Carbon offsetting through planting trees: myths and realities

Executive Summary

Carbon offsetting is increasingly promoted as a way for consumers who are undertaking carbon-emitting activities, such as air travel, to offset the negative impact of their activity by paying for others to reduce their emissions or to undertake activities designed to absorb carbon dioxide (CO_2).

One carbon offsetting mechanism, of direct relevance to the Cambrian Mountains, is that of planting trees to offset emissions by absorbing carbon from the atmosphere as they grow. This is politically very popular: the idea of planting a tree to wipe out the harm done by human activity naturally appeals to all sectors of society.

But in practical terms, a newly-planted tree takes decades to grow sufficiently to capture substantial quantities of carbon. Further, the kind of broadleaved woodlands full of open glades which are preferred for their amenity value are too low density as to bulk wood production to provide useful levels of sequestration. For practical purposes as regards carbon sequestration, the discussion must be around denser plantations including a large proportion of quick-growing conifers

The amount of CO_2 a growing tree absorbs varies depending on: tree species; soil type; amount of soil litter; and below-ground biomass. Sitka spruce are the most favoured species for commercial plantations and for carbon capture as they grow relatively quickly. However, monocultures of spruce do not promote biodiversity of native flora and fauna. In areas such as the Cambrian Mountains where the growing season is shorter than warmer and lower-lying land, trees grow more slowly.[1] The changing climate, increasing prevalence of imported tree pests and diseases, combined with the relatively inauspicious geography, is likely to mean that many trees planted and simply left to grow do not make it to maturity even if left undisturbed for the necessary length of time.[2] Trees which die prematurely – for instance shallow-rooted conifers on exposed hills falling victim to winter winds - release much of the carbon they have trapped to date back to the atmosphere as they decay.

Trees which, on reaching maturity, are harvested are also likely to release some or all of the captured carbon at that point: either through being used for 'renewable' energy generation or short life products such as pallets or fence panels, or through the unavoidable wastage both of less

[1] The Welsh Government' Glastir assessment of Welsh land area suitable for tree planting acknowledges that the uplands in general, including the high ground of the Cambrian Mountains, is least suitable for this purpose.
[2] *Tree suitability modelling: panting opportunities for sessile oak and sitka spruce in Wales in a changing climate* Environment Systems Ltd report for the Climate Change Committee January 2020

useful brash (twigs and branches), which are left on the ground, or the substantial volume (up to 50%) reduced to sawdust (and then disposed of) when trunks are milled to produce useable planks. The timber then needs to be put to long term use for the captured carbon to remain sequestered for a meaningful period compared to the persistence in the atmosphere of the emissions which it was planted to offset. But at present only around 20% of sitka spruce grown for commercial forestry goes into construction.[3]

Furthermore, competing potential land-uses, and even the demand for locally sourced timber, mean that there is no guarantee plantations will actually be left to grow until the promised mass of carbon has been captured.

The promise of offsetting today's carbon emissions by planting trees is further undermined by the fact that the average carbon footprint of a UK citizen according to the World Bank is 6.5 tonnes per annum, and the average life expectancy is 80 years, totalling 520 tonnes of CO_2 per person. To capture the projected emissions of the current UK population of 68 million would require a significant part of the UK's total land area to be planted with trees. The Climate Change Committee projects that 22% of current agricultural land will need to be planted with trees to meet the UK government's 2050 net-zero carbon target.[4]

Finally, studies have shown that soil disturbance during establishment of a new plantation on peatland and other highly organic soils can also release sufficient carbon previously stored in the soil to negate the subsequent sequestration by the trees over large areas of land.

This paper reviews the potential for carbon sequestration in the existing Welsh woodlands and the contribution which possible new woodlands might make. It concludes that although Welsh woodlands are undoubtedly contributing to carbon sequestration, increasing that sequestrations by a useful amount through new planting is not likely to be particularly successful for environmental, political, forest mensuration, timing and perhaps other forest management reasons.

More effective alternatives to tree plantations

In contrast to the limited opportunity presented by planting new woodlands, there is substantial untapped potential for additional storage from large areas of existing forest across the UK which are currently not meeting their carbon storing potential. The UK government's Climate Change Committee says that the vast majority of the UK's broadleaf forests are currently unmanaged or at least undermanaged. These stands are often damaged by deer or squirrels, or afflicted with disease. Since the trees are not being grown for timber, their lack of economic value means landowners are often unwilling to invest in them. If 80% of the UK's broadleaf forests were brought into active management in accordance with the UK Forestry Standard with the clear objective of sequestration,

---

[3] Andrew Allen, Woodland Trust, quoted in *In depth Q&A: how will tree planting help the UK meet its carbon goasl? https://www.carbonbrief.org/in-depth-qa-how-will-tree-planting-help-the-uk-meet-its-climate-goals#2help*

[4] Se discussion in Gabbiatis, *How will tree planting help the UK meet its climate goals?* Carbon Brief March 2020 [In-depth Q&A: How will tree planting help the UK meet its climate goals? (carbonbrief.org)](https://www.carbonbrief.org/in-depth-qa-how-will-tree-planting-help-the-uk-meet-its-climate-goals)

the CCC projects that significant carbon savings would result. Management can also help younger and better quality trees to thrive, which can promote carbon storage and also resilience, avoiding carbon losses from dead trees. Moreover, these trees do not require land being freed up from other uses. [5]

Natural regeneration of woodland can also capture more carbon, and may in appropriate sites and if appropriately managed do so more quickly and securely than the planting of trees, at lower cost, and result in woodland which is more diverse and resilient to climate change for the long run than a plantation, thereby contributing to carbon capture as well as stabilisation of soils, reduction of flood risk and improvement of biodiversity.

Finally, deep peat is acknowledged to be an effective form of carbon sequestration (during formation) and storage, provided that it remains undisturbed.[6] The Cambrian Mountains include a significant portion of Wales' peatlands; although not a simple undertaking, restoration and preservation of these is a more reliable mechanism to use this land area to ameliorate – or at the very least not worsen - climate change than increasing the area of monoculture forestry plantations.

Reviewing Carbon Sequestration in the Existing and Possible New Welsh Woodlands.

1. **The basis of assessment**

1.1. The approach taken here is to consider the annual wood increment of stand (plantations) of trees.

1.2. One can consider each year's increment as absorbing a certain amount of carbon dioxide. What appears most relevant to the current assessment is the amount of carbon dioxide absorbed by the annual wood increment of trees compared with the current carbon dioxide in the atmosphere.

1.3. An issue is that the annual wood increment of a tree varies according to age. For this review the maximum rate of annual wood volume increment over a rotation which maximises volume (resulting in maximum sequestration) is used. This is the most relevant value when considering the long term. It errs on the side of optimism where the carbon sequestration of stands is concerned.

2. **Basic numerical considerations**

2.1. All the numerical values quoted below are based on official or other authoritative sources. It is thought that the choice of policy from the available policy options will not be sensitive to changes in the values used.

2.2. Two models of yield are considered. Firstly oak attaining it's the maximum annual rate of growth of 6 m³ per hectare at around 70 years. This is likely to be above the average Welsh rate. On sites growing such oak one could expect as an alternative Sitka spruce achieving a

[5] This land is, however, fragmented, in multiple private and public ownership and may be being managed according to other legitimate objectives such as nature conservation.

[6] See for example Natural England Research Report NERR094 *Carbon storage and sequestration by habitat: a review of the evidence (second edition)* April 2021

maximum rate 12 m³ per hectare at 60 years. The current Welsh average rate of Sitka Spruce growth will probably be somewhere below this.

2.3. Though varying somewhat by species, a generalised value of 50% by oven dry weight has been taken for the carbon content of wood. UK wood production tables give output in volume terms of standing trees. The volumes quoted need to be converted into 'green' or felled weight and their actual carbon content will further depend on the felled moisture content and basic density, both of which vary according to species. The volume figures are for wood material down to 7 cms over bark.

2.4. The calculations are set out in the Appendix. In summary, the annual carbon dioxide equivalent sequestration of the models used are:

2.4.1. For oak:

An average wood production of 6 m^3 per year equates to 6.3 tonnes per year which comprises a basic carbon content of 1.7 tonnes and a sequestered carbon dioxide equivalent of 6 tonnes annually.

2.4.2. For Sitka Spruce:

An average wood production of 12 m^3 annually equates to 11.1 tonnes per year comprising a basic carbon content of 1.9 tonnes and a sequestered carbon dioxide equivalent of 7.6 tonnes annually.

2.5. There are two particular points to note in the above values. Firstly that the yields quoted are for idealised plantations. Actual production will be significantly less. Production forecasting methods used in forest management will take account of this. Again, the assumption made errs on the side of optimism in respect of carbon sequestration.

2.6. Secondly, the average annual wood production quoted above is the maximum that is attainable and assumes a rotation of 60 years for Sitka Spruce and 70 years for oak. Up until the rotation age the average annual production will be less and significantly so in the first twenty five years or so of the rotation even though the maximum rate of annual production (as distinct from the average) will occur at around 30-40 or so years. In developing a policy it would appear to be important to take account of the period in the early years when wood increment and potential sequestration is low.

3. Optimal management for sequestering carbon

3.1. For practical reasons and for certain conservation advantages in well-managed forest, in Wales the form of management aimed for is to plant then, as the crop grows, to thin at five yearly intervals and then to fell at a suitable 'optimal' rotation age. Sometimes, usually imposed by circumstances, the form of management may be not to thin the crop at all and to fell at an optimal rotation age.

3.2. Neither of the above forms of management lead to very significant differences in total volume production and therefore, theoretically at least, in total carbon sequestration. Nevertheless if thinnings are taken from the tree crop these can be used for paper or for wood-burning. Wood-burning, but paper too, leads to an earlier than desirable release of carbon dioxide into the atmosphere. In general the main crop left after thinning grows at the same rate regardless of being thinned, given that the thinning is not excessive. It is not clear that the released carbon dioxide from thinnings is reabsorbed by the growth of the main crop.

3.3. For thinnings of broadleaves it seems that in recent years the main use is for burning.

3.4. Thus considering optimal management policies for the sequestering of carbon the "no thin" method of management is likely to be best for storing carbon even if it should be that there is a slight drop in total volume production. Different species will have a different degree of robustness to a no thin policy. In unthinned stands there will be dead, decaying individual trees which detract from the sequestration objectives of a policy.

3.5. Stands at the final felling age will have sequestered the carbon from each annual increment of wood over its lifetime. It will therefore contain a substantial amount of sequestered carbon. The rate of release of this carbon will depend on the end use of the felled wood. This matter is not considered further.

3.6. In the past there has been publicity in Wales for what has been called the 'continuous cover' way of managing forest stands. This minimises breaks in the canopy whilst allowing a certain amount of thinning. It could be that this is better for sequestering carbon and then other management methods. Even so it has not been shown to be a practicable form of management in Wales.

4. Conflicts with environment

4.1. Management policy for maximising the sequestering of carbon in woodland is likely to conflict with the environmental and social benefit aspects of woodlands and forests.

4.2. Surprisingly, it emerges from the figures quoted above that the oak model is not particularly distant in its sequestration possibilities from the much more wood volume productive Sitka Spruce model. Nevertheless the soil quality and other environmental factors needed to plant productive oak will result in a very restricted range of land being available for it. A policy of impact will need a substantial element for conifer planting owing to the nature of the planting sites likely to be available.

4.3. An optimal carbon sequestration policy could thus have landscape effects and also adversely influence flora and fauna. Unthinned stands would be virtually inaccessible for walkers.

4.4. In discussions of carbon sequestration, pictures are commonly seen of the type of woodland valued by the public. These are often of widely spaced broadleaved trees and woodland glades. This type of woodland is not particularly conducive to sequestration though of course the presence of trees does lead to some effect.

5. The Possible Impact of existing and new Welsh woodlands on carbon dioxide amelioration in Wales.

5.1. The net carbon sequestration of UK woodlands is available at https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/uk-forests-and-climate-change/carbon-sequestration/

5.2. There are caveats to be made but the research estimate is a net 20.5 million tonnes of carbon dioxide sequestered in UK woodlands and forests. There is no separate figure for Wales but Welsh woodlands are approximately 10% of the UK whole so applying this to the above UK figure results, not unreasonably, in an estimate of approximately 2 million tonnes of carbon dioxide sequestered in Welsh Woodlands in 2019.

5.3. One can relate this to the published figure for carbon dioxide equivalent greenhouse gas emissions in Wales's of 38.5 million tonnes. (See: https://statswales.gov.wales/Catalogue/Environment-and-Countryside/Greenhouse-Gas/emissionsofgreenhousegases-by-year)

5.4. Existing Welsh woodlands' contribution of something like 5% carbon sequestration is not an inconsequential amount and is to be welcomed. It does though relate to 305,000ha. of woodlands of all types, which represents 15% of the total area of Wales.

5.5. The question then arises as to what contribution, additional to the current Welsh woodland area, new planting can make to the further reduction of atmospheric carbon dioxide. The hiatus between establishing a woodland and it sequestering significant carbon has already been mentioned. It is reasonable to think that it will take at least 30 years for a new planting to start significantly contributing to carbon sequestration.

5.6. The most recently available figures show that only 80 ha. of new planting was carried out in Wales in 2018-19. It will take time to increase the rate of new planting, if only because of the time scale of arrangements for finding land, purchasing land and obtaining regulatory permission for the type of planting proposed. It does not seem outrageous to suggest that it might be 40 or more years before a revitalised new planting policy as a whole can have a convincing influence on the level of sequestration. Even then it is doubtful that there will be a method of objectively measuring its effect.

5.7. It is considered that the most relevant criterion in determining the adequacy of new planting is that of the hectares of new forest, in being on a long term basis, which on an annual basis might make a useful contribution to ameliorating atmospheric carbon dioxide.

5.8. To give some context one can consider that an average person breathes out approximately three tonnes of carbon dioxide annually. There are 3.2 million people in Wales so the total amount breathed out is around 9 million tonnes. The estimate required is the amount of woodland that needs to be in being on a normally managed basis to sequester the carbon dioxide exhaled.

5.9. The figures in paragraph 2.4 above arrive at a value for the oak model storing 6 tonnes of carbon dioxide, on average, annually per hectare. In this scenario, to absorb the carbon dioxide breathed out by the people of Wales would need around 1.5 million hectares of idealised oak planting. The equivalent for the Sitka Spruce model with the idealised potential of 7.5 tonnes of annual carbon dioxide storage is around 1.3 million hectares of new planting. These area estimates represent four or five time the current area of Welsh woodland.

5.10. The foregoing values are probably optimistic. There is nevertheless some conviction in them in that they are comparable with values derived from the previously quoted 20.5 million tonnes of sequestration from a total UK woodland area of just over 3 million hectares. This equates to an average net sequestration of 6.8 tonnes per hectare. From this figure the 9 million tonnes of carbon dioxide breathed out by the Welsh people (and excluding all other sources of carbon dioxide emission in Wales) would demand a total area in being of 1.3 million hectares of Welsh woodland similar in form to the current Welsh woodland estate. This would require an extra one million hectares above the current Welsh woodland area. In terms of ball park values it is not very different from those previously arrived at. On a pro rata basis, doubling the size of the existing Welsh total woodland area might in the very long term potentially ameliorate atmospheric carbon dioxide, admittedly considering just its present level, by an additional 5%.

6. Availability of land for planting

6.1. ***If*** new woodlands were planned to have a further 5% emission amelioration contribution to the Welsh total 38.5 million tonnes of emitted greenhouse gas quoted at paragraph 5.3 above, then the figures available in this review indicate suggests that the current woodland area would need to be doubled to be 30% of the land area. Even so, for the new planting to double the impact of the existing 305 kha. of Welsh woodland would take very many years.

6.2. Any significant contribution above this level would imply an order of 1 million ha. or more of new planting, which only starts taking effect in the long term of 30 years or beyond.

6.3. The total area of Wales is approximately 2 million hectares. Over 30% of Wales is designated in some way or other. Wales is intensively used compared with, say, Scotland. It is not easy, perhaps impossible in practical terms, to see where the land for significant woodland carbon sequestration is going to be found.

7. Woodland management considerations

7.1. The Welsh uplands would have to take their share of planting. It must be remembered that such an environment is not conducive to broadleaves and leads to a lower production level in conifers. Establishment is not a matter of placing the tree in an open Hall in a moorland; the plantations we see in our hills have been mostly established by extensive soil disruption through ploughing and draining.

7.2. The life of an upland woodland may fall far short of what is considered optimal. An important determinant of longevity of upland coniferous plantations is the wind, and it is this factor which determines its life more than any potential biological influence.

7.3. For conifers especially, not felling the woodland at all is hardly a practical possibility as the trees would succumb to windblow with resulting dead tangled stems, carbon release from rotting and a general unacceptable visual state.

8. Economics of Forest Planting

8.1. It is not intended to assess the economics of planting trees except to make the following comments.

8.2. In the now-distant past it has been suggested that the monetary return of a forestry investment to the State is of the order of 3% net of inflation. Over the years, the emphasis on managing for non market benefits makes it likely that the monetary return will now be less than that. Including the social benefits (usually difficult to assess) would raise the return above that suggested.

8.3. Tree planting is a long term project with the costs being mainly front loaded and the money revenues, and perhaps most other benefits, being loaded later into the rotation (of the order of 30 years and more beyond planting). The 'discount rate' adopted can have a highly significant effect on the financial profitability of a forestry investment. The discount rate can also be viewed as relating to the 'time preference' of any advantage gained. A need to have early results can be reflected by adopting a higher discount rate in assessing competing projects.

8.4. The economics of tree planting will vary according to ownership, state or private. State ownership may take into account the non-market benefits of trees. The element of financial return will loom much larger in private planting by farmers and others. It would be unreasonable to expect a private owner to include a large element of unquantifiable social benefit yielding no financial result.

8.5. It is possible that the return on forestry investment to an individual is not significantly related to the value of wood but to other influences, of which taxation advantages may be significant as may be the value of land as a protection against inflation. There is a 'market' for forest plantations and it may be that these factors are the main influencers in determining the profitability of forestry to individuals. The vast majority of new private planting over the last

50 years is probably due to the taxation advantages. To qualify for these advantages a woodland has to be 'commercial', though there seems to be no precise definition of that term.

8.6. For some indication of the return from private forestry investment see: Financial return from forestry investment - Forest Research. This summary quotes a three year average return of 13.3% net of inflation in 2016. It is most unlikely that this return is significantly influenced by the price of wood. It can be considered to relate to high worth investors.

8.7. The entire thrust of Welsh government policy on new planting has been through a farm woodlands scheme. It has had no great effect to date, as evinced by the 80 ha. annual new planting achievement mentioned above.

9. **Political**

9.1. The establishment of the large upland forests in Wales has had its fair share of controversy (for example what was called the Towy Valley Afforestation scheme of circa 1951).

9.2. There has been much opposition by farmers, and on the whole government has sided with them perhaps because they hold the votes. Already in 2021 there is vocal resistance to the purchase of farms for tree planting.

9.3. The continued support of government in a practical way cannot be guaranteed. Certainly existing farm woodland schemes are not likely to have impact on carbon sequestration.

9.4. Though government grants can stimulate interest the decision to plant a new woodland is in private hands. The decision to follow a policy which is optimal for sequestration is also in the hands of the private manager. The large scale increase in planting and the achievement of social objectives may need cohesive planning, which is not particularly easy if it is in the hands of separate private owners even if they include large forestry companies.

9.5. Somewhat similar woodland creation pressures existed in implementing post war forest expansion in 1945. At that time forestry and its expansion was in the almost complete hands of the then Forestry Commission, best regarded as a body which at the time was somewhat distant from central government. Times have changed, government attitudes appear to be more bureaucratic and it is not suggested that the Forestry Commission would have been more successful to-day.

9.6. Nevertheless if it is regarded as an important task then woodland expansion may need to be in centralised hands with a clear obligation to develop suitable policies and act upon them.

10. **What can be concluded?**

10.1. Welsh woodlands are contributing in terms of carbon sequestration but not in an overly significant manner. Increasing the sequestrations by new planting is not likely to be particularly successful for environmental, political, forest mensuration, timing and perhaps other forest management reasons.

JFM 5/12/21

Appendix

Carbon Content of Sitka Spruce and Oak

Values from Forestry Commission Booklet 39

Sitka Spruce (SS):

To convert green volume to green tonnes: divide by 1.08 ; thus 1 m^3 =0 .92 green tonnes of SS
Convert SS green tonnes to oven dry weight;
moisture content of green SS = 164%
thus total weight = ovenDryWeight +164%
= ovenDryWeigh +(1.64 * ovenDryWeight)=2.64 * ovenDryWeight

Thus for 0 .92 green tonnes of SS: ovenDryWeight=0.92 / 2.64= 0.348 tonnes
An oven dry weight of 0.348 contains 50% carbon= 0.174 tonnes of carbon
Since 0.92 green tonnes of SS = 1 m^3 of SS then 1 m^3 of SS contains 0.174 tonnes of carbon.

carbon mass of 1 tonne is contained in 3.67 tonnes of carbon dioxide

Thus 1 green m^3 of SS sequesters 3.67 * 0.174 tonnes of carbon dioxide= 0.63 tonnes of carbon dioxide

Therefore an annual average increment of 12 m^3 per hectare sequesters 0.63 * 12=7.6 tonnes of carbon dioxide averaged annually.

Oak:

Oak green volume to green tonnes: divide by 0.98 ; thus 1 m^3 = 1.02 green tonnes of Oak

Green tonnes to oven dry weight: moisture content of green oak = 89%
Thus total weight = ovenDryWeight + 89%= ovenDryWeight + (0.89 * ovenDryWeight)= 1.89* ovenDryWeight

Thus for 1.02 green tonnes of Oak : ovenDryWeight=1.02/1.89 = 0.54 tonnes
An oven dry weight of 0.54 tonnes contains 50% carbon= 0.27 tonnes of carbon
Since 1.02 green tonnes of Oak = 1 m^3 of Oak then 1 green m^3 of Oak contains 0.27 tonnes of carbon.

A carbon mass of 1 tonne is contained in 3.67 tonnes of carbon dioxide

Thus 1 green m^3 of Oak sequesters 3.67 * 0.27 tonnes of carbon dioxide= 0.99 tonnes of carbon dioxide
Therefore an annual average increment of 6 m^3 ***per hectare sequesters 6 * 0.99 tonnes = call it 6 tonnes annually of carbon dioxide.***