Section 3

Variations in Forest Management in Great Britain

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3. Variations in Forest Management in Great Britain

A.M. Thomson
Centre for Ecology and Hydrology, Edinburgh

3.1. Introduction

The C-Flow model developed by CEH (Cannell and Dewar, 1995; Dewar and Cannell, 1992; Milne et al., 1998) models the carbon accumulation over time in forest biomass, dead material, soil and forest products, as reported under category 5A2 (Land converted to Forest Land) in the GHG inventory. The input data for C-Flow are (a) areas of new forest planted in each year in the past and (b) the stemwood growth rate and harvesting pattern. The areas of annual new planting come from time series of broadleaf and conifer planting in each country of the UK, obtained from national statistics compiled by the Forestry Commission (Great Britain) and Forest Service (Northern Ireland). Stemwood growth rates and harvesting patterns are based on tree species and yield classes, with standard management scenarios for thinning and felling ages.

Up to the present inventory, C-Flow has not made use of the more detailed data available from the National Inventory of Woodland and Trees (NIWT) for Great Britain (Forestry Commission, 2003). Potentially this would provide more detailed information on forest species and age structure, at a larger spatial scale than the national level. Previous work (Milne and Brown, 2003) has shown that there are large discrepancies between the national planting time series and forest establishment rates inferred from the NIWT (Figure 3-1) and the causes of these merit further investigation. Additional data and management information on GB forests can be found in the historical woodland censuses. These censuses can be used with the NIWT to provide a more detailed picture of forest management in GB and to investigate the validity of C-Flow's standard management assumption.

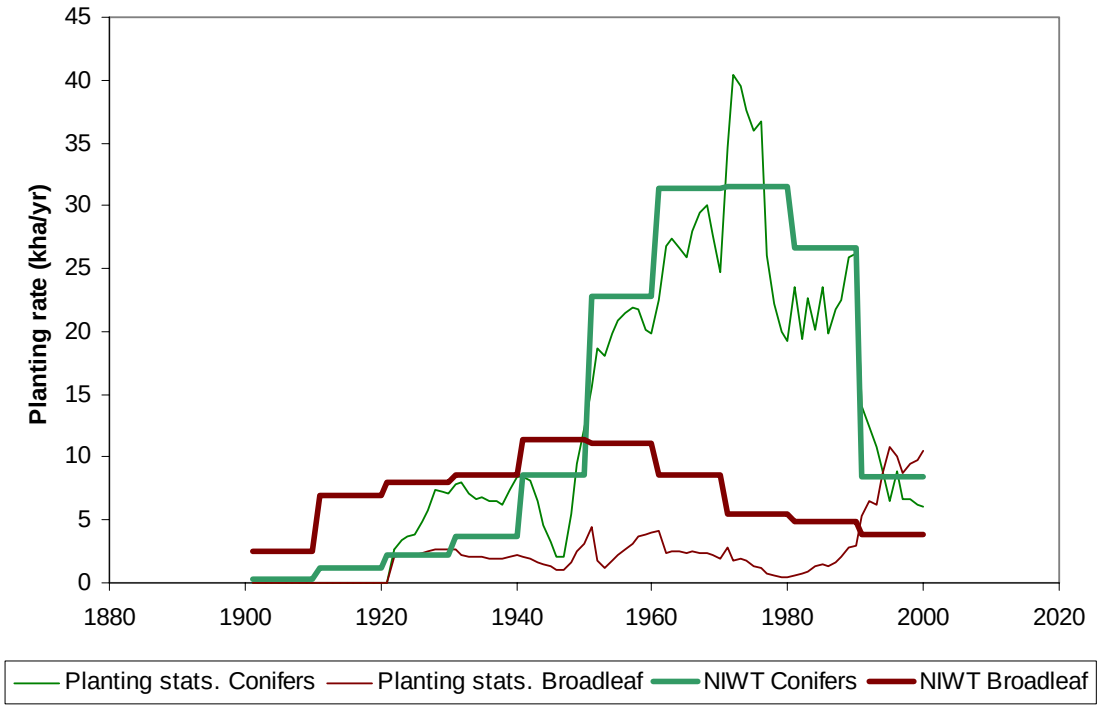

Figure 3-1 National planting rates vs. forest establishment rates inferred from the NIWT

By using these additional sources of information to explore variations in forest planting and management over time, the work in this chapter aims to fulfil three main objectives:

1. to explain the difference between the national planting time series and the NIWT;
2. to assess the validity of the assumption of standard management in C-Flow using information from the historical woodland censuses; and,
3. if applicable, to derive and apply new planting series for C-Flow.

3.2. Materials and methods

3.2.1. Data sources

3.2.1.1 National planting statistics

These statistics record the area of conifer and broadleaf woodland planted annually on previously unforested land. The statistics have been recorded since 1921 for England, Scotland and Wales by the Forestry Commission, and since 1900 for Northern Ireland by the Forest Service.

3.2.1.2 The National Inventory of Woodland and Trees (NIWT)

The NIWT consists of two surveys: the Main Woodland Survey (MWS) of woods ≥2 hectares, and the Survey of Small Woodland and Trees. The MWS is composed of a digital woodland map (derived from 1:25 000 aerial photographs) and a ground sample survey to evaluate woodland information, such as species, age and stocking (Forestry Commission, 2003). Survey fieldwork was undertaken between 1994 and 2000. Planning is underway to undertake a second inventory of GB woodlands (NIWT2) from 2007 onwards. There is no equivalent woodland inventory for Northern Ireland.

The establishment 'date' (within a decade) for a woodland stand is inferred from the average age of its trees recorded by the NIWT sample survey. For newly planted woodland the establishment dates and the planting date should be equivalent. However, because the NIWT functions as a 'snapshot' of woodland in the late 1990s, the following points should be noted. (1) Not all woodland established within a certain decade will appear in the equivalent age class in the NIWT, due to deforestation or disturbance. (2) The NIWT does not distinguish whether a woodland stand was afforested (i.e. established on previously unforested land) or replanted (established on land that had previously been forested but whose tree cover had been felled or disturbed in some way).

3.2.1.3 Historical woodland censuses

Censuses of woodland in Great Britain were carried out in 1924, 1947, 1965 and 1980 (Forestry Commission, 1928; Forestry Commission, 1952; Locke, 1970; Locke, 1987). The censuses are reported at the GB, national (England, Scotland, Wales) and county scale, but are not linked to woodland maps at the larger scales.

There are differences in sampling methodologies and minimum mapping units (from 1 to 5 acres, or 0.4 to 2 hectares) between censuses. However, very small woodlands are a small proportion of the total woodland area and sampling is sufficiently dense that the censuses are broadly comparable at the national level. Woodland area, type, species composition and age classes (from <10 years to pre-1860) are reported in all censuses. After a quality assessment,

the 1965 census was omitted from analyses, as it was not a complete survey of all woodlands (both state and private) and was not comparable with the other censuses. The quality issues associated with the different censuses were kept in mind during the analysis and interpretation. Commentaries in the census reports also give useful information on the processes affecting woodland areas in different parts of Great Britain.

3.2.2. Methods

The national planting series and the NIWT inferred establishment dates were compared for conifer and broadleaf woodlands, and for England, Scotland and Wales (NIWT is not available for Northern Ireland). The annual figures in the national planting series were aggregated into decadal figures to match the NIWT.

Changes in woodland categories and age classes were compared between censuses, to investigate changes over time. The 1924 and 1947 censuses report woodlands in 10 to 20 year age classes, while the 1980 and NIWT census link the age classes more closely with specific decades. The different classes were combined for analysis as shown in Table 3-1. Care was taken when interpreting changes in very young woodland (under 20 years old) as it is difficult to correctly identify the age of such woodlands during fieldwork. The 1947 census also lists an uneven aged class, which contained around half of the broadleaved woodland in England and Wales and 17% in Scotland.

Table 3-1 Combination of census age classes for analysis

Analysis age class	**Census age class, age in years**			
	1924 census	**1947 census**	**1980 census**	**NIWT (1999)**
1991-99				(1-9)
1981-90				(10-19)
1971-80			(1-10)	(20-29)
1961-70			(11-20)	(30-39)
1951-60			(21-30)	(40-49)
1941-50		(1-10)	(31-40)	(50-59)
1931-40		(11-20)	(41-50)	(60-69)
1921-30		(21-30)	(51-60)	(70-79)
1911-20	(1-10)	(31-40)	(61-70)	(80-89)
1901-10	(11-20)	*0.5**(41-60)	(71-80)	(90-99)
1861-1900	(21-40) + *0.5**(41-80)	*0.5**(41-60) + (61-80) + *0.25**(81-120)	(81-120)	(100-139)
pre-1861	*0.5**(41-80) + (over 80)	*0.75**(81-120) + (over 120)	(over 121)	(over 140)

The 1924 and 1947 censuses split forests between conifer, hardwood and mixed categories, but the 1947 census also reports forest as mainly coniferous and mainly broadleaved. This two-way split is used by subsequent censuses. The 1924 mixed woodland category is of varying significance between countries (30% of English woodlands, 20% of Welsh woodlands and 11% of Scottish woodlands) and falls predominantly into the pre-1900 age classes. In 1947 mixed woodland accounted for 11% of English woodland, 6% of Welsh woodland and 6% of Scottish woodland. The mixed woodland is split between the mainly conifer and mainly broadleaf categories in 1924 in the same proportion for pre- and post-1900 woodland as in 1947.

- Pre-1900 broadleaf:conifer split: 60:40 (England), 69:31 (Wales), 58:42 (Scotland)
- Post-1900 broadleaf:conifer split: 40:60 (England), 33:66 (Wales and Scotland).

3.3. Results

3.3.1. Differences in the national planting time series and the NIWT

Conifer planting in Scotland since the 1950s dominates the UK total, as shown in Figure 3-2 While both national planting series and NIWT inferred establishment rates of conifer woodland are broadly similar for individual countries over time, there are greater differences between the two data sources during certain periods. In the 1920s-1940s national planting rates ("afforestation") exceeds NIWT establishment rates in all countries. Afforestation rates dip in the 1940s in England and Scotland, but both afforestation and NIWT establishment rates increase in all countries between 1950 and 1970. Afforestation rates decline in England and Wales after 1970, but in Scotland rates do not fall until after 1990. The difference between afforestation rates and NIWT-inferred establishment rates increases in England and Wales from the 1970s, but this is not evident in Scotland.

In contrast, Figure 3-3 clearly shows that NIWT-inferred establishment rates of broadleaf woodland exceed afforestation rates in all countries from the 1920s to the 1990s. England and Scotland have increased rates of inferred woodland establishment between 1940 and 1960, which then gradually decline to 1990. In Wales, inferred establishment rates are higher in the 1930s and then decline to 1970, remaining steady after that. Afforestation exceeds NIWT-inferred establishment rates from 1990 onwards in England and Scotland. This is thought to be an artefact of the NIWT sampling method, as different regions within each country were sampled at different times (England was completed in 1998, Scotland in 1995 and Wales in 1997).

3.3.2. Evidence from the historical woodland censuses

The majority of conifer woodland in the UK is plantation forest established during the 20th century (Figure 3-4), which can be assumed to have a harvesting rotation of 50-70 years. Felling of woodland (or loss of area due to other disturbances) can be inferred from loss of area in age classes between successive censuses. Normal harvesting practice would explain some of the differences in planting/establishment rates at either end of the time period (shown in Figure 3-2), as in normal circumstances woodland planted in 1921-1940 would be felled and replanted in the 1980s and 1990s. This can be seen in the reduction in area between the 1980 and NIWT census in the 1921-30 and 1931-40 age classes. Other sources of difference may arise from normal management of conifer woodland planted before 1920 and the perturbation caused by the extensive felling during and after the 1939-1945 war. (This is particularly evident in the difference between the 1924 and 1947 censuses in the pre-1900 age class). There was also a reduction in rates of new planting at this time (presumably due to a lack of materials and labour).

Harvesting of pre-existing conifer woodland, if replanting is assumed, is sufficient to account for most of the difference between the afforestation rate and the NIWT-inferred rate during the 20th century. The uneven age class in the 1947 census only contains a small amount of conifer woodland, so does not affect the shape of the graphs. Loss of area in the 1950-1980 age classes between the 1980 and NIWT censuses is apparent in Figure 3-4. These changes in age structure between censuses suggest that some conifer forest may be managed on shorter rotations than that assumed by the standard management scenario. Conversely, some forests planted in the early decades of the 20th century may be managed on longer rotations. This may be due to the use of different conifer species: the standard scenario in C-Flow assumes that all conifer planting is of Sitka spruce with a 59 year rotation, but Scots pine (rotation of 71-75 years) and larch (rotation of 40-45 years) have also been widely planted. A shorter rotation

might also be a response to losses from natural disturbance, particularly wind throw (Grayson, 1989; Quine et al., 1995). The census reports also mention that replanting was not immediate after the extensive felling during the 1939-1945 war, and the age structure suggest that this replanting continued into the 1960s.

Analysis of the changing age class structure between censuses for broadleaf woodland (Figure 3-5) indicates different processes of woodland change, operating over longer timescales. In the UK the broadleaf woodland area has an older age structure than the conifer woodland area, and woodland that was established before 1920 is a larger component of the total. The uneven age class in the 1947 census is a very significant component in England (Figure 3-5(b)), complicating interpretation. Broadleaved woodland in Scotland was poorly reported in the 1924 census so the interpretation of change using these figures should be treated with caution.

Commentary in the census reports suggest that the difference between the broadleaf afforestation rate and the NIWT-inferred establishment rate has arisen from a combination of sources. These are: normal management (i.e. harvesting and replanting) of broadleaf woodland planted before 1920, conversion of coppice woodland to broadleaved 'high forest', the reclassification of mixed or scrub woodland to broadleaved woodland, and natural regeneration on forested areas that were cleared but not replanted between 1914 and 1945.

1. Normal management of pre-1920 broadleaf woodland. Given that harvest rotations for broadleaved woodlands under normal conditions are in the region of 90-120 years, some of the difference between the afforestation rate and the NIWT-inferred rate is a result of normal harvesting and replanting, although active management of broadleaf woodland also declined during the 20th century.

2. Conversion of coppice to broadleaved 'high forest'. The total area of broadleaf-based woodland categories (broadleaf high forest, coppice and mixed woodland) changed relatively little between 1924 and 1947 (Figure 3-6). In all countries the area of broadleaf high forest increased at the expense of coppice and mixed woodland categories. Commentary in the 1947 woodland census suggests that the expansion in the area of broadleaved forest, given the relatively small scale of active replanting, has been obtained partly by the reclassification of coppice (after abandonment of coppice management systems) and mixed forest as broadleaved forest (Forestry Commission, 1952). This process of coppice conversion seems to have continued between 1947 and 1980 in England and Wales (coppice in Scotland had almost entirely disappeared during the previous period). Coppice may also have been over-exploited and degraded to scrub woodland.

3. Mixed woodland and scrub conversion. The definition of mixed and scrub woodland changes between the historical censuses, and mixed woodland is not described separately after 1947, but is divided between the "mainly broadleaved" and "mainly coniferous" categories. Woodland that was not classified as broadleaved woodland at the time of one census, but as scrub or mixed woodland, may have developed into broadleaved woodland with age, and therefore will appear in the NIWT age classes as having been established further back in time. This process is reflected by comments in the census reports, for example:

> 'Most of the younger crops classified as mixed have been established with the object of raising crops of broadleaved trees with the aid of conifer nurses, and will, in due course, become classifiable as broadleaved when the conifers have served their purpose.' (Forestry Commission, 1952):50.

And:

> '…owing to less intensive agricultural land use and better control of fires, many commons and open spaces which fifty years ago were quite bare, today carry Stands of timber. In nearly all such cases an initial stage in this process is the establishment of Scrub.'(Forestry Commission, 1952):105.

4. Natural regeneration on cleared areas. Extensive felling of mature broadleaf woodland took place during and after the 1939-1945 war. Large areas were also cleared and abandoned during and after the 1914-1918 war. Such areas were classified as "felled" or "devastated" in the 1924 and 1947 census, and commentary in the reports suggests that only a percentage of these areas were replanted in the short term. The remaining unplanted areas, particularly in England, tended to revert to some form of broadleaved scrub or forest. This process may explain the peak in broadleaved woodland establishment between 1941 and 1960:

> 'Many of these crops are ones which arose from fellings during the Second World War, either from broadleaved crops cleared during the period or as a result of broadleaved species naturally regenerating sites which had previously carried coniferous or broadleaved crops…It is likely that many of the crops on sites felled during the First World War and in the twenties and thirties also arose in this fashion.' (Locke, 1987): 48

Both conversion of coppice to forest and natural regeneration of felled woodland will produce relatively young broadleaved woodlands on woodland sites that pre-date the 1920s. These woodlands do not contribute to the broadleaf planting statistics as they have not arisen from deliberate new planting, but should be visible in the NIWT age classes as woodlands between 30 and 80 years old. Coppice conversion (particularly of coppice-with-standards) and natural regeneration of devastated woodland would produce a bi-model age distribution, and would therefore account for the large area in the uneven age class in 1947. The proportionately large increase in the 1941-50 age classes between the 1947 and 1980 census in all countries is interpreted as being largely due to natural regeneration. Losses of mature timber (some due to normal harvesting, and some probably due to extensive felling during the 1939-45 war) are particularly evident in the change in the pre-1861 class after the 1924 census. In Scotland and Wales, the age classes in the 1980 and NIWT censuses seem to be stable after 1950.

In summary, different processes affecting broadleaf woodland age structure were more active in some countries than others: coppice conversion and active management (felling and replanting) is more prevalent in England, while scrub reclassification and natural regeneration are thought to play a greater role in Scotland and Wales. After 1990 the broadleaved planting rate exceeds that derived from the NIWT. This is thought to be due to the fact that the age classes recorded in the NIWT are based on samples collected in the early 1990s, and therefore do not capture later planting.

3.3.3. Standard and non-standard management in C-Flow

Changes in the standard management assumptions in C-Flow will affect the modelled carbon flux because the timing of forest growth and harvesting is altered. There is not necessarily a direct relationship between increased forest area and increased carbon fluxes. This variable impact is illustrated in Figure 3-7, which shows the estimated carbon flux (conifer and broadleaf woodland) by country. The greatest differences are apparent for England, where the inclusion of coppice/scrub conversion and natural regeneration of existing woodland increases the carbon flux by approximately 0.4 MtC a^{-1} between 1990 and 2004.

It was decided to include only adjustments to post-1921 woodland in this inventory, as with forest planted before 1921 and processes of woodland conversion and regeneration it is impossible to estimate the original establishment date of the woodland area. Evidence from a comparison of the various data sources suggests that the standard conifer management scenario of post-1921 forest in C-Flow could be adjusted. At present all conifer planting is assumed to be Sitka spruce, with a harvesting rotation of 59 years, and a yield class of 12 m^3 $ha^{-1}a^{-1}$. The C-Flow management scenario could be adjusted by using the current species class and afforestation series, but split between different rotation lengths.

Standard planting scenarios

- Planting 1921-1989– Sitka, 59 year rotation – England, Wales, Scotland, Northern Ireland
- Planting 1990-2004 – England, Wales, Scotland, Northern Ireland

Additional non-standard planting scenarios

- Planting 1921-1950, Sitka, 50 year rotation – England and Wales
- Planting 1931-1940, Sitka, 40 year rotation – England

The impact of these adjustments is relatively minor, producing an estimated carbon flux of 4.45 Mt C in 2004 compare to a flux of 4.40 Mt C without the adjustments (Figure 3-8), but represents a first attempt at improving the modelling of actual forest management in C-Flow.

With respect to broadleaf woodland, at present all broadleaf planting in C-Flow is assumed to be beech, with a harvesting rotation of 92 years and a yield class of 6 m^3 ha^{-1} a^{-1}. The management adaptation used for conifer cannot be used for broadleaved woodland as it is difficult to tell whether the length of the harvesting rotation has changed as the assumed standard rotation is so long. There is also the issue of whether conversion/regeneration is unintentional or deliberate forest management: sometimes it may begin as a natural process and then be brought under management at a later stage. The issue of how to modify base carbon emission/removal factors when woodland change does not result in soil disturbance also needs to be resolved. Therefore, at the present time, the standard management assumption for broadleaf woodland in C-Flow is left unaltered.

3.4. Conclusions

The additional information in the NIWT and the historical woodland censuses is useful for unpicking changes in woodland structure in Great Britain during the 20th century at the national scale, producing a more detailed picture than was previously available. The discrepancies between the national planting series and the NIWT can be explained in terms of normal harvesting practice and management and regeneration of woodland that existed before 1921. Broad-scale variation in harvesting rotations and unintentional processes of woodland change (coppice conversion and natural regeneration) can be inferred by examining the changes in forest age structure over time and using the commentaries in the censuses.

These historical data sources open the possibility of including woodland that was first established before 1920 (i.e. visible in the NIWT but not in the afforestation rates) in C-Flow. This would make it possible to include all British woodland in the C-Flow model, and therefore in the greenhouse gas inventory, but key issues remain. At present, forest carbon fluxes are reported under category 5A2 (Land converted to Forest Land) and zero flux is

assumed for category 5A1 (Forest land remaining Forest land). The inclusion of older forest would invalidate this assumption, and the assignment of forest fluxes between the two sub-categories (5A1 and 5A2) needs to be considered. Secondly, carbon fluxes in soil, as a result of forest planting on previously unforested land, are an important component of the overall forest flux. However, because the planting series only date from 1921 it is not possible to say whether forest dating from before this time was newly planted or of considerable age. Thirdly, the variability in methodologies and data quality between historical woodland censuses would make it unwise to extend the analysis below the national/regional level, making it difficult to model spatially disaggregated forest carbon fluxes (a long term aim in the greenhouse gas inventory). Finally, issues remain with the mismatch between the national planting series and the NIWT in the 1990s, but it is hoped that this can be resolved by using data from the Woodland Grant Scheme to produce a more spatially detailed picture of recent forest planting.

3.5. References

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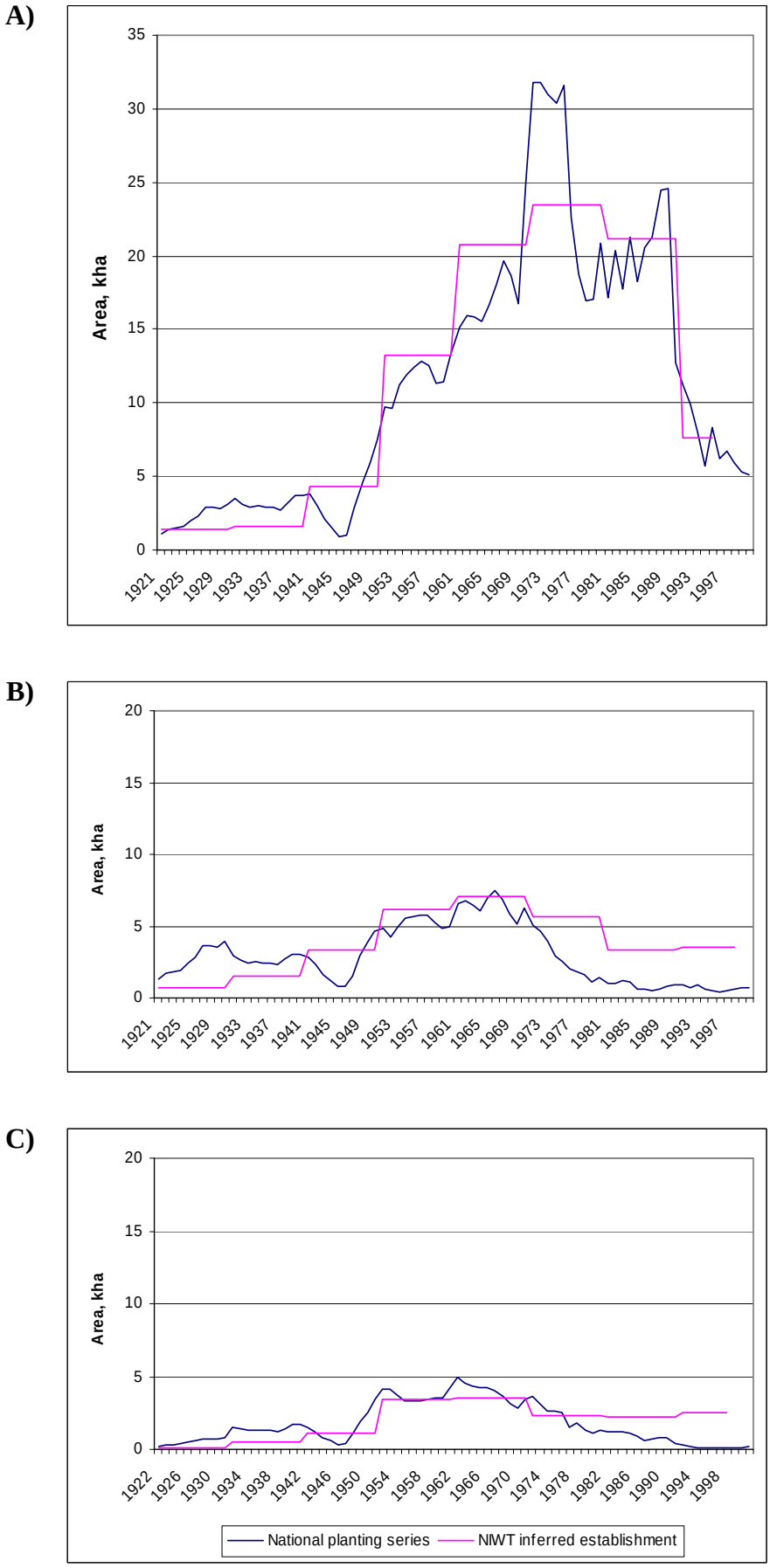
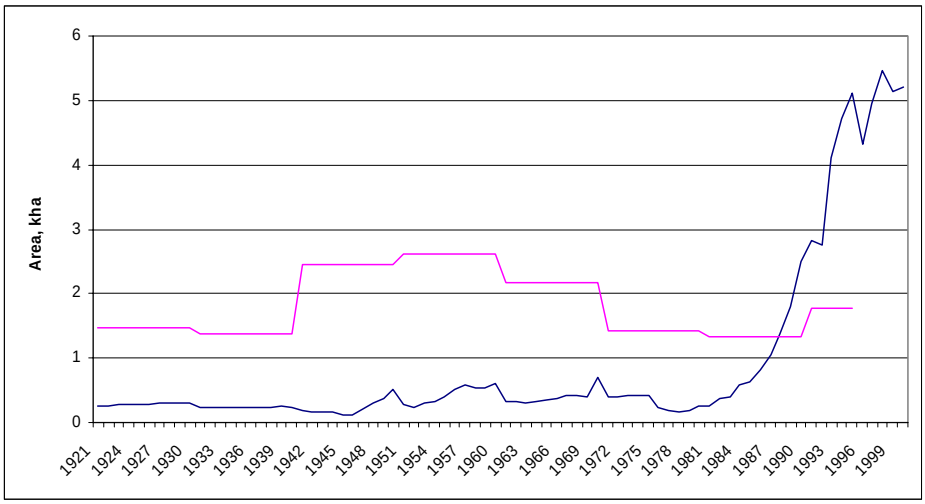


Figure 3-2 Differences in conifer planting rates in A) Scotland, B) England and C) Wales.

A)



B)

C)

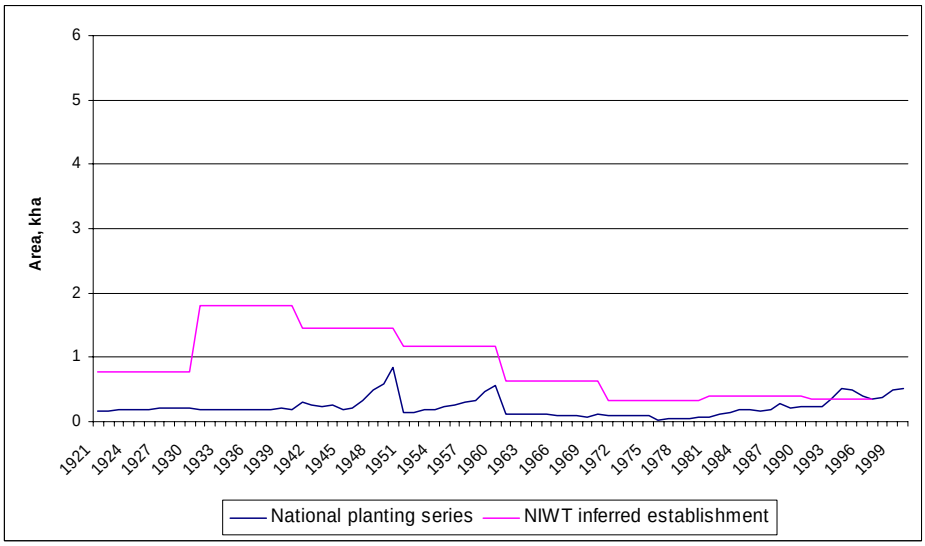


Figure 3-3 Differences in broadleaf planting rates in A) Scotland, B) England and C) Wales.

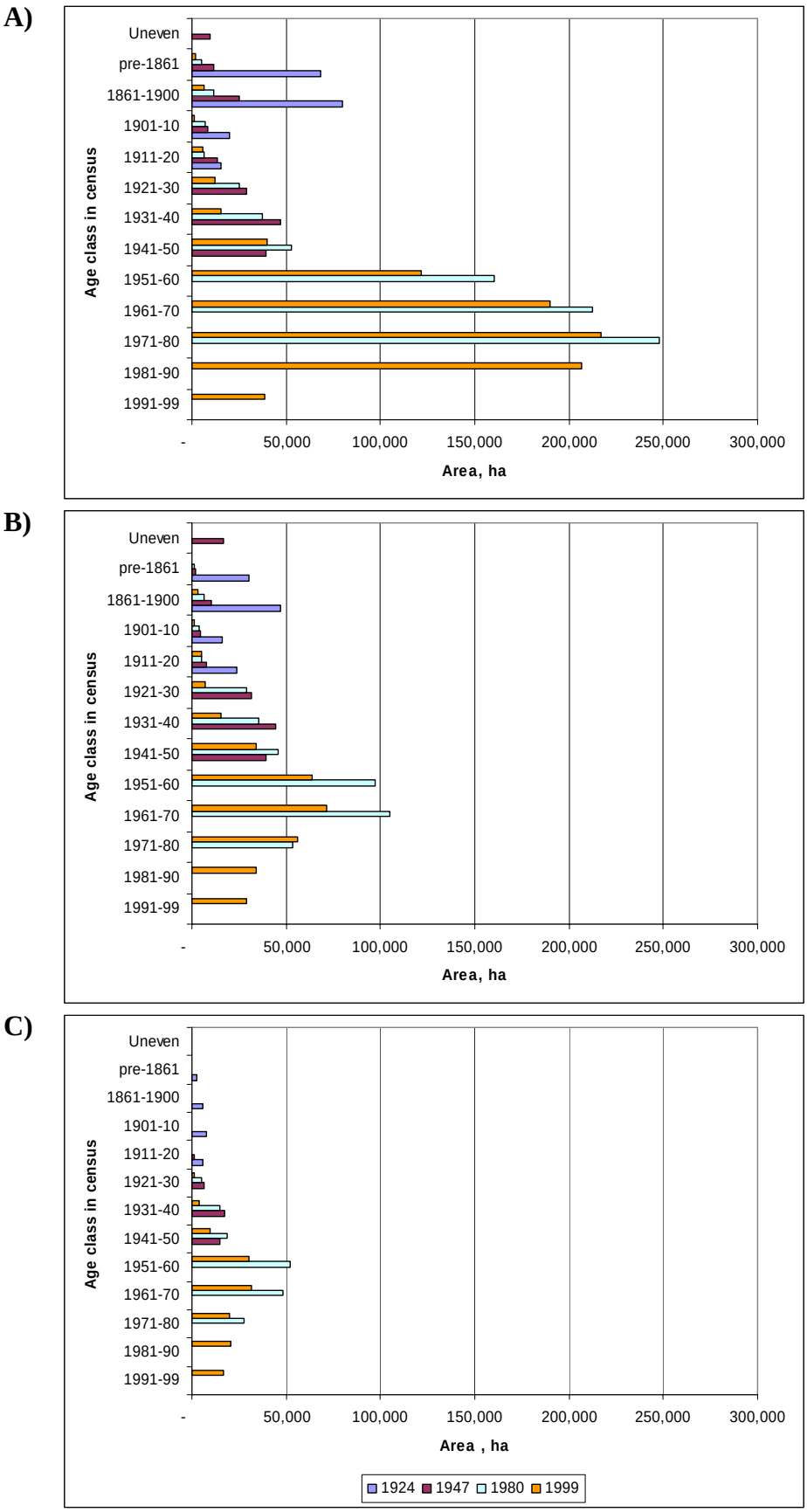


Figure 3-4 Conifer woodland age classes from the historical woodland censuses in A) Scotland, B) England and C) Wales. (1924 values include some mixed woodland).

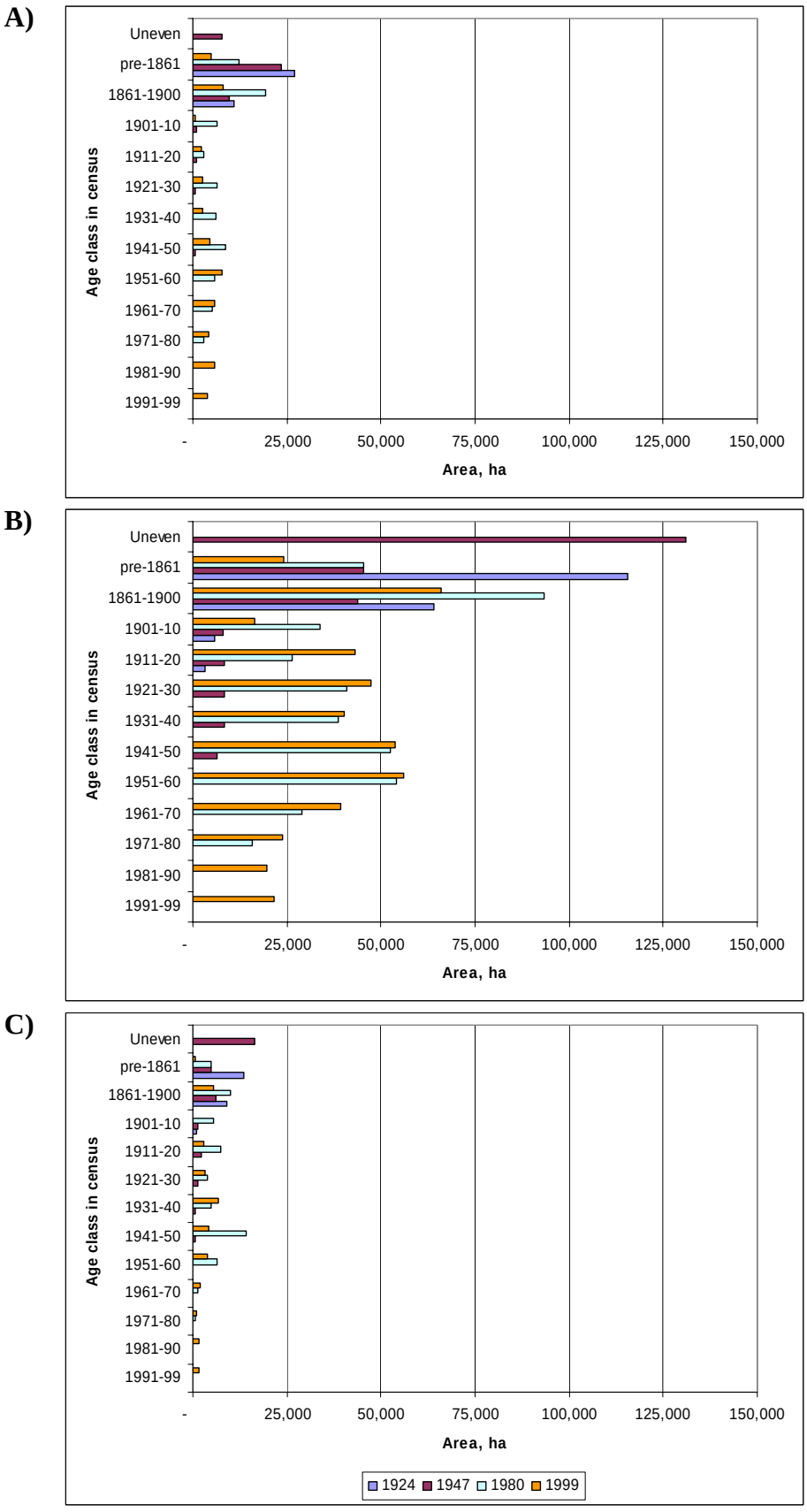


Figure 3-5 Broadleaved woodland age classes from the historical woodland censuses in A) Scotland, B) England and C) Wales. (1924 values include some mixed woodland).

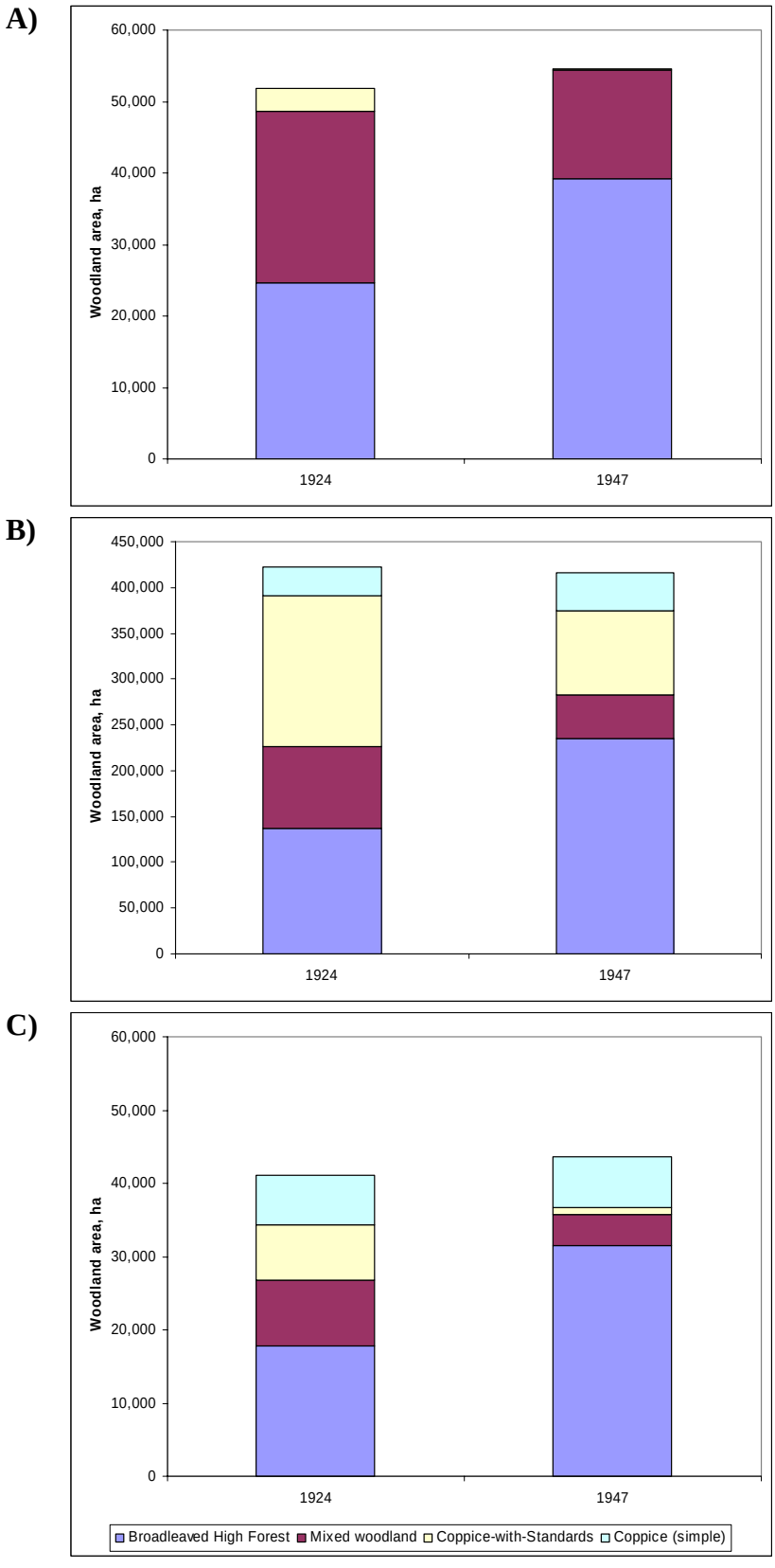


Figure 3-6 Areas of broadleaf-based woodland categories in the 1924 and 1947 censuses, in A) Scotland, B) England and C) Wales.

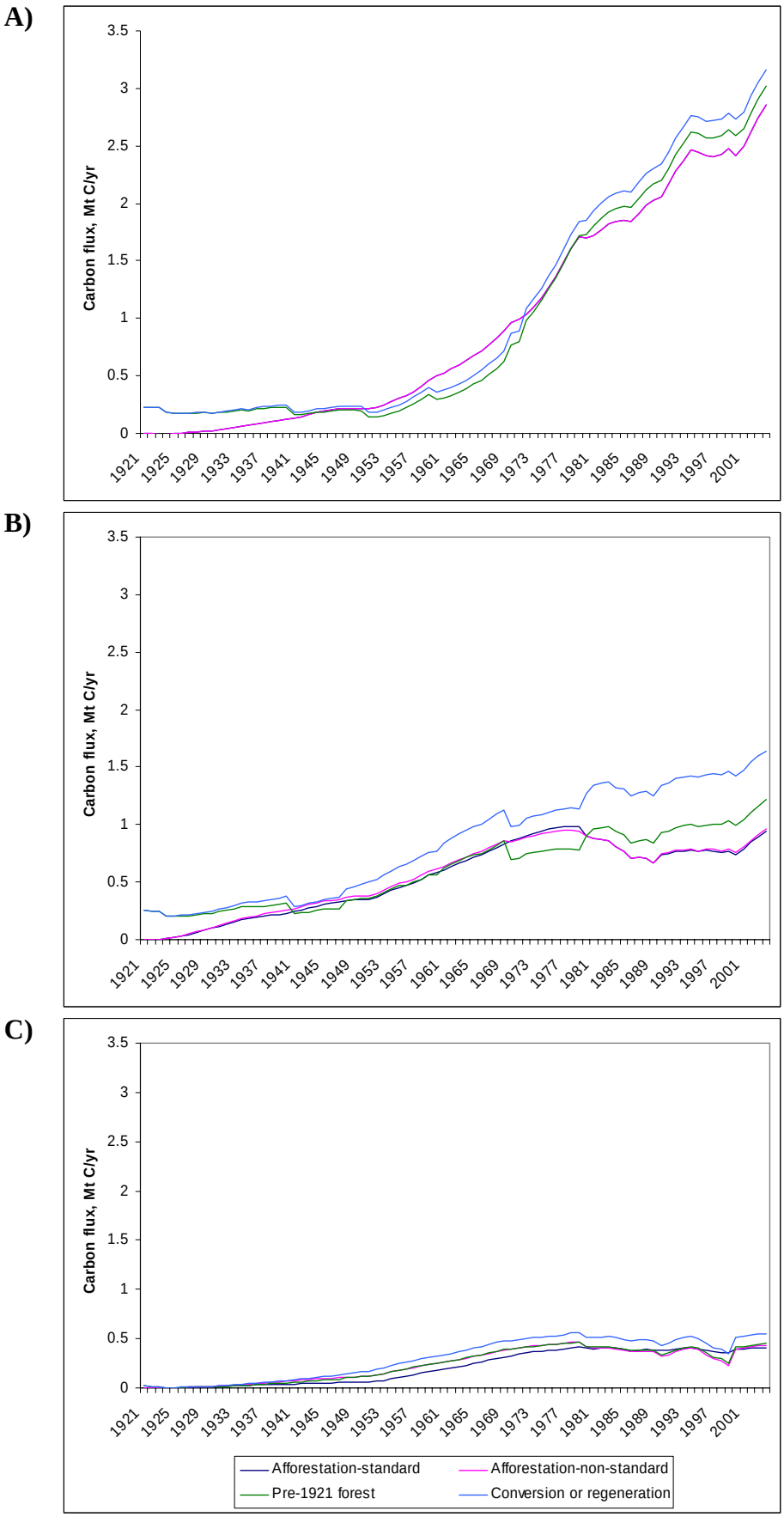


Figure 3-7 Additional impact on forest carbon fluxes through changes in management and inclusion of pre-1921 forest, in A) Scotland, B) England, and C) Wales.

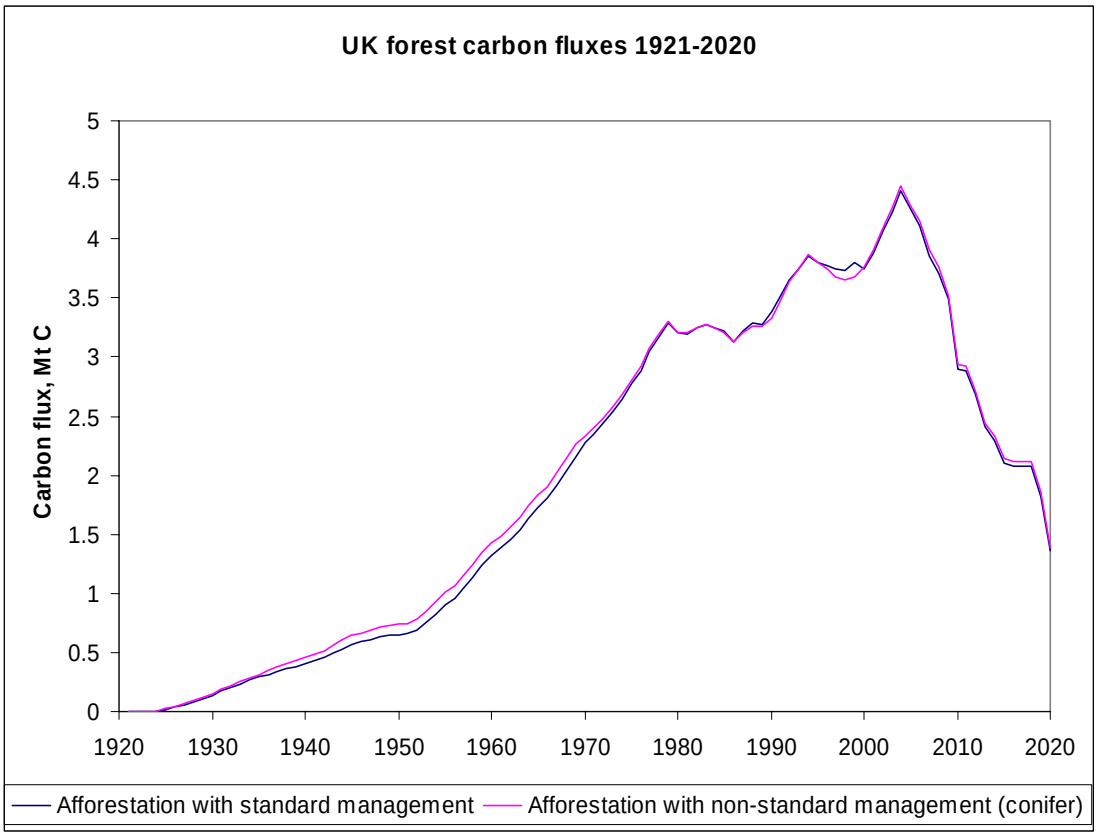


Figure 3-8 Impact on forest carbon fluxes in the UK modelled by C-Flow with standard and non-standard management.