Can silvo-pastoral agroforestry systems contribute to Scotland's emission reduction targets?

Matthew Saunders[1], Mike Perks[2], Bill Slee[1], Duncan Ray[2], Robin Matthews[1]

[1] James Hutton Institute, [2] Forest Research

1. Key Points

- Significant carbon and greenhouse gas emission savings can be made through silvo-pastoral agroforestry systems[1] in which woodlands or forests are integrated with forage and livestock production systems.
- Between 12-20 years, depending on yield class, are required for broadleaf silvo-pastoral agroforestry systems to recover the soil carbon lost during land conversion (from managed grassland to silvo-pasture).
- The net carbon uptake and potential GHG emission savings of a low tree density silvo-pastoral agricultural system can be increased by between 55 to 107 t C ha^{-1} for example, over a 55 year period of growth, depending on site productivity.
- Agroforestry systems can provide multiple benefits, including diversification of farm income, shelter for livestock, fuelwood, carbon sequestration, nutrient management, reductions in soil erosion and leaching, biodiversity enhancement, and amenity value.
- Tailoring of incentive schemes to account for lower planting densities may improve the uptake rate of silvo-pastoral systems.
- Additional climate mitigation carbon benefits may be accrued from the use of timber products arising from agroforestry.

2. Introduction

This policy brief reports the findings of the research undertaken by the James Hutton Institute and Forest Research to identify the potential of agroforestry options to achieve carbon savings in Scotland. The Scottish Government supports a policy to create 100,000 hectares of new woodland by 2022, which will make a significant contribution to achieving Scotland's long-term greenhouse gas (GHG) emission reduction targets (Forestry Commission Scotland, 2009; Scottish Government, 2013; WEAG, 2012). However, to date, the uptake of woodland expansion opportunities in Scotland has not reached 10,000 hectares per year. This may, in part, be attributed to large areas of Scotland being unsuitable or unavailable for afforestation, such as the deep peat soils in uplands, prime agricultural areas or land that has conservation or heritage status. Whilst heritage and conservation status land is likely to be excluded as an option for agroforestry, the current perception for potential loss of productive land has led to reluctance among land owners to convert agricultural areas exclusively to woodlands or forests (Duesberg et al. 2013). In addition, incentivisation schemes designed to increase rates of afforestation are often not as successful as anticipated, due to insufficient economic stimuli and/or the level of bureaucracy required to access grant aid for woodland creation.

There is scope therefore to revisit the role of integrated agroforestry (AF) systems in Scotland, and in particular to identify silvo-pastoral options that have the potential to minimise land use conflicts. They also have potential to contribute to the diversification of agricultural productivity and provide additional ecosystem services such as carbon sequestration and GHG mitigation. As such agroforestry offers the potential for 'win-win' scenarios to be

[1] **Silvopastoral systems** are those in which trees are planted at wide spacing into grazed, permanent pastures. Silvopastoral agroforestry is also known as wood pasture, one of the Priority Habitats in the UK Biodiversity Action Plan.

adopted in agricultural land holdings by realising the carbon and other ecosystem benefits of woodland development and the potential contribution to farm economics through the management of agricultural greenhouse gas balances and the provision of woody biomass and timber.

3. Potential benefits of agroforestry

3.1. Economic and environmental impacts

The Woodland Expansion Advisory Group (WEAG, 2012) identified a range of options by which trees may be integrated into the agricultural landscape. These options include small woodland areas and shelter belts, hedgerows with trees, riparian woodlands, productive farm woodlands with and without grazing, short rotation coppice, short rotation forestry and silvo-pastoral agroforestry. Such systems have the potential to provide multiple benefits such as the production of timber or biomass for energy production, climate change mitigation through increased carbon sequestration, a reduction in soil erosion and diffuse pollution and improvements to the aesthetic appearance of rural landscapes (Table 1).

Experimental trials have also indicated that particular silvo-pastoral options have significant potential in Scotland. For example, sycamore trees planted at a density of 400 stems per hectare on a grassland system at the Glensaugh research station showed low rates of tree mortality (0.1%), no detectable reduction in agricultural production over the 12 year study period and even an increase in pasture productivity during periods of decreased summertime precipitation, due to the microclimatic control on evapotranspiration by the trees (Sibbald, 2006). However, despite the apparent benefits of silvo-pastoral agricultural systems, planting rates in Scotland to date are significantly lower than expected.

Table 1. The combined benefits and potential economic and environmental impacts of agroforestry systems.

Agroforestry benefits	Economic and environmental impacts
Diversification of farm income	Silvo-pastoral systems can provide additional income through thinning, timber production and farm subsidies
Shelter for livestock	Trees can provide shelter during extremes of temperature in both summer and winter. Livestock have been shown to prefer birthing in/close to woodland areas.
Fuelwood supply	The residues from canopy management and thinning can provide additional fuelwood for combined heat and power generation.
Carbon sequestration and GHG mitigation	Trees can significantly increase carbon sequestered in biomass while grassland productivity can be maintained with suitable planting densities. Some carbon will however be lost from the soil stocks due to disturbance during planting. Residual soil nitrogen will be utilised by the trees potentially reducing nitrous oxide emissions.
Nutrient management	The utilisation of nitrogen fixing tree species such as Alder can reduce the fertilisation requirements of the understorey grass canopy.
Soil erosion and leaching	The presence of trees will help to stabilise the soil and increase the interception and retention of precipitation, reducing particulate erosion and diffuse pollution.
Biodiversity	Integrated agroforestry systems can improve habitat fragmentation in rural and agricultural landscapes.
Amenity value	The presence of woodlands and in particular broadleaf trees has been shown to improve the aesthetic and amenity value of rural landscapes.

3.2. Carbon sequestration and greenhouse gas mitigation potential.

It is important from both a land use and policy perspective to quantify the carbon storage and GHG emission impacts of the transition from improved grassland to an integrated silvo-pastoral system. Based on information presented in Sibbald (2006), The James Hutton Institute and Forest Research have modelled the cumulative carbon budgets of improved grassland and two integrated agro-forestry options over a 55 year period. A more detailed description of the methodology used is presented in Appendix 1.

The results of these models are illustrated in Figure 1 and indicate that the initial soil disturbance associated with planting results in carbon losses of approximately 16 t C ha^{-1}, for an organo-mineral soil. These losses are recovered in the tree biomass over a 12 to 20 year period depending on site-specific productivity. While site and species selection in addition to the long-term management requirements of AF sites require careful consideration, the net carbon gains and potential GHG emission savings for both AF options are apparent, with lower yield class sites improving net C sequestration potential by approximately 55 t C ha^{-1} relative to an undisturbed grassland over the 55 year rotation, with more productive sites making a greater contribution (~107 t C ha^{-1}) to increasing the net GHG sink strength of such ecosystems over the same timeframe. If mineral soils are considered, then net carbon gains will increase up to ~115t C ha^{-1}. In addition productive broadleaf woodland can be managed for a number of silvicultural outcomes including high quality timber and woodfuel provision over the life-cycle of the woodland development. Such products have potential to provide additional mitigation benefit through carbon substitution and carbon storage.

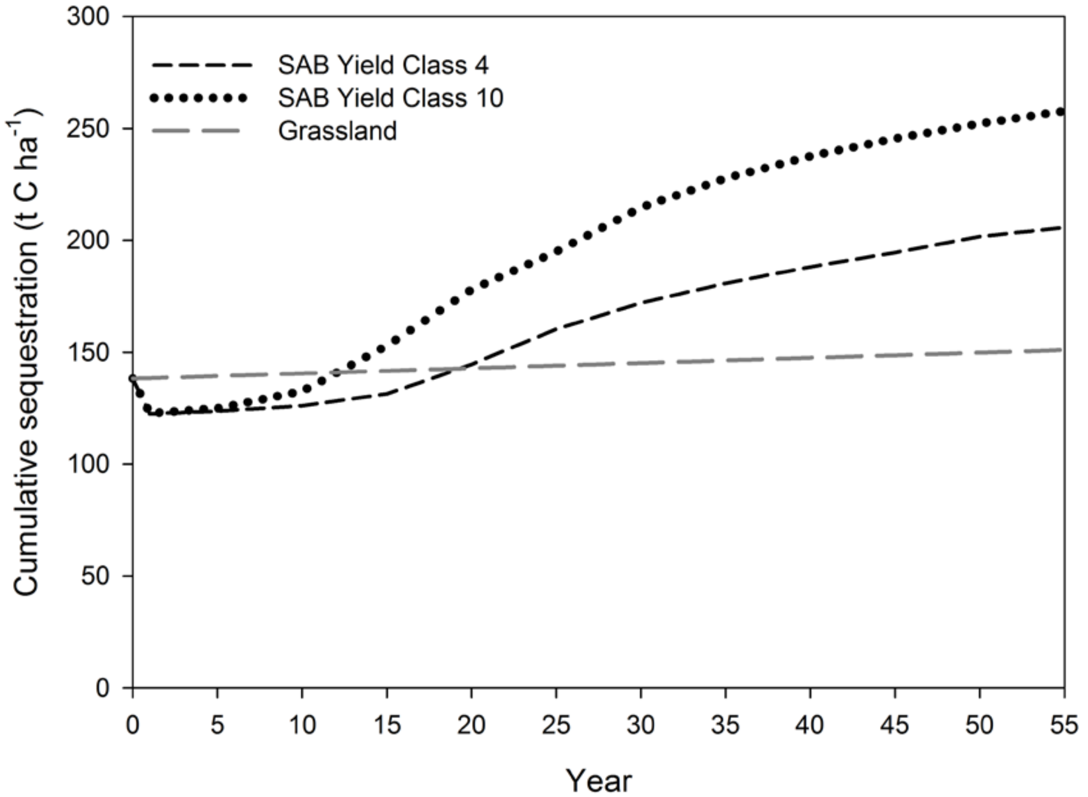

Figure 1. The cumulative carbon sequestration potential of undisturbed improved grassland and two sycamore agroforestry options assessed for different levels of site productivity.

4. Barriers to adoption of agroforestry

There are currently few financial incentives designed to increase the uptake of agroforestry practices, as single farm payments may be lost depending on planting densities, and at present no support is available under the Scottish Rural Development Programme (SRDP). However, the Scottish Government's investment priorities for rural development proposed under SRDP 2014-2020, includes support for agroforestry systems to encourage better integration between woodland creation and farming systems under Recommendation 10 from the Woodland Expansion Advisory Group (WEAG, 2012).

Furthermore the cost of establishment and subsequent management of agroforestry systems are generally higher in comparison to conventional woodlands and forests, as individual trees require protection from livestock, while the forest canopy requires active management in order to maintain the productivity of both the grass sward and the trees in order to produce high quality timber. However, when both the potential economic and environmental benefits associated with agroforestry systems are identified and assessed, the combined returns are potentially greater than plantation forests alone (Table 1).

5. Conclusion

It is apparent therefore, that certain agroforestry options could make a significant, integrated contribution to meeting national GHG emission reduction targets and also provide a combination of additional economic and environmental benefits. There is a real need, however, to raise the profile of agroforestry systems within the development of national policy directives and underpinning research strategies within Scottish conditions, in order to accurately determine the investment requirements and to assess the combined benefits of these systems, within the remit of future climate change, in order to further engage land managers regarding the utility and wider benefits of these systems. On this basis, future incentivisation schemes need to be carefully tailored in order to improve rates of uptake.

6. References

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7. Appendix 1

The assessment of changes in carbon stocks and GHG emissions associated with land-use change from an improved grassland system to an integrated agro-forestry system was made using the information outlined in Equation 1.

$$\Delta C_{tot} = Soil_{ST} - Soil_{DIST} + GHG_{Grass} + NPP_{Trees} \quad \text{Equation 1.}$$

Where ΔC_{tot} is the total emission or uptake of carbon (t C ha^{-1}); $Soil_{ST}$ is the mean soil carbon stock to a depth on 100 cm, of an improved grassland in Scotland which is assumed to be at equilibrium at the time of conversion (t C ha^{-1}), this value was derived from Chapman et al., (2013); $Soil_{DIST}$ represents carbon lost from the soil due to disturbance associated with planting trees and was derived from the Forestry Commission soil carbon look-up tables and represents an approximate 10% reduction in the soil carbon content of the upper layers (0-30 cm) of an organo-mineral pasture soil in Scotland during establishment (t C ha^{-1}); GHG_{grass} represents the net carbon and GHG budget of managed grasslands (this value accounts for carbon assimilation through net primary productivity, carbon export through grazing or forage harvest, nitrous oxide emissions from the soil, methane emissions from livestock, and was derived from literature values and is expressed in t C ha^{-1}); NPP_{trees} represents the carbon sequestered in tree biomass (t C ha^{-1}) and was calculated using the Forestry Commission Carbon Calculator having selected the sycamore/ash/birch scenario at a spacing of 2.5 metres (which was subsequently modified to reflect a planting density of 400 stems per hectare) for two yield classes (4 and 10) to reflect variability in site productivity.