke, Magnusson, & Hörnfeldt, 2013; Magnussen & Russo, 2012) or a stratified sample of points or pixels (Lister et al., 2014; Nowak & Greenfield, 2010). When land-use change events are rare, sub-samples of imagery may not be sufficient to provide accurate quantification of change areas (Dymond, Shepherd, Arnold, & Trotter, 2008). In such cases, a complete, "wall-to-wall" manual interpretation of imagery may be required to provide a spatially explicit map of land-use change events, whereby all areas are assessed. Wall-to-wall manual photo-interpretation for monitoring forest land-use change may be appropriate for regions or small countries with rare, fine-scale deforestation events, and/or operating a predominantly clear-cut – replant forest management system.

Although the natural vegetation cover of much of Ireland is forest (Cross, 2006), by 1900 forest cover was <1% following millennia of deforestation (Mitchell, 2000). Since then both state and private afforestation has increased forest cover to 10.5% (Forest Service, 2013). In recent times, newly afforested areas have generally been small, privately owned land parcels, driven by grant payments from the government and the European Union (O'Donnell, Cummins, & Byrne, 2013). This has resulted in a highly fragmented forest landscape in Ireland, with privately owned forests being on average <11 ha in size (COFORD, 2009). The fragmented nature of forest cover, and a national forest size definition of just >0.1 ha, dictates that deforestation events are generally small, fragmented and difficult to quantify.

Recent evidence from Ireland's National Forest Inventory (NFI) suggests that the gross national annual deforestation rate is increasing (Forest Service, 2007; Forest Service, 2013). As in many other countries (Tomppo, Gschwantner, Lawrence, & McRoberts, 2010), NFI information is used for reporting deforestation areas under the Land-Use, Land-Use Change and Forestry (LULUCF) sector of Ireland's National Inventory Report (NIR) on greenhouse gas emissions to the United Nations Framework Convention on Climate Change (UNFCCC) (Duffy et al., 2014). However, deforestation estimates based on this sample based methodology are associated with a high level of uncertainty (up to 50%). In addition, due to its sample based design, NFI derived deforestation estimates can only be applied on a national scale and are not useful for monitoring change on regional or local scales. Currently, on a local, regional or national scale, no spatially explicit data on the extent and character of contemporary deforestation in Ireland exists.

Here, we quantify the extent and causes of deforestation in regions where forest loss is rare. The principal objective of the study was to assess the nature of deforestation in two study regions in Ireland for the period 2000 to 2012. Deforestation area estimates derived from using wall-to-wall photointerpretation, official records, and a semi-automated approach are compared. For the purposes of this analysis, the forest definition used for international forest reporting in Ireland (land with a minimum area of 0.1 ha, trees >5 m in height and canopy cover ≥20%) has been adopted.

2. Materials and methods

2.1. Study areas

The study areas encompassed the northwest region (counties Donegal, Mayo and Sligo) and the midlands region (counties Offaly, Laois and Tipperary) of Ireland (Fig. 1). The northwest (12,285 km^2)

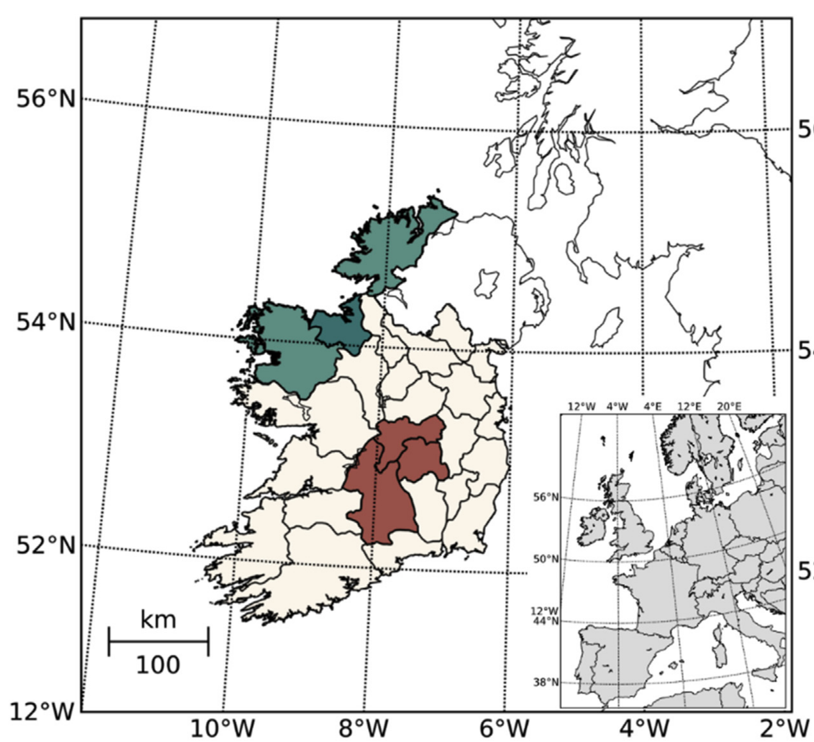

Fig. 1. Location of the northwest (shaded green) and midlands (shaded red) study regions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)