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Carbon forestry in the United Kingdom

Potential for carbon capture in climate change mitigation through Woodland Carbon Code

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Abstract

This thesis explores the important role of carbon forestry in the United Kingdom through Woodland Carbon Code scheme as a sustainable approach to mitigating climate change. The growing concerns surrounding climate change, excessive greenhouse gas emissions and set out national targets have led to the re-evaluation of forestry practises in the UK. Forests have been recognized as major carbon sinks, helping to sequester carbon dioxide from the atmosphere, contributing to the nation's pathway towards Net Zero 2050.

The research combines a statistical data analysis of Woodland Carbon Code Projects between years 2011-2023 and a comprehensive review of existing literature and publications.
The results indicate that through a significant growth of number of Woodland Carbon Code projects over the years, the scheme has become a tool contributing to the UK commitment towards the Paris Agreement and Net Zero Target in 2050, however, it may not be enough to reach the desired levels of sequestration in time. Additionally, the results point out several threats, weaknesses, and possible opportunities to the Carbon Forestry in the UK to be considered in rapidly changing world and ever-increasing climate change. The finding of incorporating agroforestry into the program being one of the solutions for addressing climate change as well as promoting a sustainable future.

In conclusion, this thesis highlights the need for continued improvement in research and policy development, the more projects are implemented, the more our environment changes. More importantly, it brings attention back to the core reminding everyone that the most effective way to tackle the emission problem in the first place is to pressure the UK government to change carbon emission policies for sustainable future.

Language: English
Key Words: carbon dioxide, forestry, sequestration, Woodland Carbon Code, United Kingdom

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1 Introduction

Since the beginning of the industrial revolution in 1800s, human activities have been the main driver leading to climate change, mainly through burning fossil fuels like coal, gas, and oil. Transport, deforestation, and clearing land amongst many other actions, generate harmful greenhouse gas emissions (GGE) like methane and carbon dioxide (CO_2), which is reshaping the planet's climate systems, leading to unprecedented challenges for ecosystems, economies, and societies worldwide. The World Meteorological Organization (WMO) has observed that the temperature between 1800 and 1950 has risen by 1.1°C and the last decade has been declared the warmest so far (World Meteorological Organization, 2021). In the UK alone, 9 out of 10 warmest years have occurred since 2002. The urgent need to mitigate climate change has started a quest for innovative solutions, that can be effective in lowering the emission of greenhouse gases (GG) while improving our lives and protecting the environment.

As our understanding of climate science has deepened, so has the recognition of the role that forests and woodlands play in the global carbon cycle. Through the natural process of photosynthesis, forests sequester carbon dioxide from the atmosphere and store it within their ecosystems offering an invaluable liability for carbon capture and storage. One of the United Kingdom initiatives designed to harness this potential, the Woodland Carbon Code (WCC), stands as an innovative approach within the UK's strategy for addressing climate change. The WCC is a voluntary UK standard that aims to sequester carbon through woodland creation. The Code is aligned with the core requirements of other international voluntary forest carbon standards and of the Kyoto Protocol (Forest Carbon, the Woodland Carbon Code, Our Role & Future Developments, n.d.). Carbon forestry has become a widely recognizable woodland creation motive in the last 12 years that can help to combat the effects of climate change in the nation and around the world. The scheme can be a significant and popular tool in afforestation of the UK for future generations that can support the ongoing decrease of the CO_2 emissions and help the nation to achieve its climate targets before 2050.

United Kingdom needs forests as it has one of the lowest forest cover percentages amongst all Europe, which currently stands at 13% (Forest Research n.d.). This lack of woodlands is attributed to a complex history of exploitation by society and natural climate changes

throughout the Holocene (Holl and Smith, 2007, Tipping et al., 2008, as cited in Burton et al., 2018). By the beginning of the 20th century, forest cover was down to an estimated 4.7% of land cover (Forestry Commission, 2019). Since the timber crisis, caused by World War I in the mid-20th century, forestry has become an important sector, and it has finally started to be understood and taken seriously. Today, a public organization Forestry Commission England, the newly established country equivalents, and Forest Service in Northern Ireland are responsible for creating and managing woodlands and setting policies in the UK forests.

Moreover, combining afforestation with agriculture, known as agroforestry, could modernize the code and improve its outcomes. Growing trees on farms dates from the ancient years and when planned and managed correctly, it does not only sequester carbon, but also bring many other benefits to farmers and the public. Despite UK being made up of 216,000 farm holdings having in total 17.2 million hectares of land, which is 71% of the UK land in total, only a handful of farms are actively involved with agroforestry in the UK (Department for Environment, Food & Rural Affairs, 2022).

The Woodland Carbon Code, as an integral component of the United Kingdom's climate action plan, represents a new approach that warrants comprehensive examination and critical appraisal. Understanding its challenges, its successes, and limitations is essential for creating evidence-based policy recommendations that can guide future climate mitigation efforts within the UK and potentially serve as a model for other regions facing similar challenges.

1.1 Aim of the study

The aim of this study was to explore the potential for carbon capture in climate change mitigation through creation and management of woodlands using Woodland Carbon Code scheme and agroforestry practices in the UK. The research seeks to investigate the Code’s effectiveness and implementation by studying the WCC scheme principles and its projects, reviewing the previous research findings, literature review, and comparing statistical datasets in the context of the broader climate change mitigation view.

Research Questions:

1. Is Woodland Carbon Code an effective tool contributing to the UK climate pathway towards the Paris Agreement and Net Zero Target in 2050?
2. What are the barriers and challenges of Carbon Forestry in the UK?
3. Can agroforestry practices improve the WCC, and should they be linked together?

2 Outline

The introduction chapter provides background information about the topic as well as the aim of the study outlining the main research questions. Chapter 3 focuses on the relevant theoretical background giving the reader a basic understanding of the meaning behind the main subjects of the research. Chapter 4 explains the methodology used behind choosing relevant datasets and dividing them into three separate result chapters. Statistics presented in chapter 5 result in datasets for WCC projects in years 2016, 2018, 2020 and 2022. They were broken down into three separate groups to better illustrate and focus on different values. Chapter 6 covers discussion which presents advantages and disadvantages of WCC, potential of agroforestry in climate change mitigation, WCC challenges and opportunities for improvement. Conclusions and recommendations are included in chapter 7.

3 Definitions and background study

The background study of the research includes reasons for the creation of Woodland Carbon Code and what it is planned to achieve. The concept of ‘climate change’ has appeared as a driver to take control of a variety of problems, such as deforestation or excessive GG emissions. Understanding the meaning behind natural processes like carbon emissions or forest carbon sequestration as well as the solutions, like Woodland Carbon Code itself, agroforestry, and the United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol or Paris Agreement, is crucial to be able to investigate the topic and answer all the research questions.

3.1 Climate change and Carbon Emissions

NASA describes climate change as a long-term shift in global temperature and weather pattern. While Earth's climate has changed throughout its history, the current warming is happening at a rate not seen in the past 10,000 years, human activity being the main cause of this change. (Global Climate Change, NASA, n.d).

Since the beginning of the big industrialisation in the 18th century, the growing human activity has been contributing to the excessive production of the harmful long-span atmospheric gasses, like Carbon Dioxide or methane, which absorb light, generated by the sun, and trap heat, contributing to the enhanced greenhouse effect and raising temperatures on Earth.

In the mid-1800s, scientists noticed the first changes in the climate and started linking facts together. According to NASA, in 1824 Joseph Fourier calculated that an Earth-sized planet, should be much colder at our distance from the Sun. He suggested that something in the atmosphere must be acting like an insulating blanket. From that moment on, several studies were done exposing the data to the world and proving that there is indeed something very important happening with Earth's climate that everyone needs to understand. The temperature had already risen to a dangerous level of 1.1°C between 1850-1900. It is estimated that in the next 20 years, global temperature is expected to reach or exceed 1.5°C (IPCC, 2021) and actions must be taken to combat the changing climate, or at least slow the process down.

The burning of fossil fuels (such as coal, oil, and natural gas) for energy production, transportation, and industrial processes is the primary source of anthropogenic CO_2 emissions. Land-use changes, including deforestation and urbanization, also release CO_2 into the atmosphere. These emissions result in a buildup of GGEs, leading to the catastrophic outcomes and can already be seen through a number of evidence around the world: increased ocean temperature, retreating of glaziers, decreasing of snow cover, sea level rising, increasing ocean acidification and extreme weather events that are frequently become greater around the world (Global Climate Change by NASA, n.d).

The good news is, according to the UK 2020 statistical release of Department for Business, Energy & Industrial Strategy, it is estimated that the greenhouse gas emissions were 49.7%

lower in 2020 than they were in 1990. The noticeable fall of the seven gasses: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) covered by the Kyoto Protocol, was dominated by the Carbon Dioxide which covered 79% of total GG emissions (Final UK Greenhouse Gas Emissions National Statistics: 1990 to 2020, 2022). The total decrease in emissions by almost 50% can be compared with, amongst other management practices, to the increased woodland area (ha) between the same timescales (Forestry Research, 2022).

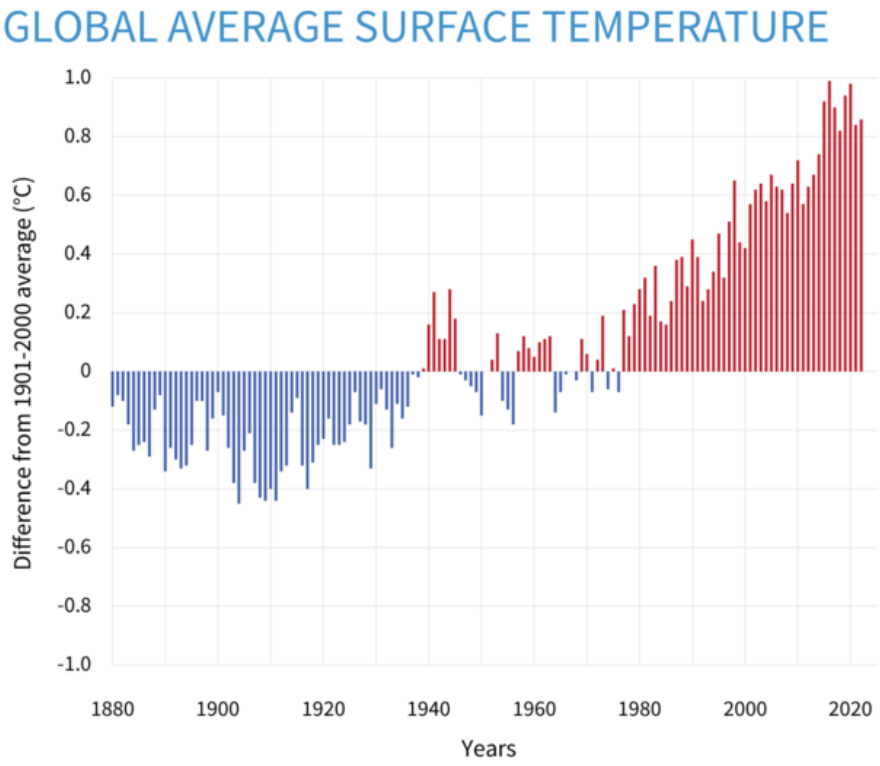


Figure 1. Global average surface temperature (Lindsey R. and Dahlman L. - Climate Change: Global Temperature, 2023)

Figure 1 shows yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years. NOAA Climate.gov graph, based on data from the National Centres for Environmental Information. (R. Lindsey, L. Dahlman, 2023)

3.2 The United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol

After recognition of the problem, in the 1994 the United Nations Framework Convention on Climate Change (UNFCC) came into force. The convention was ratified by 198 countries, preventing “dangerous” human interference with the climate system. (United Nations Climate Change, n.d.). According to the United Nations article, the ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system."

In December 1997, in Kyoto, Japan, over 160 parties took part in the United Nations Framework Convention on Climate Change (FCCC or Convention) and adopted the Kyoto Protocol, which, for the first time, established legally binding limits for industrialized countries on emissions of carbon dioxide and other “greenhouse gases.” (Breidenich C., Magraw D., Rowley A., Rubin J.W., 2017) The authors laid out that it entered into force ninety days after at least fifty-five parties to the FCCC, encompassing FCCC Annex I Parties that accounted in total for at least 55 percent of the total emissions for 1990 of carbon dioxide (CO^2) of Annex I parties, have ratified, accepted, approved, or acceded to the Protocol (Boisson de Chazournes, n.d.).

Countries that ratified the Kyoto Protocol were assigned maximum carbon emission levels for specific periods and participated in carbon credit trading. If a country emitted more than its assigned limit, then it would be penalized by receiving a lower emissions limit in the following period (Tardi, 2022). Tardi explains further that the reason the Kyoto Protocol was created is to respond to concerns surrounding climate change. The treaty was an agreement between developed nations to reduce carbon dioxide emissions and greenhouse gases. The framework implemented the United Nation's target of reducing global warming consequences including a general rise in seal levels, disappearance of some island states, melting of glaciers, and increase in extreme climate-related events.

3.3 Paris Agreement

The Paris Agreement is a legally binding international treaty on climate change. The treaty is the first global accord on climate change that contains policy obligations for all countries.

It is a hybrid that enshrines both bottom-up and top-down approaches to global climate governance (Bodansky 2011, as cited in Dimitrov, 2016).

To date, the UK has taken a leading role in calling for action to tackle Climate Change. Alongside 195 countries, the UK negotiated and secured the historic Paris Agreement in December 2015. As a precursor to ratification, the European Union and its 28 Member States signed the Paris Agreement on 22 April 2016 at the high-level signing ceremony in New York. (Explanatory Memorandum on the Paris Agreement, n.d.)

Under the Paris Agreement, the UK pledged to cut at least 68% levels of emissions by 2030. The plan sets out ambitious policies and investment, with the potential to deliver over £40 billion of private investment by 2030, so that UK can develop innovative technologies and make significant strides in cutting emissions across energy, transport, and buildings (Gov.uk, 2020). However, according to the Climate Action Tracker, as of date 17 October 2022, the UK may have problems in achieving its goals and may not be as compliant with the Paris Agreement as anticipated. It is due to many policy gaps and the lack of the fair share of the global effort to address climate change, which is one of the principles centralised by the Paris Agreement (Climate Action Tracker, 2022).

The United Nations (n.d.) describes the main goal of the treaty as to limit global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve such change and keep the average temperature long term, all the participating countries must reduce greenhouse gas emissions as soon as possible to reach the goal of climate neutrality by 2050.

3.4 Forest Carbon Sequestration

Carbon forestry, also known as forest carbon sequestration, represents a critical approach to mitigating climate change by harnessing the carbon sequestration potential of forests. Carbon Sequestration implies transfer of atmospheric CO_2 into other long-lived global pools including oceanic, pedologic, biotic and geological strata to reduce the net rate of increase in atmospheric CO_2 (Lal, 2007). In their article, Lal describes that the biotic pool contributes to increase in atmospheric carbon dioxide concentration through deforestation and biomass burning. It means that to decrease the levels of CO_2 in the atmosphere, afforestation and responsible management of woodlands is needed. Trees and forests act

as collectors of CO_2 through the process of photosynthesis, biomass accumulation and carbon storage through soil.

Photosynthesis is a biological process where the sun's energy is captured and stored by a series of events that convert the pure energy of light into the free energy needed to power life (Blankenship, 2021, p.1). The energy created, simple sugar molecules, are then combined to produce cellulose or lignin. Some amounts of the carbon are released back to the atmosphere through respiration and decomposition, but the remaining carbon is distributed across the whole tree to its leaves, roots, seeds, wood, and branch biomass (Broadmeadow & Matthews, 2003). Trees play a central role in carbon sequestration, with their long lifespans and large biomass. By decomposing of organic matter, woodlands enrich carbon content in soils. Different tree species have varying sequestration capacities, influenced by factors such as growth rate, age, and environmental conditions.Carbon Forestry acts as a productive expansion of responsibly managed forests, and in certain way the creation of an effective carbon sink that will significantly reduce the amounts of CO_2 and slow down climate change around the world. Accurate measurement and monitoring of carbon stocks and fluxes are essential for assessing the carbon sequestration potential of forests and the effectiveness of carbon forestry projects. In the Emergency Tree Plan for the UK policy paper (2020) the authors state that the UK has become a country with one of the lowest levels of woodland cover in Europe, and it is also one of the most nature depleted countries in the world.

The creation of forests for carbon sequestration has become an important tool to combat climate change in the UK and help the nation to meet the requirements stated in the international treaties. Well-designed new woodlands not only capture carbon dioxide but deliver a wide range of other benefits too. They improve air quality, reduce the 'urban heat island', provide timber, wood, and wood fibre products, provide opportunities for people to re-connect with nature and new spaces to improve health and well-being, help to reduce flood risk, and can reduce the costs of water treatment too (Forestry Commission, 2022). Therefore, it is crucial for implementation of variety of projects that will support woodland cover creation and provide a list of other indirect benefits to the United Kingdom.

3.5 The Woodland Carbon Code

The Woodland Carbon Code (WCC) is a UK government- backed scheme administered by the Scottish Forestry established in 2011, under the framework of the UK's efforts to reduce GGEs and combat climate change. It allows organizations wishing to offset carbon dioxide equivalent emissions to landowners who then plant woodlands for sold carbon units. It is based on science from Forest Research, the UK's principal organization for forestry and tree-related research, and it uses a developed carbon model that allows to predict the amount of carbon that the woodland will sequester in its life for up to 100 years. It allows to calculate carbon stocks in trees, soils, and associated biomass, as well as accounting for carbon losses due to management practices like timber harvesting. The landowners can predict how much carbon they will sequester by calculating how many units they can generate; one carbon unit equals one ton of carbon.

The process of establishing a woodland carbon project begins with project development. This stage involves site selection, species choice, and a thorough carbon assessment to estimate the project's potential carbon sequestration. The project must then be registered and validated with the accredited organization, Soil Association or Organic Farmers & Growers. These two organizations are the only accredited bodies in the UK that are allowed to verify and validate the WCC projects.

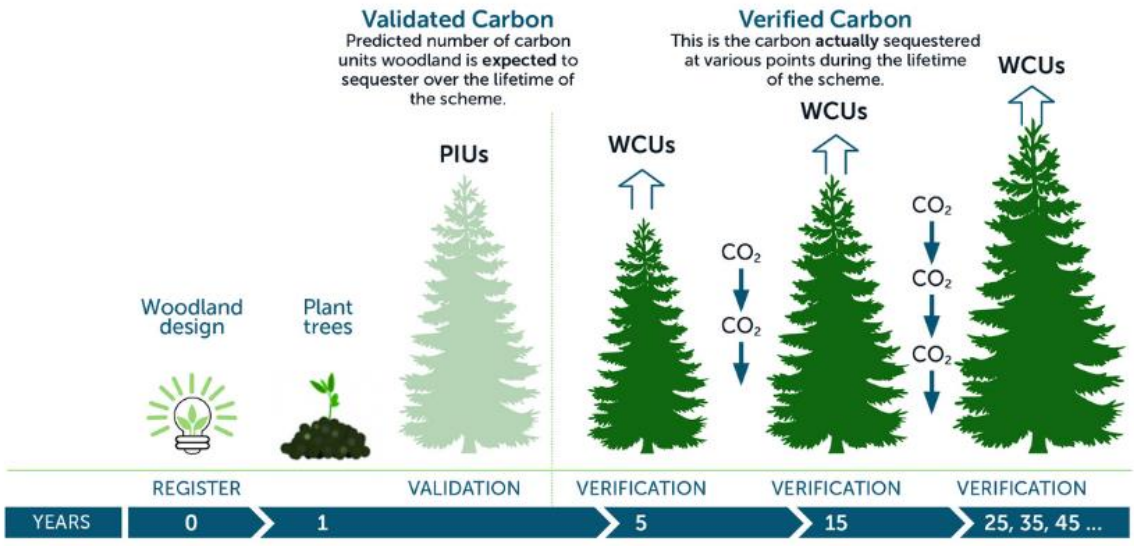


Figure 2. The timeline of the Woodland Carbon Code project and its main stages. (Scottish Woodlands, n.d.)

When the project is first registered and planned, the actual validation phase begins. This includes tree planting, land management, and monitoring activities. In this stage, the Pending Issuance Units (PIUs) are calculated, representing units of carbon that will turn into Woodland Carbon Units (WCUs) in the future, but cannot be used to report against UK-based emissions until verified. These units are an estimate and can allow companies to plan to compensate for future UK-based emissions, or make credible Corporate Social Responsibility statements in support of woodland creation (Woodland Carbon Code, n.d.)

After the project is validated, it undergoes third-party verification to ensure it meets the WCC's standards and criteria. Once certified, the project can generate carbon credits, known as WCUs. The units can provide a financial incentive for woodland owners by being sold to entities seeking to offset their carbon emissions. Before the business or other organization wants to take part in the project and buy WCUs, they must understand and measure how much carbon footprint they generate as a business and set themselves targets to reduce their emissions. By contacting the project developers with verified units to sell, they can choose which project they would like to invest in. The Woodland Carbon Code is listed as a quality, credible and developing standard, endorsed by ICROA (International Carbon Reduction & Offset Alliance) which provides a great market trust in the product sold by the landowners. (Woodland Carbon Code, n.d.)

3.6 Agroforestry

Agroforestry is the practice of growing trees and crops in interacting combinations - it is recognized worldwide as an integrated approach to sustainable land use (Ramachandran, D. Nair, Kumar, Showalter, 2010). The variety of agroforestry systems and their flexibility to design fits every modern farming system and can balance food production with other public goods. It can enhance farm productivity, increase wildlife, improve soil health and animal welfare, manage water flow, and contribute to climate change mitigation. (Soil Association, n.d.). According to the article, it is possible to distinct 5 types of agroforestry:

- Silvoarable: trees and crops;
- Silvopastoral: trees and livestock;
- Hedgerows and buffer strips;
- Forest farming: cultivation within a forest environment;

- Home gardens: small-scale, mixed, or urban settings

On the Woodland Trust website (n. d) it is stated that 72% of UK land is agriculture but only 3% of the farmed area practices agroforestry. By reaching as little as 10% of farmland cultivating agroforestry, we will be able to hit the set-out climate change targets.

Figure 3. Silvoarable agroforestry experiment with poplar and barley in Bedfordshire in 2002. (Agroforestry Research Trust, n.d.)

4 Methodology

This research was conducted using both quantitative and qualitative methods. It covers analysis of Woodland Carbon Code Projects quantitative information datasets in the United Kingdom between years 2016 and 2023. Introduction, definitions, and the background were based on literature and publication review. Additional information was taken from the National Forestry Statistics (Forestry Research, n.d.), and Woodland Carbon Code websites (Woodland Carbon Code, n.d.). The analysed figures showed the area of projects in hectares, the number of projects and their projected carbon sequestration value in

thousand tonnes of carbon dioxide equivalent divided by country. The values were further broken down into awaiting validation, validated, and verified.

To assess whether the WCC scheme has potential for climate change mitigation, I looked at the statistical values and the code's evolution overtime. By developing a SWOT analysis of the code, it was possible to identify the barriers and challenges. The Agroforestry case study results allowed to investigate honest opinions of farmers and landowners and helped to formulate actions to work upon in the future.

The research allowed to predict the further contribution of the WCC to the UK's pathway towards the Paris Agreement considering its strengths, weaknesses, and opportunities for expansion of the scheme in the future.

5 Results

The Woodland Carbon Code Scheme presents a promising mechanism for carbon sequestration through afforestation. The code ensures quantification and verification of carbon sequestration by woodlands through a rigorous measurement of tree growth, biomass accumulation, and soil carbon content. The scheme contributes not only to climate change mitigation but also to broader environmental and ecological benefits.

5.1 Woodland Carbon Code in the UK - Statistics

Through attentive measurements, it was possible to estimate the amount of carbon stored and provide a basis for carbon offsetting calculations. With a help of the National Woodland Statistics and the UK Land Carbon Registry, it was feasible to find and present the historical data. Tables 1,2,3 and 4, present all data values of the WCC projects in England, Scotland, Wales, and Northern Ireland from years 2016, 2018, 2020 and 2022. The values in the tables were divided to show the number of projects, the area of woodlands in hectares and a projected carbon sequestration in thousand tonnes of carbon dioxide equivalent. Detailed datasets helped to better understand the evolution of WCC over the years and its impact on woodland creation for carbon sequestration in the UK. To assess all the values from the tables separately, the data was broken down and grouped to show the number of projects in Figure 4, area of woodlands in Figure 6 and projected carbon sequestration over the years in Figure 8.

Forestry Commission defined steps of the validation and verification as below (Forestry Research, 2022):

- **Awaiting Validation** is when a project or group is undergoing assessment by a certification body.
- **Validated** is the initial evaluation of a project or group against the requirements of the Woodland Carbon Code. Upon completion a project/group will receive a 'Validation Opinion Statement'. The project or group will then be certified for a period of up to 5 years.
- **Verified** Verification is the evaluation of a project as it progresses to confirm the amount of CO^2 sequestered to date as well as that it continues to meet the requirements of the Code.

To sum up, all Tables 1,2,3 and 4 and corresponding Figures 4,6 and 8 present growing tendency in WCC project development and what comes with it, an increasing number of woodlands area and projected CO^2 sequestration.

Table 1. Woodland Carbon Code projects at 31 March 2016

	England	Scotland	Wales	Northern Ireland	UK
Number of projects					
Awaiting validation	72	33	3	0	108
Validated only	54	60	6	1	121
Verified	0	1	0	0	1
Total	**126**	**94**	**9**	**1**	**230**
Area of woodland (hectares)					
Awaiting validation	808	10,264	14	0	11,087
Validated only	1,425	3,087	229	9	4,749
Verified	0	5	0	0	5
Total	**2,233**	**13,356**	**243**	**9**	**15,841**
Projected carbon sequestration (thousand tonnes of carbon dioxide equivalent)					
Awaiting validation	465	3,048	7	0	3,519
Validated only	811	1,354	109	3	2,278
Verified	0	2	0	0	2
Total	**1,275**	**4,404**	**116**	**3**	**5,799**

(Forestry Commission, 2022)

Table 2. Woodland Carbon Code projects at 31 March 2018

	England	Scotland	Wales	Northern Ireland	UK
Number of projects					
Awaiting validation	18	37	27	1	83
Validated only	50	57	11	1	119
Verified	18	17	2	0	37
Total	**86**	**111**	**40**	**2**	**239**
Area of woodland (hectares)					
Awaiting validation	143	10,553	165	7	10,868
Validated only	1,216	2,155	301	9	3,680
Verified	183	1,358	37	0	1,578
Total	**1,542**	**14,065**	**503**	**15**	**16,125**
Projected carbon sequestration (thousand tonnes of carbon dioxide equivalent)					
Awaiting validation	60	3,148	76	1	3,285
Validated only	686	948	152	3	1,790
Verified	106	583	24	0	713
Total	**853**	**4,679**	**252**	**4**	**5,788**

(Forestry Commission, 2022)

Table 3. Woodland Carbon Code projects at 31 March 2020

	England	Scotland	Wales	Northern Ireland	UK
Number of projects					
Awaiting validation	47	50	27	0	124
Validated only	51	17	82	1	151
Verified	36	3	48	1	88
Total	**134**	**70**	**157**	**2**	**363**
Area of woodland (hectares)					
Awaiting validation	748	464	1,750	0	2,962
Validated only	884	250	8,224	14	9,372
Verified	376	52	2,196	9	2,633
Total	**2,008**	**766**	**12,170**	**23**	**14,967**
Projected carbon sequestration (thousand tonnes of carbon dioxide equivalent)					
Awaiting validation	460	144	517	0	1,121
Validated only	503	143	2,827	8	3,480
Verified	208	33	963	3	1,207
Total	**1,171**	**319**	**4,308**	**11**	**5,809**

(Forestry Commission, 2022)

Table 4. Woodland Carbon Code project summary at 31 March 2022

	England	Scotland	Wales	Northern Ireland	UK
Number of projects					
Awaiting validation	443	175	468	82	1,168
Validated only	63	24	158	2	247
Verified	45	5	68	1	119
Total	**551**	**204**	**694**	**85**	**1,534**
Area of woodland (hectares)					
Awaiting validation	5,381	1,385	33,618	520	40,905
Validated only	1,373	466	8,224	14	9,372
Verified	638	52	2,196	9	2,633
Total	**7,392**	**1,951**	**49,563**	**543**	**59,449**
Projected carbon sequestration (thousand tonnes of carbon dioxide equivalent)					
Awaiting validation	2,235	493	8,896	236	11,860
Validated only	737	181	4,001	8	4,927
Verified	349	49	963	3	1,927
Total	**3,320**	**722**	14,423	247	**18,714**

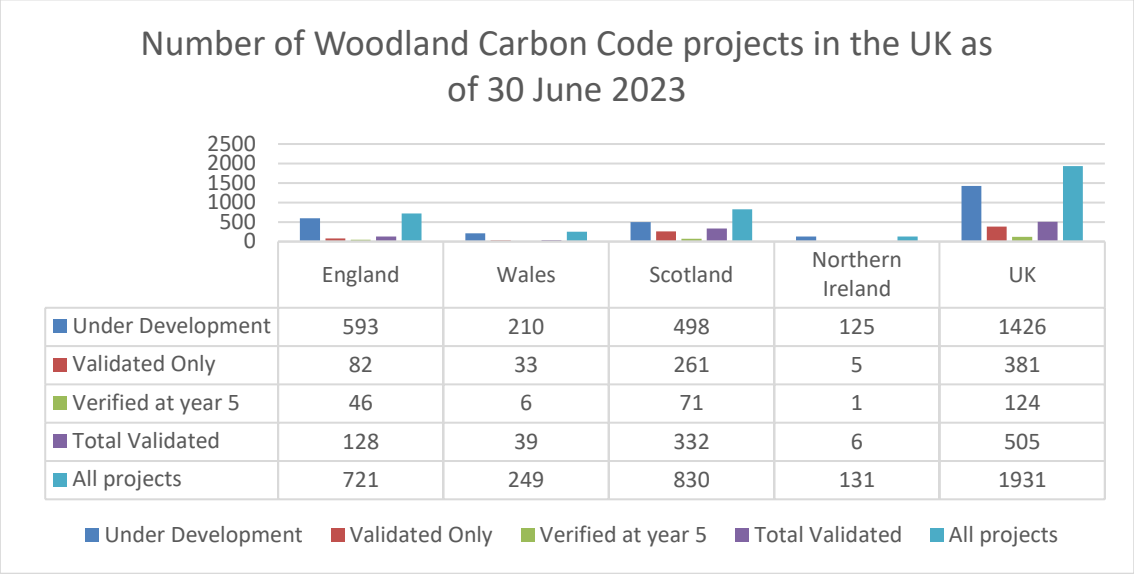
(Forestry Commission, 2022)

5.1.1 The number of WCC projects between 2011-2022

In the early years of the Woodland Carbon Code operation, there were a limited number of projects accredited under the code. From 2016, the scheme experienced steady growth as awareness of climate change and the need for carbon offsetting increased and more landowners and organizations became interested in establishing and maintaining woodlands. Between 2020- 2022, the code experienced an accelerated expansion through multiple factors from the government support, businesses engagement and growing public awareness. The Climate Change Committee - Insights Briefing 1 of the UK Climate Change act introduced in October 2022 enshrined in law the need of the UK to reduce emissions and prepare for climate change (Insights Briefing 1 of the UK Climate Change act, 2020)

Figure 4 shows the total WCC projects as of 30 June 2023. Over the years, the ongoing design and implementation of the scheme resulted in the creation of 1931 projects in the UK. Scotland, with a total land area of 77,933 km², validated 261 projects and had 498 under development, resulting in the 830 projects in total. England, being approximately

1.5 bigger than Scotland with 130,279km² land area, validated 82 projects and had 593 under development, leading to 721 registered projects in total.



	England	Wales	Scotland	Northern Ireland	UK
Under Development	593	210	498	125	1426
Validated Only	82	33	261	5	381
Verified at year 5	46	6	71	1	124
Total Validated	128	39	332	6	505
All projects	721	249	830	131	1931

Figure 4. Number of Woodland Carbon Code Projects on the UK Land Carbon Registry - Interim statistics as of 30 June 2023. Note: Projects can be validated/verified individually or as part of a group. This table shows the number of projects validated or verified, whether they were administered individually or as part of a group. (Woodland Carbon Code, n.d.)

As shown in the Figure 5 below, the distribution of projects is visibly denser in the smaller countries like Wales, Scotland, and Northern Ireland. It is also explained by the smaller number of populations in these areas. Less people mean less urbanized areas and more space for natural expansion and woodland creation.

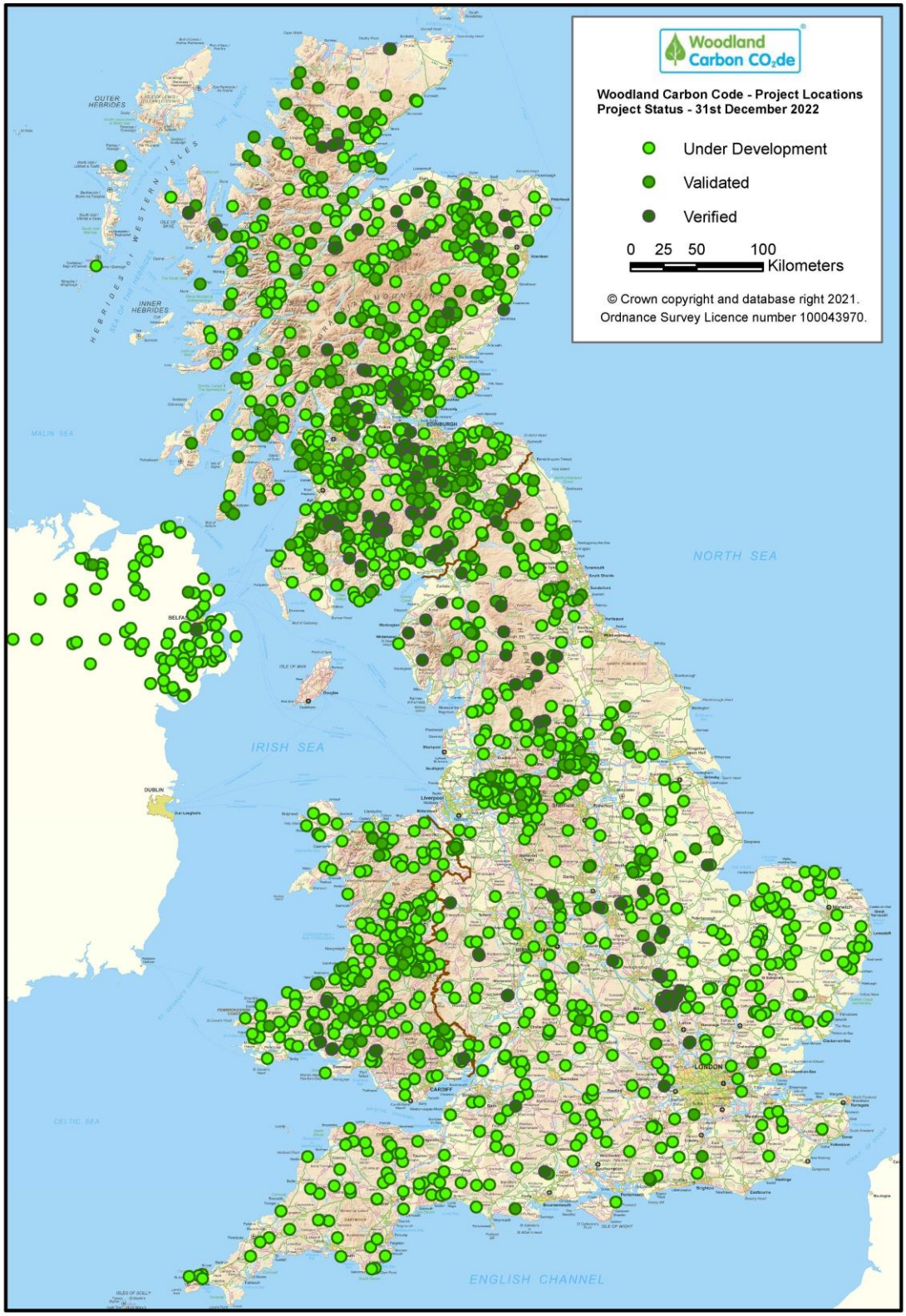
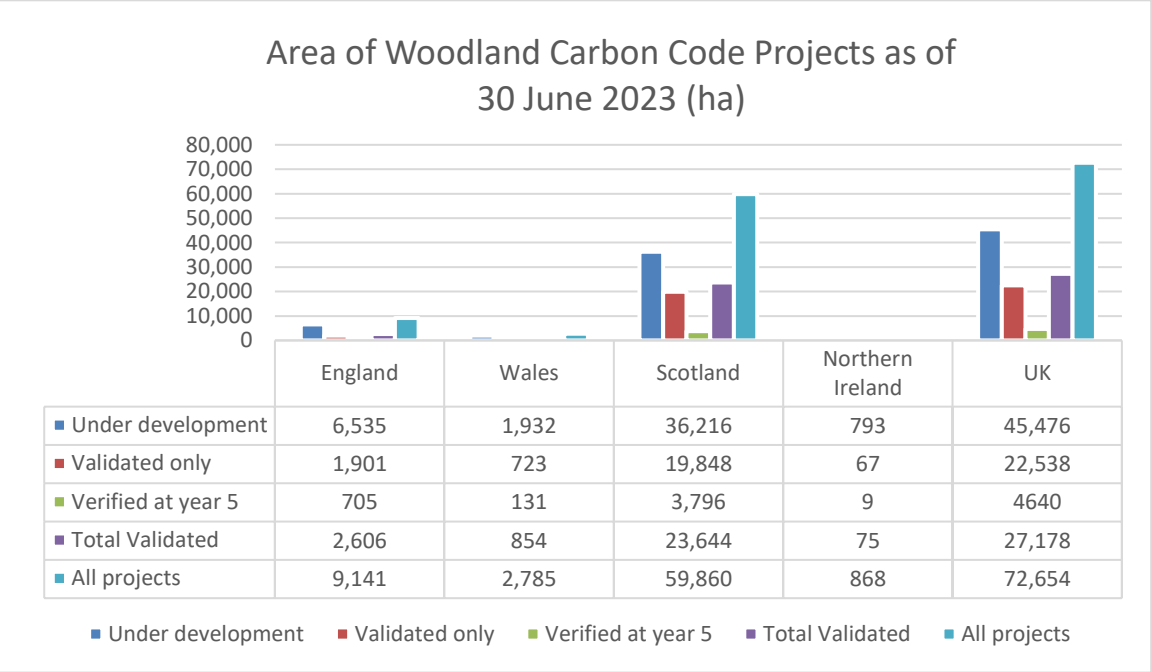


Figure 5. Map of Woodland Carbon Code projects, by status - 31st December 2022. (Woodland Carbon Code, n.d.)

5.1.2 Forest area and management of woodlands

Woodland cover in the United Kingdom currently stands at 13% and is estimated to be 3.24 million hectares, 19% in Scotland, 15% in Wales, 10% in England, and 9% in Northern Ireland (Forest Research, 2022). Figure 6 shows that the WCC projects area covers approximately 72,654 hectares, marking a total of 2.2% of the total woodland cover in the UK as of 30th of June 2023. These projects range from small-scale community woodlands to large commercial plantations, collectively sequestering a substantial amount of CO^2. The UK woodland cover is gradually increasing, and the more projects are developed, the bigger area of woodlands is reached.



	England	Wales	Scotland	Northern Ireland	UK
Under development	6,535	1,932	36,216	793	45,476
Validated only	1,901	723	19,848	67	22,538
Verified at year 5	705	131	3,796	9	4640
Total Validated	2,606	854	23,644	75	27,178
All projects	9,141	2,785	59,860	868	72,654

Figure 6. Area of Woodland Carbon Code Projects on the UK Land Carbon Registry - Interim statistics as of 31 Dec 2022 (Woodland Carbon Code, n.d.)

In the 'Land-use legacies of twentieth-century forestry in the UK: a perspective' Susanne Raum states, (according to Forestry Commission 2019), public organizations such as Natural Resources Wales, Forestry and Land Scotland, Forest Service Northern Ireland, Forestry Commission England and other equivalents functioning in the UK own or manage 0.86 million hectares - 27% of the total woodland area - ranging from 16% in England to 55% in Northern Ireland. The author explains, (according to Smith et al. 2001), the other forest owners consist of 43.6% private owners, 12% businesses, 3.6% charities and 4.9% local authorities and other public owners.

5.1.3 Tree species selection in WCC projects

Tree species selection is a crucial factor in Woodland Carbon Code projects and carbon sequestering in general. The species should align with the specific objectives of the project. Different types of trees have varying rates of carbon intake, some are fast growing and capture carbon from the atmosphere more rapidly whereas others grow slower, and their capacity is limited. Choosing trees that live longer and are more resistant to pests and diseases also plays a crucial role in the selection. The long-lived species ensure the permanence of carbon storage over the project lifetime, reducing the risk of carbon release due to factors like tree mortality or harvesting.

The species are selected by the project developers considering the UK Forestry Standard requirements. When selecting trees or shrubs for new woodlands and restocking, the risks and opportunities of climate change and vulnerability to pests and diseases for species are decided if alternative species or increased species diversity are merited (UK Forestry Standard, 2017). The composition of the forestry management unit must be diversified, however, in cases where only one species is suited for planting, 75% must consist of that species and the remaining 35% must have a minimum of:

- 10 % of open ground or ground managed for the conservation and enhancement of biodiversity
- 10 % other species
- 5% native broadleaved trees or shrubs

According to Figure 7, more than 50% of the projects area in England considered of broadleaved tree species, where in Northern Ireland, 63% of the area was planted with mixed species, including mainly Conifers. Welsh projects area was also dominated by broadleaved species. Scotland had a similar cover percentage of conifers as the broadleaved trees.

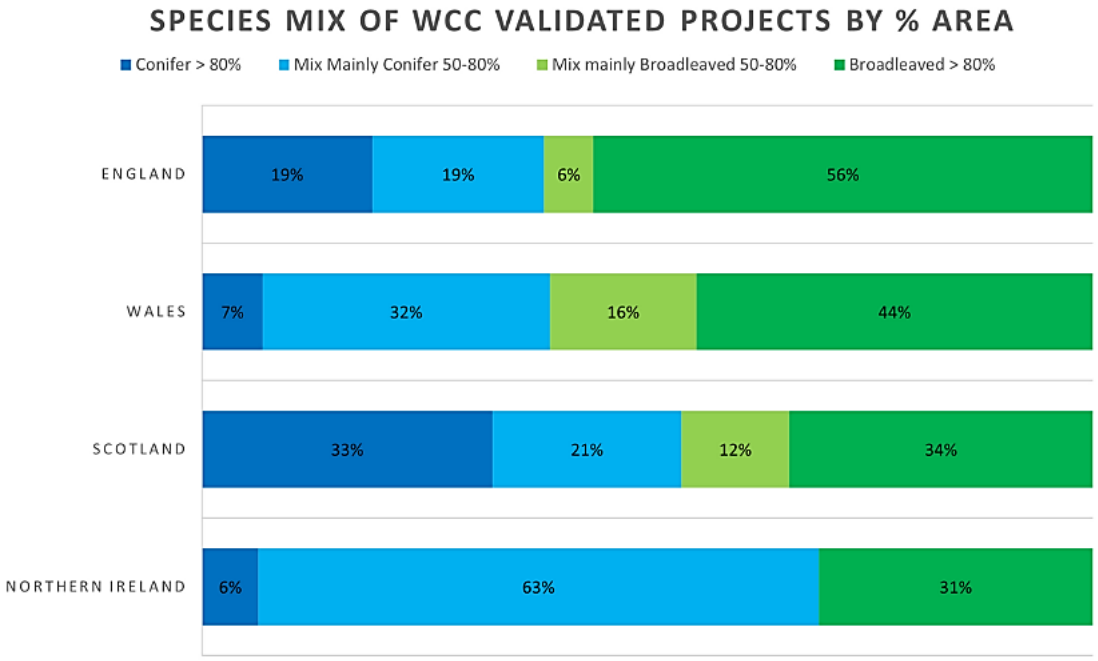
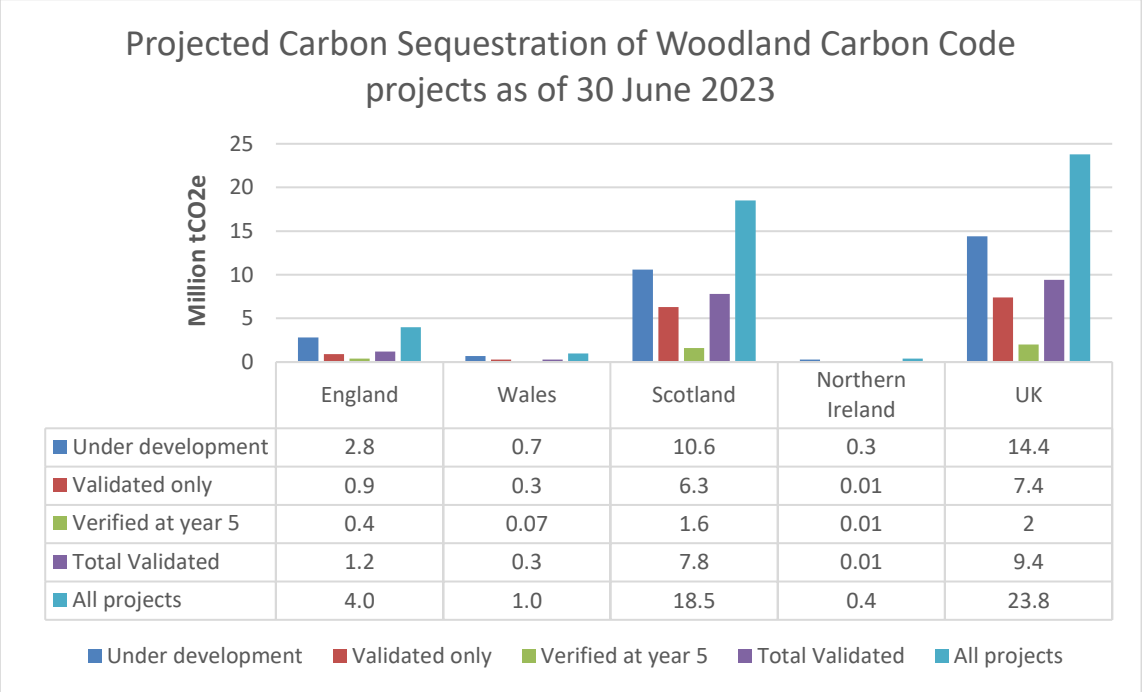


Figure 7. Species mix of validated projects, by % area and country - 30 June 2023 (Woodland Carbon Code, n.d.)

Tree species selection in Woodland Carbon Code projects is important because it directly impacts the effectiveness, sustainability, and success of these initiatives in sequestering and storing carbon, as well as achieving other environmental and economic objectives. Careful consideration of tree species is fundamental to maximizing the benefits and minimizing the risks associated with carbon offset projects.

5.1.4 Carbon sequestration through WCC

The Woodland Carbon Code Scheme ensures accurate quantification and verification of carbon sequestration by woodlands. Forests are among the most effective and efficient natural systems for carbon storage. As explained before, for the Woodland Carbon Code project datasets for the years 2016-2023, carbon sequestration indicates the total projected sequestration of the projects over their lifetime of up to 100 years and includes the amount claimable by a project and the amount allocated to a shared safety account in case of unanticipated losses (Forestry Commission, 2022). The losses can include emissions resulting from removal of vegetation (trees or biomass) or disturbance of the soil through preparation of a site prior to planting (Woodland Carbon Code, n.d.).



	England	Wales	Scotland	Northern Ireland	UK
Under development	2.8	0.7	10.6	0.3	14.4
Validated only	0.9	0.3	6.3	0.01	7.4
Verified at year 5	0.4	0.07	1.6	0.01	2
Total Validated	1.2	0.3	7.8	0.01	9.4
All projects	4.0	1.0	18.5	0.4	23.8

Figure 8. Projected Carbon Sequestration of Woodland Carbon Code projects - Interim statistics as of 30 June 2023. Note: These figures include both the carbon units which can be sold and those which are allocated to the WCC buffer. (Woodland Carbon Code, 2023)

According to the UK National Statistics, Carbon Dioxide emissions in the UK are estimated to have decreased by 2.4% in 2022 from 2021 to 331.5 million tons (National Statistics, 2023).

A total of 505 Woodland creation projects that were validated, including those that were also verified on 30 June 2023, were predicted to sequester a total of 9,4 million tons of CO_2 over their lifetime of up to 100 years. A total of all 1931 registered projects under the Woodland Carbon Code as of 30 June 2023, covering around 73 thousand hectares, is projected to sequester almost 24 million tons of carbon dioxide over their lifetime as shown in Figure 8. Since the beginning of the scheme, Scotland had the biggest input into the total number of projects, area of woodlands and finally, a total carbon sequestered.

According to the Office for National Statistics (2022), in 2020 the average person in the United Kingdom emitted around 6 tons of CO_2 into the atmosphere. With the current life expectancy for UK in 2023 of around 81 years (Office for National Statistics, 2021), the average person would emit 486 tons of CO_2 within their lifetime. The UK's population is estimated to be around 68 million. As shown in Table 5, within 81 years, the population of the UK can emit around 33 billion tons of CO_2 into the atmosphere. All registered at this

time WCC projects are estimated to sequester only around 19,4 million tons of CO_2 which would cover only 0.05% of the population. The estimate is given not considering new deaths, births, or development of the new WCC projects and only if there are no external disruptions.

Table 5. Average emission of CO^2 of the UK population and projected sequestration of CO^2 in projects lifetime of up to 81 years.

	1 person	68,000,000 UK population
Average emissions of CO_2 over an average UK person's lifetime of 81 years old	486 tons CO_2	≈ 33 billion tons CO_2
	1 WCC project (average)	1931 WCC projects
Projected Sequestration of CO^2 over project's lifetime of up to 81 years	10,000 tons CO_2	≈ 19,4 million tons CO_2

(Own dataset, 2023)

5.2 Woodland Carbon Code – SWOT analysis

The main objective of creating the Woodland Carbon Code was its role in mitigating climate change by sequestering CO_2 from the atmosphere through afforestation, reforestation, and sustainable forest management practices. In the UK, as in many other regions, the successful implementation of the program came with its weaknesses and threats that must be addressed to maximize its effectiveness in combating climate change. The opportunities created a space for improvement, to be accounted for in the future development of the scheme.

Table 6. SWOT analysis of the Woodland Carbon Code

STRENGTH	WEAKNESSES
- Effective Carbon Sequestration - Supported by recognized standards and the UK government - Long-term impact in the fight against climate change - Biodiversity conservation and enhancement - Public awareness	- Time- intensive - Land and tenure requirements - Maintenance challenges - The lack of a comprehensive and supportive policy framework - Funding issues
OPPORTUNITIES	**THREATS**
- New Carbon Markets - Policy support - Increased eco-tourism services - Partnerships creation - Innovation improvements	- Climate change impact - Land degradation - Changing Policies - Market uncertainty - Public perception

Source 1. Own dataset

Apart from the contribution to climate change mitigation, the WCC can promote biodiversity and enhance ecosystem services such as improving air and water quality, creating habitats for wildlife, and enabling recreational opportunities for communities. The WCC projects can raise awareness about climate change and encourage public involvement in conservation efforts. The potential of woodlands to soak up CO_2 from the atmosphere while providing a host of other benefits for society and biodiversity is increasingly recognized, and many individuals and businesses wish to contribute to tree planting to help society soak up the carbon it emits (Woodland Carbon Code, n.d.).

While the WCC scheme presented various environmental benefits beyond carbon sequestration, it also uncovered many challenges and spaces for improvement including long-term monitoring issues, funding availability, and potential land use conflicts. The land tenure issues emerged because many lands are ‘rented’ from private owners, meaning that

land managers do not want to invest in land that is not theirs. The lack of a supportive policy framework for carbon forestry was also something that desperately needs improvement. Ensuring the permanence of carbon storage or long- term monitoring and verification can be resource intensive and can require technical expertise and support. As mentioned before, the WCC main objective was always climate change mitigation. Climate change itself is amongst the biggest threats to the scheme as the changing temperature, precipitation patterns and extreme weather events can affect forest health, growth rates and overall carbon sequestration potential.

Addressing issues related to WCC is important to unlock the full potential of the scheme and according to its opportunities and collected evidence, there is much to be improved.

5.3 Agroforestry in the UK (case study)

In July 2019, Soil Association and the Farm Woodland Forum published the 'Agroforestry Handbook, an advisory book for farmers' to help them assess benefits of agroforestry for their farmlands and the environment. The 150 pages long handbook takes a reader through the basic principles of tree planting on farmlands, the practical management and design ideas. The survey was originally designed to assess the impact of the handbook and to identify what further support was needed to encourage agroforestry planting in the UK (Institute of Chartered Foresters, 2020).

The survey, which was completed by 346 people, revealed that significantly more support, information, and payment certainty are required for the landowners to implement agroforestry in the UK. Apart from the available handbook, around 40% of responders did not know where to seek further guidance and the information that should be provided on the government websites was not found. According to the article from the Institute of Chartered Foresters, the survey results revealed the need for:

- More financial modelling and case studies
- More information on UK specific benefits (environmental and otherwise)
- Greater knowledge exchange on systems design, species choice, and management
- Market development for the broad range of outputs from agroforestry systems
- Greater policy support and funding

The survey results showed that the UK is lacking fundamental support in government policy. The inability to provide the basic sources of information to landowners who own most of the land in the UK is delaying the nation reaching its climate goals quicker and prevents the development towards the greener and more sustainable future.

6 Discussion

The results indicated that creation and functionality of the Woodland Carbon Code scheme can be a useful tool contributing positively to nation's pathway towards the Paris Agreement, however, in order to achieve its full potential, additional measures need to be considered.

Through verification and validation of projects of various area since 2016, it was possible to predict the total CO_2 sequestration of 505 projects to reach 9,4 million tons of CO_2 over their lifetime of up to 100 years. Furthermore, the majority of 1426 projects were still under development as of 30 June 2023. This analysis supports the theory that if all these projects get verified within the next 5 years, and their area and duration of the projects stay proportionally the same, a total of 1931 verified and validated projects will be able to absorb around 23.8 million tons of CO_2 from the atmosphere over their project's lifetime of up to 100 years. Of course, the yearly absorption of CO_2 will vary over the years dependent on a variety of factors. It may not seem as much, especially in a timeline of 100 years, but given the fact that Woodland Carbon Code is one of many solutions designed to mitigate climate change and successfully expanding its operations just like other schemes, for example the Woodland Carbon Guarantee or the Peatland Code, together, they will be able to protect and create more woodlands and absorb a noticeable amount of the yearly CO_2 emissions.

Without question, the monetary reward is a factor that benefits those participating in the scheme and applying for a project development on their land. The landowners can generate an upfront income to help with the establishment of the woodland through sale of Pending Issuance Units (PIUs), based on predicted carbon sequestration. They can then sale Woodland Carbon Units once the woodland has sequestered and stored the carbon from the atmosphere (Woodland Carbon Code, n.d.). Additionally, depending on how the woodland is managed, it can also generate an additional income through sale of timber or

non-timber products. Farmers should definitely be able to see direct benefits to their farms, but perhaps money is not enough? Some owners may have a special connectivity with their land and nature. They would like to be more involved and are fearful for the long-term commitment which might not align with short-term goals or expectations. The wider indirect benefits of woodland creation bring a whole range of social and environmental changes like enhancement and restoration of local landscapes, water and soil protection, biodiversity habitat creation, temperature regulation in urban areas and many more.

However, considering the growing population, which is predicted to reach 10.4 billion by the end of the century (Our World in data, n.d.), as well as the rapid and extensive urbanization and development, 100 years, the standard project length, is the time that humanity simply does not have. The issue that cannot be overseen, is how fast a tree can grow and what ultimately comes with it, the length of a project. Many trees can take tens or hundreds of years to reach maturity, depending on species and the geographical location of the tree. The scheme focuses on planting new trees, and those ones grow quicker in their youth, so they absorb CO_2 faster. The older trees get, their density is much greater so they can absorb more CO_2 (EcoTree, n.d.).

Perhaps incorporating agroforestry within the scope of the WCC scheme would be an answer to improving the overall land management issue. Forestry paired with agricultural lands, can be multifunctional and play a significant role in helping farmers adapt and become more resilient in the face of climate change (Westaway, Grange, Smith, G. Smith, 2023). Climate change is a real threat to the scheme and can cause already planted forests to die off during the changing conditions in the future years. Landowners may be fearful to lose valuable rich soil for planting only trees. Trees may be planted on unused parts of land but eventually they will have to be planted on agricultural lands too due to lack of space. The benefits of doing so can be easily predicted: more diverse farm economy and stimulation of the whole rural economy what leads to more stable farms and communities. Economic risks are reduced when systems produce multiple products so why not maximize the measures? (Agroforestry Research Trust, n.d.). The WCC scheme flexibility should be revised, giving farmers more freedom to plant the right trees for their lands dependable on their individual needs. And finally, better advice and guidance in planning and implementation should also be developed. Trees are a long-term responsibility and planned establishments are essential. If landowners are to be confident in adopting

agroforestry, they will require the reassurance of advice and support based on a continuation of methodical research into later phases of agroforestry rotation (Forestry Commission, 2000).

Many of the WCC projects are planned for 100 years, but the Net Zero Target in 2050 is only 27 years away from now. In a 'Dangerous Distraction' article on the Friends of the Earth policy website, Mike Childs and Paul de Zylva suggest that carbon and nature offsetting are both worsening the climate and nature emergencies. They can't work, at least not at scale, and trying to do so is a dangerous distraction from the real jobs at hand: cutting carbon emissions and restoring nature (A Dangerous Distraction – the Offsetting Con, n.d.). Moreover, in another article '7 Reasons Why Carbon Offsetting Doesn't Actually Work', Lebreton brings up several carbon offsetting examples from all around the world, proving that carbon offsetting does not work in most cases and some of the most popular carbon offsetting programs have been proven not to reduce as much – if any – CO_2 as they promise (Tatiana Lebreton, 2023). There is no denying that the issue should be addressed at its core, because simply, there are far more emission levels than offset. Yes, more discussion and funds should be dedicated to implementing changes and developing solutions, but it is also important to try and reverse the negative impacts that have already been released into the world.

Despite all this, according to the Climate Action Tracker website (Climate Action Tracker, n.d.), land use and forestry has no significant impact on the rating of the UK in reaching Net Zero Target. It is because all the projects are relatively new and all the plans to increase forest cover in the UK are still ongoing. Lifting the whole nation up, from one of the lowest levels of forest cover in Europe, will be a lengthy and not an easy process to go through. However, despite this and the statements from the authors Childs, Zylva and Lebreton, the importance of the forestry carbon sequestration schemes is extremely important, and they are creating opportunities for improvement, especially in a nation where almost half of the land is privately owned. Encouraging private landowners to grow and manage trees through participation in forest creation schemes, either through agroforestry or carbon forestry or other possible cooperations is the only way to achieve a common goal. It will open possibilities for partnerships between national government organizations, local communities, and other stakeholders to enhance the impact of carbon projects. Through shared resources and expertise, the innovations would be quickly improved.

Emission cutting in leading industries such as transportation or heat and electricity production should be done simultaneously and should be done now. Walking away from burning fossil fuels, changing our habits, and turning towards renewable energy is the key for us to gain more time on planet Earth.

7 Conclusions

By analysing the progress of the first 12 years of the implementation of the Woodland Carbon Code, and by discussing its strengths and weaknesses, this thesis has shown the journey of the forest carbon sequestering scheme in the UK since its creation in 2011. By uncovering its weaknesses and threats, it was possible to reveal its potential and the opportunities for improvement in the future. Based on quantitative analysis of Woodland Carbon Code's projects, it can be concluded that the scheme is an effective tool in the UK's pathway towards the Paris Agreement and the Net Zero 2050 target, however, the qualitative results are still in question.

Further research is needed to determine the development of the existing and incoming WCC projects and their effect on the CO_2 sequestration from the atmosphere. The monitoring of future innovations and new studies should be undertaken in the light of the ongoing climate change and the whole system of determining what counts as a carbon offset and how to measure it should be revised to make the program more efficient and aligned with its purpose.

This research illustrates that in order for the code to improve, scheme developers need to think outside the box, make it more flexible and perhaps consider incorporation of agroforestry or other practices within the scope of WCC scheme. Moreover, it raises the question of a dangerous distraction from the real problem such as excessive carbon emissions around the world. It is unavoidable for the CO_2 emissions to stop completely in the perpetual world, and the temperatures will keep on rising as long as humanity lives. All we can do is to pressure governments to change carbon emission policies with an immediate effect and hold on to every measure to slow the climate change down and protect the future generations by any means.

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