Climate Change and (In)Security Project Briefing Note

Optimising Carbon Sequestration through Afforestation on Defence Estates: A GIS Solution

Introduction

This note explores UK Defence's Sustainability and Net Zero ambition, more precisely, the role of afforestation, the act of expanding forests, in improving carbon sequestration within Defence Estates. The output is a methodological proof of concept which uses landcover, land-use, soil, solar radiation and elevation data to identify sites for afforestation within Sennybridge Training Area (SENTA), Wales. The note concludes with visualisations identifying 1,681.6 hectares of the highest priority areas suitable for afforestation, resulting in up to 56.5 kilotons (kt) of carbon sequestered by 2050, with an estimated value of £32 million. If the remainder of Defence Estates were to have a similar number of sites suitable for afforestation, there would be potential to offset approximately 28% of Defence's annual emissions.

The MOD is responsible for approximately 50% of Central Government's greenhouse emissions, emitting approximately 3.95 million tonnes of CO^2 in 2019-20, which is comparable to Namibia's total emissions (MOD 2021). The MOD owns approximately 225,000 hectares of land and foreshore in the UK, which is nearly 0.9% of the UK's total landmass. The significance of the MOD's land holdings presents an opportunity to contribute to net-zero by reforming land use; one such method is carbon sequestration through planting trees. Carbon sequestration is an integral part of the UK's plans to reach net-zero by counter-balancing emissions from hard to decarbonise sectors, such as Defence. In addition, the UK Committee on Climate Change has stated that 30,000 hectares of mixed woodland require planting each year to help achieve the National goal (Committee on Climate Change 2020).

Methodology

For this proof of concept, Sennybridge Training Area (SENTA) was selected as an area that has varied topology, soil type and land use. The methodology, Figure 1, primarily uses Multi-Criteria Decision Analysis (MCDA) within Esri's ArcPro software to select sites to plant trees. MCDA is an accepted method used to evaluate and compare multiple criteria that logically often compete against one another to find the most suitable area (Ryan and Nimick 2019).

The criteria for inclusion within the analysis (land use, solar radiation, slope, protected areas, and soil) were decided after expert consultation with forestry ecologists and the data, analytics and insights team working within Defence Infrastructure Organisation (DIO) (Parker 2021). After data collection, areas which were not to be analysed were removed using a Boolean filter (see Table 1). The

remaining areas of SENTA, i.e., those which would be analysed, were categorised as grassland, on mineral soil, which was not protected or a designated training area.

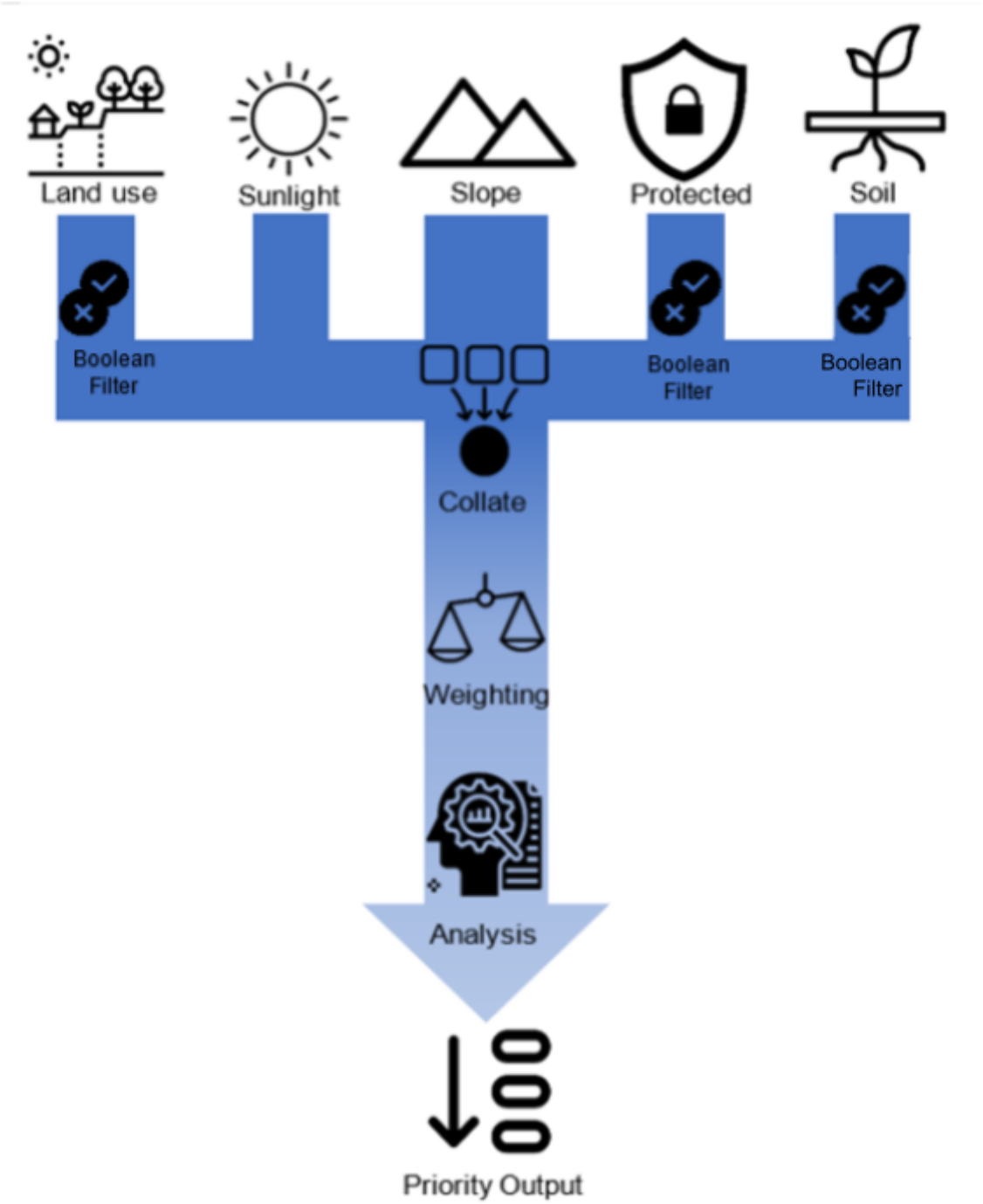

Figure 1. Methodological outline for priority afforestation identification

Name	Areas Removed
Protected Areas	Removal from analysis of any area classified as: Site of Special Scientific Interest (SSSI); Special Protected Area (SPA); Special Area of Conservation (SAC), Wetlands of International Importance (RAMSAR); Area of Natural Beauty (AONB); Natural Nature Reserve (NNR); Local Nature Reserve (LNR); World Heritage Site (WHS); or Protected.
Soil	Removal from analysis of any areas of 'Open Water' and 'Organo-Mineral Soil'. Planting trees on Organo-Mineral Soil has been found to be detrimental to net carbon capture. The remaining soil type for analysis is Mineral Soil.
Vegetation Cover	Removal from analysis of any areas of Coniferous Woodland; Deciduous Woodland; Heather Grassland; and Suburban areas. The remaining vegetation cover is Acid and Improved Grasslands.
Land Use (Agricultural Tenancy)	Removal from analysis of any areas which is currently an active Agricultural Tenancy.
Land Use (Training Area)	Removal from analysis of any areas currently classified as an active Training Area.

Table 1. Areas removed from the afforestation analysis through Boolean filter

To weight the remaining areas, which enabled the prioritisation of sites for afforestation, the remaining criteria (slope and solar radiation) were transformed using Equation 1. The results for slope are inverted to favour areas with a lower slope value. The outputs were categorised into quintiles, quintile 1 being the most suitable sites for afforestation.

$$Solar\ Scale = 100\left(\frac{X_{Pixel} - X_{Min}}{X_{Max} - X_{Min}}\right)$$

$$Slope\ Scale = 100 - \left(100\left(\frac{X_{Pixel}}{Y}\right)\right)$$

$$Afforestation\ Score = \frac{w_1(I_1) + w_2(I_2) + \ \ldots\ w_n(I_n)}{w_1 + w_2 + \ \ldots\ w_n}$$

$X = \text{Input Raster}$

$Y = \text{Max Slope}$

$I = \text{Scaled Input}$

$w = \text{Input Weight}$

Equation 1. The equations for both Solar Radiation and Slope converted values into a standard scale (0-100), enabling them to be combined into an Afforestation score (Source: Feeney 2021).

Results and Discussion

Priority Areas for Afforestation. The results returned approximately 1,680 hectares of quintile 1 (most suitable) for afforestation within SENTA or 14% of the training area additional to those areas already planted (Figure 2). The addition of quintile 2-5 increases the size areas to afforest to approximately 2,210 hectares or 18.5% of SENTA.

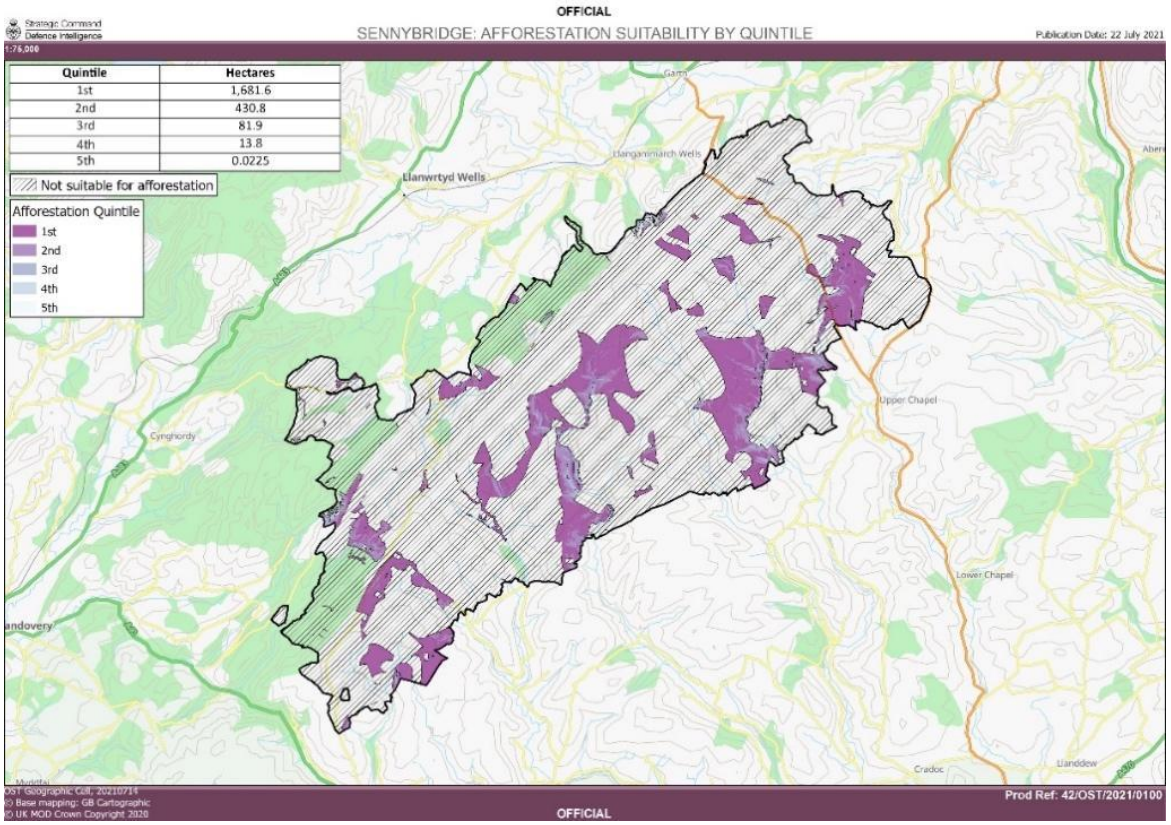

Figure 2. The results of the study, the visualisation identifies priority areas of afforestation on SENTA derived from the MCDA model (Operational Support Team 2021)

The most significant criteria contributing to the resulting distribution is the agricultural tenancies accounting for approximately 80% of SENTA, resulting in a substantial restriction to possible areas for afforestation. This pattern is replicated across Defence Estates, with a total of approximately 101,000 hectares, 45%, of MOD land managed by tenants (Burgess *et al.* 2021).

Projected Carbon Sequestration. Taking the centre-point quintile-1 areas of afforestation, the most common recommendations for tree species by the Ecological Site Classification Decision Support System (ESC-DSS) were Sycamore, Scots Pine, Corsican Pine, Lodgepole Pine, Sitka Spruce, and Norway Spruce.

At the time of writing, a total of 29 years remain for Defence to meet its 2050 net-zero carbon ambition. Although planting Corsican Pine would result in the most carbon sequestration by 2050, 56.5 kt, the species is susceptible to disease and so would present significant risk. Sitka Spruce is a much more climate/ disease resistant species, with significant lumber value, it is also estimated to sequester 38.5 kt of carbon by 2050 (Figure 3).

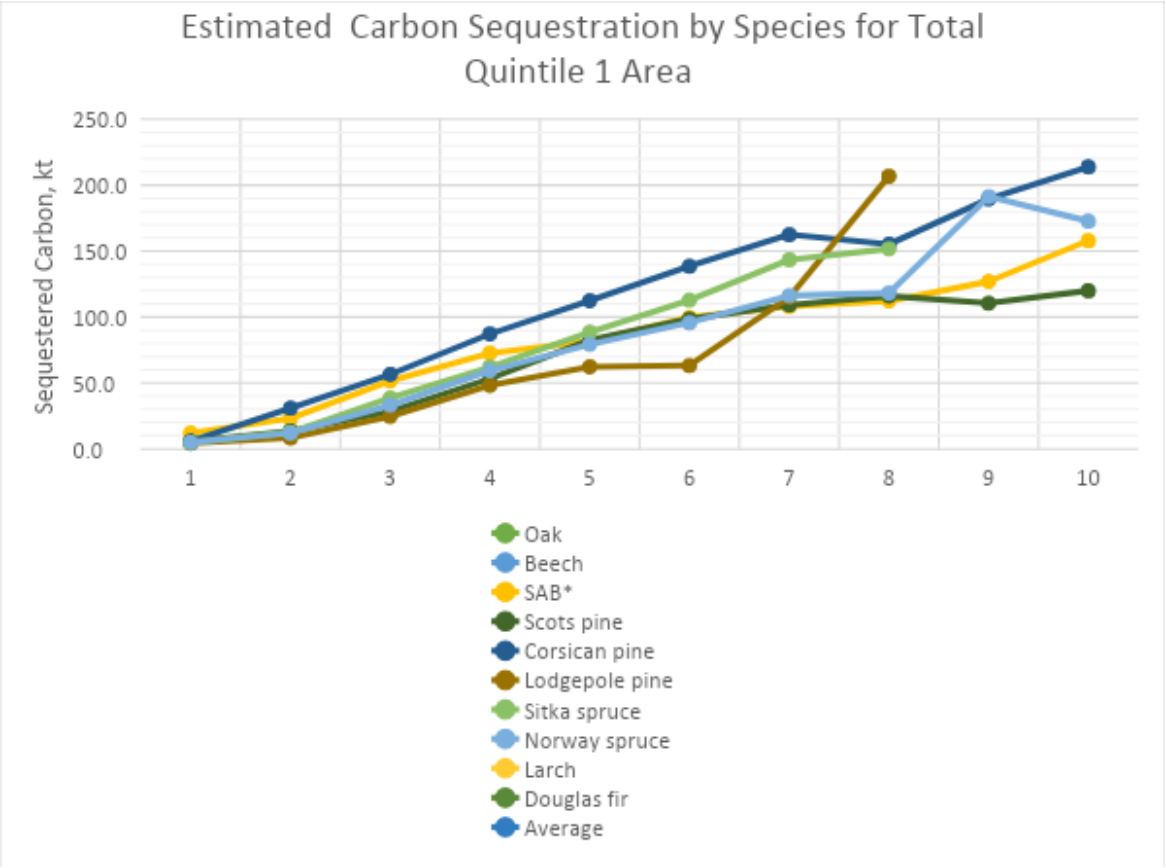

*Figure 3. Calculation and visualisation of the estimated carbon sequestration over time by different species in quintile 1 areas of SENTA. The values are represented in kilotons and calculated using look-up tables from Milne and Brown (1997). *SAB – Sycamore, Ash, Birch.*

Timber Yield and Financial Projection. Sikta Spruce compromises approximately 60% of the total softwood harvested within the UK (Moore 2012). If the entirety of the 1,681.6 hectares of identified land were planted with Sitka Spruce, this would yield 506,161.6m^3 of harvestable timber (Table 2). The current market value of the Sitka Spruce crop in real terms would be £13.6 million (Table 3), adjusted for inflation, in 2050, this is equivalent to £32

million. However, due to the reduction in softwood availability in the 2050s, this price is likely to be much higher.

Summary

This study has used various spatial data within a Geographic Information System (GIS) to identify 1,681.6 hectares of priority area for afforestation on SENTA. Using estimated sequestration rates per hectare, up to 56.5 kilotons (kt) of additional carbon can be sequestered across SENTA through afforestation, which is 0.015% of the current UK Government's emissions. However, extrapolating similar sequestration rates across the entirety of Defence Estates would result in the potential to offset approximately 28% of the annual UK Government emissions.

Although Sitka Spruce does not sequester the most carbon per hectare, it is recommendation for planting within SENTA. Planting of Sitka Spruce over SENTA is estimated to sequester 38.5kt over the next 30 years and is projected to yield at least £32 million in lumber.

The most significant limiting factors to a greater level of afforestation on Defence Estates are agricultural tenancies and soil type. Agricultural tenancies account for approximately 45% of the 225,000 hectares of MOD owned land. With agrarian land projected to be in shortage by 2030, Defence will face significant pressure to maintain its tenancies by agricultural tenants to the detriment of afforestation potential.

Species	Yield class	Thinning treatment	Max MAI age	Initial spacing	Stand area
Sitka spruce	12	No Thinning	55	2.0	1.00

Age yrs	Top ht m	Maincrop after thinning					Yield from thinnings	
		Trees/ha	Mean dbh cm	BA m^2/ha	Mean vol m^3	Vol m^3/ha	Percentage mortality	MAI vol m^3/ha
35	14.9	1911	18	49	0.16	301	2	8.6
36	15.4	1871	18	50	0.17	318	2	8.8
37	15.8	1832	19	51	0.18	335	2	9.0
38	16.3	1792	19	52	0.20	352	3	9.3
39	16.7	1753	20	53	0.21	369	3	9.5
40	17.2	1714	20	54	0.23	386	3	9.7
41	17.6	1680	20	55	0.24	402	4	9.8
42	18.0	1647	21	55	0.25	418	4	9.9
43	18.4	1613	21	56	0.27	433	4	10.1
44	18.8	1580	21	57	0.28	449	4	10.2
45	19.2	1547	22	58	0.30	465	5	10.3
46	19.5	1518	22	58	0.32	479	5	10.4
47	19.9	1490	22	59	0.33	493	5	10.5
48	20.3	1461	23	59	0.35	506	6	10.6
49	20.6	1433	23	60	0.36	520	6	10.6

Table 2. Yield for Sitka Spruce; yield class 12, unthinned, at 2m spacings (Source: Forestry Commission 2016)

Year to:	Average price in nominal terms (£ per m³ over bark)	Average price in real terms (2016 prices, £ per m³ over bark)	Index in nominal terms (Sept 2016=100)	Index in real terms (2016 prices, Sept 2016=100)
30-Sep-12	14.03	14.89	84.5	89.7
31-Mar-13	13.29	13.96	78.6	82.6
30-Sep-13	13.93	14.51	82.5	86.0
31-Mar-14	15.62	16.12	90.9	93.8
30-Sep-14	17.90	18.29	105.7	108.0
31-Mar-15	18.48	18.81	108.8	110.7
30-Sep-15	18.24	18.48	108.2	109.6
31-Mar-16	16.79	16.95	98.5	99.4
30-Sep-16	17.31	17.31	100.0	100.0
31-Mar-17	19.05	18.77	110.0	108.4
30-Sep-17	20.74	20.27	121.4	118.7
31-Mar-18	24.64	23.85	143.5	138.9
30-Sep-18	30.26	28.91	177.5	169.6
31-Mar-19	31.66	29.95	185.5	175.5
30-Sep-19	30.87	28.91	177.7	166.4
31-Mar-20	28.22	26.11	161.0	149.0
30-Sep-20	26.78	23.86	151.1	134.6
31-Mar-21	31.03	26.88	173.7	150.5

Table 3. Coniferous Standing Sales Price Index for Great Britain (Fisher 5 yearly Index) (Source: Forest Research, 2021e)

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