Integrating ecosystem markets to co-ordinate landscape-scale public benefits from nature

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Abstract

Ecosystem markets are proliferating around the world in response to increasing demand for climate change mitigation and provision of other public goods. However, this may lead to perverse outcomes, for example where public funding crowds out private investment or different schemes create trade-offs between the ecosystem services they each target. The integration of ecosystem markets could address some of these issues but to date there have been few attempts to do this, and there is limited understanding of either the opportunities or barriers to such integration. This paper reports on a comparative analysis of eleven ecosystem markets in operation or close to market in Europe, based on qualitative analysis of 25 interviews, scheme documentation and two focus groups. Our results indicate three distinct types of markets operating from the regional to national scale, based on modes of operation, funding and outcomes: regional ecosystem markets, national carbon markets and green finance. The typology provides new insights into the operation of ecosystem markets in practice, which may challenge traditionally held notions of Payment for Ecosystem Services. Regional ecosystem markets, in particular, represent a departure from traditional models, by using a risk-based funding model and aggregating both supply and demand to overcome issues of free-riding, ecosystem service trade-offs and land manager engagement. Central to all types of market were trusted intermediaries, brokers and platforms to aggregate supply and demand, build trust and lower transaction costs. The paper proposes five options for integrating public and private funding for the provision of ecosystem services and proposes a framework for integrating national carbon markets and green finance with regional ecosystem markets. Such integration may significantly increase funding for regenerative agriculture and conservation across multiple habitats and services, whilst addressing issues of additionality and ecosystem service trade-offs between competing schemes.

Keywords: Payments for Ecosystem Services, blended finance, green finance, impact investment, Landscape Enterprise Networks, carbon markets, public-private partnerships

1 Introduction

Worldwide, benefits from nature to society have been estimated to be worth more than the global gross domestic product[1]. When ecosystems become degraded, the cost of restoration can be prohibitive, and businesses and communities who rely most directly on these services are typically the first to suffer the consequences[2]. Neoclassical economics suggests that if property rights are clear and well defined (and if transaction costs are not too high), a social optimum can be attained via bargaining amongst ecosystem service providers and beneficiaries[3]. This sets the basis for the market to theoretically protect and sustain those services[4,5]. While this may work for some provisioning services over short time-horizons (e.g. food and fibre), markets often fail to reward those responsible for providing service (e.g. upstream farmers or forest managers whose work benefits those downstream) when benefits are hard to attribute a financial value to (e.g. mental health or spiritual benefits from nature) or when benefits mainly accrue to others in society (e.g. downstream flood protection) over longer time-horizons (e.g. climate change mitigation). As a result, many resource management decisions generate short-term private benefits to the owner or manager at the expense of longer-term public benefits, often leading to negative externalities (e.g. pollution or flooding).

In response to this, governments commonly pay resource managers to adopt more sustainable practices and carry out other work that can protect or enhance public benefits from nature. Businesses may also pay for these public benefits for a variety of reasons, including the need to mitigate risks to their business (e.g. from climate change), reduce costs (e.g. by delivering cleaner water), secure social licence to operate or contribute towards corporate sustainability goals[1,6,7,8]. This is increasingly being done via Payment for Ecosystem Service (PES) schemes, which offer monetary incentives to individuals or orgnanisations to adopt or alter behaviours, beyond what is legally mandated, to improve the provision of ecosystem services that would otherwise have been economically unviable to provide[9,10,11,12].

However, there are a number practical challenges to the development and operation of PES schemes[13,14]. Challenges that may deter buyers (such as food processors and water companies) and investors in ecosystem services (such as insurance companies and impact investors) include: the complexity of demonstrating the additionality and permanence of benefits (i.e. proving that they would not have happenned without investment and the benefits will be long-term), costs of monitoring and verifying benefits, coordination between investors to avoid non-paying beneficiaries piggybacking on investments (i.e. benefiting from the investment of competitors without contributing themselves) or benefits for one investor cancelling out benefits for others (for example, tree planting creating habitat for predators of a species being protected by a neighbouring scheme)[15,16,17,18,19].

There are also many potential barriers discouraging resource managers (for example, landowners, tenants and other businesses managing natural resources; the typical 'suppliers' whose actions shape ecosystem service delivery) from engaging in schemes. These include: poorly defined property rights, perceived (and real) risks of entering long-term contracts (including unknown impacts that managing for ecosystem services would have on land value), lack of clarity as to their eligibility for funding from public schemes after entering a privately[1] funded scheme, as well as more straightforward capacity issues relating to how they would implement and manage such schemes[3,13, 20,21,22,23,24].

There is also potential for private ecosystem markets to compete with publicly funded agri-environment schemes, which are becoming increasingly PES-like in their design. For example, the latest Rural Development Programmes under the EU's Common Agricultural Policy pay more for environmental outcomes than ever before[25,26] and post-Brexit agricultural policies in the UK are increasingly focusing on "public money for public goods" [27]. Even if publicly funded schemes pay

[1] Funded by private enterprise or investment

lower amounts over shorter time-horizons than privately funded schemes, they may still displace private funding if they are perceived to be simpler or more familiar, and hence lower risk to resource managers[23].

The integration of different private ecosystem markets could address some of these issues by actively managing synergies and trade-offs. However, to date there have been few attempts to do this, and there is limited understanding of either the opportunities or barriers to integration of private markets. There is also limited analysis of interactions between public and private schemes, or how these might be better "blended". While much has been written about international voluntary and compliance carbon markets in recent years[28,29,30], much less is known about the national and sub-national ecosystem markets that have proliferated in recent years, and how they operate or interact with each other.

This paper therefore uses a comparative analysis of existing private ecosystem markets in operation or close to market at national and sub-national scales in the UK and elsewhere in Europe, to explore governance issues associated with integrating different types of ecosystem markets. Specifically, it aims to:

- Develop a typology of ecosystem markets by comparing ecosystem markets currently in operation or close to market in the UK, Germany, Switzerland and the Netherlands;
- Question some of the operating assumptions of ecosystem markets and offer insights that could enable the cost-effective operation of schemes that minimise trade-offs and integrate benefits across a wide range of land uses at landscape scales; and
- Propose an approach that could be used to integrate multiple ecosystem markets, operating over multiple land uses and habitats, including the integration of private markets currently focusing on different systems, habitats and/or ecosystem services and the blending of public and private schemes designed to deliver public goods.

The analysis includes all known private schemes operating or close to market in the UK, where the development of ecosystem markets has been a policy priority since the launch of the Woodland Carbon Code in 2011 and the 2011 Natural Environment White Paper (which included a Payment for Ecosystem Service Action Plan[31]). It also includes all known privately funded schemes targeting peatland restoration in Europe, where innovative funding mechanisms have proliferated in recent years, providing insights into the operation of ecosystem markets internationally for this habitat.

2 Methods

We conducted a comparative analysis of: 1) all known private ecosystem markets operating (or near to market) across dairy, arable, forestry and peatland systems in the UK (Table 1); and 2) all four private peatland ecosystem markets known to be operating in Europe (Table 1). Schemes that were deemed out of scope included non-UK schemes (other than European peatland schemes), schemes at concept or early development stages, and single transaction bilateral arrangements that were not part of a longer-term scheme sourcing multiple projects for multiple buyers or investors. For this reason, voluntary and compliance carbon markets were not included in the analysis. Research was conducted in four phases, as shown in Figure 1. For more detailed methods, see Gosal et al.[32] and Olesen et al. [33].

Phase 1: Scoping: A narrative literature review was conducted to identify all private ecosystem markets currently operating or near to market in the UK (in any agro-ecosystem) and all private ecosystem markets operating in peatlands in Europe. Unlike systematic reviews or meta-analyses, a narrative literature review is an expert-based "best-evidence synthesis" of key literature[34], which is better suited to reviews that aim to provide a broad overview via expert synthesis, where it is difficult to identify specific outcome measures[35]. This literature also served to identify interview topics and questions for Phase 2. To ensure all relevant schemes were identified (including those close to

market, which were not in the public domain) and refine the parameters of the analysis, scoping interviews were conducted for the UK comparative analysis and the two case studies, and a focus group was conducted with seven participants (including researchers, consultants and EU policy stakeholders) for the European comparative analysis of peatland schemes. During this phase debate emerged over whether the analysis was considering schemes, markets or stakeholder engagement frameworks. Some were formalised as schemes with clear governance structures and rules of engagement, while others (especially those close to market) were more loosely conceived, but operated as a market with buyers and sellers.

Phase 2: Data collection: Data was collected in 2020 via a review of documentation for each scheme and semi-structured interviews with scheme representatives and intermediaries, which covered governance and legal matters, economics and funding and the operation of each scheme. For the UK, 12 interviews were conducted with representatives the eleven markets: the Woodland Carbon Code (WCC), Landscape Enterprise Networks (LENs), Habitat Banking (HB), the proposed Natural Infrastructure Scheme (NIS), Nature-Climate Bond (NCB), Natural Capital Pioneer Fund (NCPF), Habitat Banking (HB) and the Blue Impact Fund (BIF). For the European peatland market analysis, a further 13 interviews were conducted with representatives of four private peatland ecosystem markets (the PCC in the UK, MoorFutures (MF) in Germany, max.moor (MM) in Switzerland and the Dutch Green Deal (GDNL).

Phase 3: Analysis. Qualitative data from interview and focus group discussions were analysed thematically alongside documentation from each scheme. Interviews were recorded, transcribed and anonymised in line with ethical approval from the Newcastle University. The thematic analysis approach outlined by Braun and Clarke[36] was used to undertake in-depth analysis of the interview and focus group transcripts in three stages: initial coding of ideas, views and concepts into minor themes; review and refinement of minor themes to identify major themes; evaluation of themes in relation to the objectives of the study to draw in relevant insights to the comparative analysis[37]. Theoretical saturation was considered to be achieved when no new themes were identified from transcripts.

Phase 4: Triangulation: Finally, preliminary findings from interviews and review of scheme documentation were triangulated via individual written feedback from interviewees (with those providing extensive inputs offered co-authorship), with the addition of a focus group for the UK schemes. In the focus group, findings from the interview phase were presented to participants for discussion in plenary, before breaking into two parallel groups to discuss options for integration between the three main private schemes in operation in the UK, and between public and private schemes. The focus group was attended by 12 participants including researchers, consultants, businesses, the third sector, an intermediary/broker and policy stakeholders from regulatory bodies and Government departments in Scotland and England.

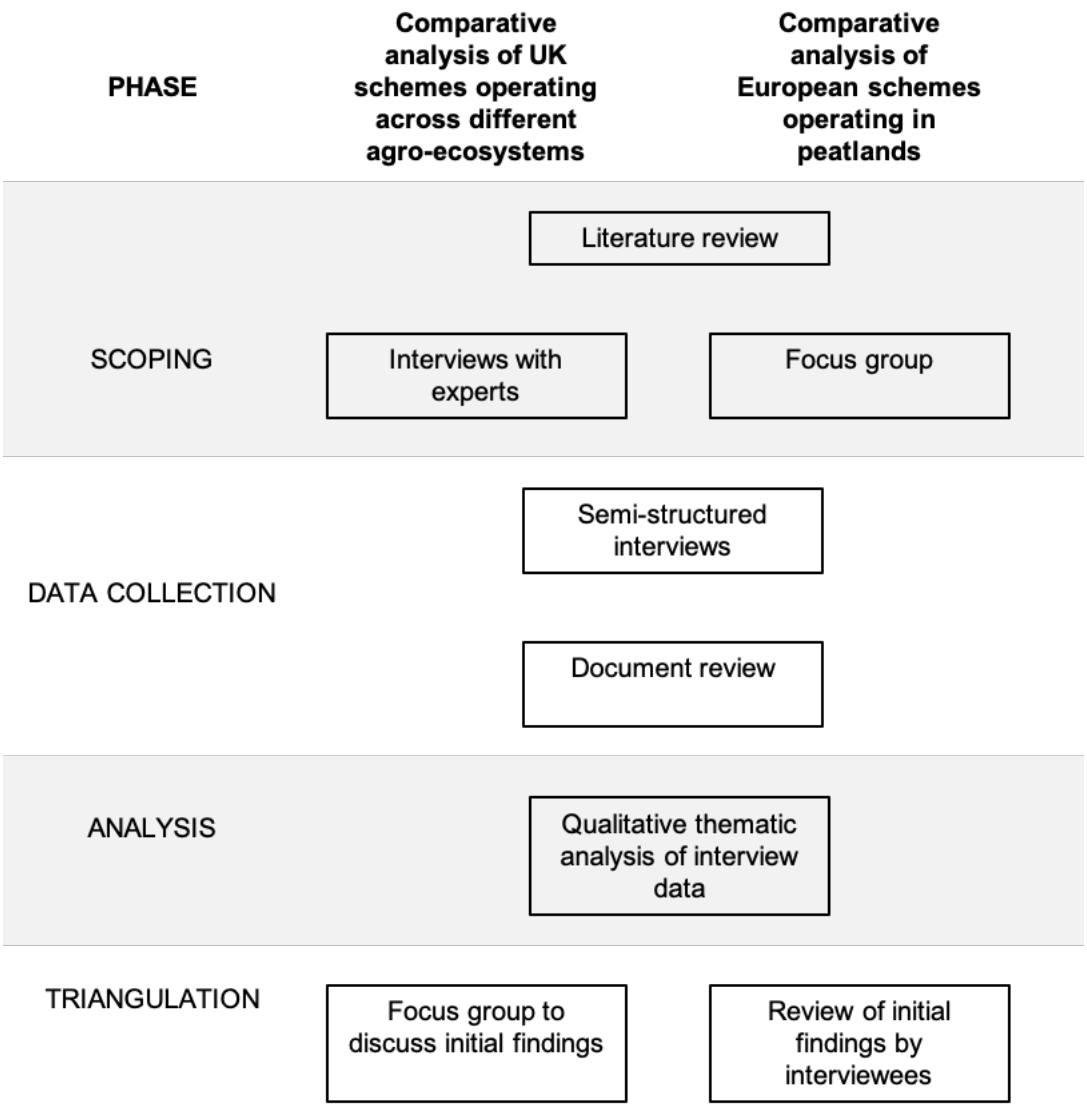

Figure 1: Research design showing different phases of the research showing where identical methods were used (centre) or where different methods were used in each phase for the UK comparison of PES schemes across different agro-ecosystems (left) and the comparison of peatland schemes across Europe (right).

3 Results

Table 1 describes and then compares each of the schemes reviewed in terms of their approach to: validation and verification of outcomes; additionality and leakage; permanence; supply and demand issues; interaction with public funding; and scheme governance. These are discussed further in the Supplementary Material, Gosal et al.[32] and Olesen et al.[33].

Table 1: Comparison of UK ecosystem markets and European peatland restoration markets

	UK ecosystem markets							European peatland markets			
	Landscape Enterprise Networks (LENs)	**Natural Infrastructure Scheme (NIS)**	**Woodland Carbon Code (WCC)**	**Blue Impact Fund**	**Habitat Banking (HB)**	**Nature-Climate Bond (NCB)**	**Natural Capital Pioneer Fund (NCPF)**	**Peatland Code (PC, UK)**	**Moor Futures (MF, Germany)**	**max.moor (MM, Switzerland)**	**Dutch Green Deal (GDNL, The Netherlands)**
Status	Operational	Near to market	Operational	Operational	Operational	Near to market	Near to market	Operational	Operational	Operational	Operational
Description	Natural capital risks and dependencies are mapped for businesses across a region to create demand-side consortia who invest in soil, water and biodiversity related interventions delivered by landowners across a landscape to reduce risks (e.g. from climate change) and increase sustainability and resilience of ecosystem services that underpin business operations. Launched initially by 3Keel with Nestle in 2016, the approach is now open source and used more widely. There are currently 8 projects in operation with a further 4 projects under development. Contracts with individual farmers last from 1-2 years, but measures last much longer (such as hedgerow	A theoretical avoided cost-based model to harness commercial investment in the delivery of natural flood management. Brings together demand and supply side actors to procure natural flood management interventions, that are monitored and maintained for up to 15 years. The scheme was proposed by Green Alliance and the National Trust, but has not yet formally launched or developed any projects.	Voluntary standard for UK woodland creation projects that sequester carbon. The code encourages a consistent approach to woodland carbon projects, and provides assurances to purchases that carbon sold is real, measurable and additional. Launched in 2011 by the Forestry Commission (and now owned by Forest Scotland), there are currently 241 projects validated and a further 154 projects registered but not yet fully validated. Projects last up to 100 years (with the minimum determined by rotation length).	The Blue Impact Fund is a UK-focussed fund seeking to build and enhance the sustainable aquaculture sector through tailored investment and targeting strategic portfolio synergies. The Blue Impact Fund seeks to scale financial, environmental and social outcomes through its investments. The Blue Impact Fund aims to: 1) Protect and restore marine ecosystems e.g. creating no take zones, improving water quality, reducing disease and invasive species, reducing waste and pollution; 2) reduce the climate and ecological footprint of the blue economy e.g. carbon sequestration/storage, habitat creation, renewable energy; and 3) Improve livelihoods, health and wellbeing for communities e.g. employment/skills, economic growth, locally-sourced and healthy food. The Blue Impact Fund was co-developed by Finance Earth and WWF UK, and launched fundraising in November 2020. The fund has a pipeline of ~£90 million. The Blue Impact Fund has been created alongside an aligned charity, the Ocean Recovery Trust, that will work to restore ocean health by funding innovation, capacity	The creation of new woodlands, wildflower meadows, wood meadows, rewilded sites and wetlands is funded by housing, commercial and retail developers that are required to compensate for biodiversity losses via the planning system in each UK country, and to ensure a biodiversity net gain in England and Wales. Launched by Environment Bank in 2006, 19 projects have been delivered to date as bespoke offsets. Larger scale habitat banks are to be rolled out in 2021 to satisfy increasing demand under a mandated regime in planning law.	Abundance Investment and City of Edinburgh Council are developing bonds that could be issued by Local Authorities direct to the public who could invest from as little as £5. This would be facilitated through Abundance Investment's crowdfunding platform to fund interventions such as the creation of urban green spaces or sustainable urban drainage systems. These would provide long-term savings or revenue that would enable Local Authorities to repay investors.	A scheme led by Conservation Capital that is planning to fund biodiversity projects via unsecured loans from impact investors to businesses that are unable to access traditional lending due to the size of their asset base. Profits from these businesses would then enable investors to be repaid with interest. Examples of investments could include nature tourism, oyster reef restoration and development of peat free composts.	Voluntary standard for UK restoration projects that reduce GHG emissions from degraded peatlands. The code sets out best practice requirements and a standard method for the quantification of GHG benefits and provides buyers assurances that the climate benefits being sold are real, quantifiable, additional and permanent. Launched in 2015 by IUCN UK Peatland Programme, there are currently 4 validated projects and a further 6 registered and others in the process of registering. Projects last 30-100 years.	Voluntary standard for German peatland restoration projects based closely on Verified Carbon Standard methodologies. The founders developed the Greenhouse gas Emission Site Type (GEST) approach to assess emissions based on vegetation composition (Couwenberg et al., 2011). Credits cannot be traded on voluntary markets as of now, as they are issued ex-ante. Credits usually sold to private people or German companies wishing to offset emissions. Launched in 2011 in one federal state of Germany, it has now (2020) been taken up by four federal states. There are currently five projects that are validated (three of them verified). Projects last 30-50 years.	A methodology for voluntary carbon market projects restoring Swiss raised bogs. Driven by local authorities and credit developers, and selling to buyers in Switzerland. Targeting lands already retired from agricultural use because of conservation laws in place since the mid 1980ies, but where the rewetting and restoration of vegetation cannot find funding. Launched in 2017 by the Swiss Federal Institute for Forest, Snow and Landscape Research. Projects lasts up to 50 years.	A mutual agreement under private law between a coalition of companies, civil society organizations and local and regional government. The deal defines interventions and outcomes to be delivered and financial and other inputs to be provided by all participants. A three year Green Deal Pilot National Carbon Market launched in 2017, covering forestry, land use change and renewable energy. Projects last 10-50 years.

	planting) and the LENs scheme itself is open-ended.			building, and marine conservation programmes, growing the sustainable blue economy and delivering ocean restoration. The Ocean Recovery Trust will be funded through a 'conservation dividend' generated by the Blue Impact Fund, alongside additional philanthropic donations.							
Validation and verification of outcomes	Current projects are focussing on soil carbon, biodiversity, animal health and water quality. Implementation of interventions is validated but outcomes are not verified yet. In future, verified carbon units will be offered via integration of WCC and PC projects as part of a portfolio of benefits across a landscape.	A range of ecosystem services could be delivered, but the focus of the scheme is primarily on hydrological outcomes. No projects have been validated and there is no guidance for project validation yet. There are no plans yet verify outcomes, issue carbon units or enable trading on voluntary carbon markets, and any units generated would not be eligible for the compliance market.	Verified Woodland Carbon Units from WCC projects can be used by companies to compensate for their UK-based greenhouse gas emissions, but cannot be traded on voluntary or compliance carbon markets. A registry enables units to be bought and sold by companies within the UK. Forward selling of Pending Issuance Units is possible after validation, in addition to the purchase of Verified Carbon Units ex-post.	The Blue Impact Fund was co-developed with WWF UK, who will have two seats on the fund's investment committee responsible for assessing the impact of each investment. The basis for the Blue Impact Fund's impact assessment is the Sustainable Blue Economy Finance Principles, which were developed by the WWF to inform private investment into the blue economy. The Blue Impact Fund's investments will comply with relevant ASC/MSC standards and Sustainable Development Goals (in particular SDG 14 – life below water). These more detailed standards will be used to set deal specific KPIs for impact monitoring.	Environment Bank validate their own projects but are designing a third-party accreditation system for on-site and off-site biodiversity net gain delivery. Environment Bank also validate biodiversity net gain calculations made by developers to ensure effective biodiversity accounting.	Not yet established.	Not yet established.	Verified Peatland Carbon Units from PC projects can be reported by companies, but cannot be used as carbon offsets or traded on voluntary or compliance carbon markets. A registry enables units to be bought and sold by companies within the UK. Forward selling of Pending Issuance Units is possible after validation, in addition to the purchase of Verified Carbon Units ex-post.	Carbon Units from MF projects can be reported by companies, but cannot be used as carbon offsets or traded on voluntary or compliance carbon markets. A federal state ministry registry enables units to be bought and sold by private individuals and companies anywhere in the world. Forward selling of Pending Issuance Units is possible after validation, in addition to the purchase of Verified Carbon Units ex-post.	A certificate is issued, which represents remaining peat layer thickness as a proxy for avoided future emissions. Project developers then issue credits based on these, following third part verification following carbon markets standards.	Validation is conducted by a committee of experts, with certification bodies verifying projects based on data collected from monitoring wells.
Additionality and leakage	No formal additionality tests. The likelihood of leakage is low due to the landscape scale of projects.	No formal additionality tests or consideration of leakage yet.	Additionality tests cover legal compliance, contribution of carbon finance (at least 15%), evidence projects would not have been economically viable without carbon finance, and where the project has overcome other barriers would	The Blue Impact Fund has been structured to fill a gap in the market, providing tailored finance and support to businesses that otherwise wouldn't be able to access the same level of support. The BIF will also work with businesses to create portfolio level synergies and work with our pipeline to maximise impact.	Conservation or biodiversity credits generated from bespoke offsets or habitat banks are calculated using the defined Defra metric[38,39]. The number of biodiversity units generated from a habitat bank take into account the existing condition of the receptor	Not yet established.	Not yet established.	Additionality tests cover legal compliance, financial feasibility (at least 15%), evidence projects would not have been economically viable without carbon finance, and where the project has overcome other	Tests focus on financial additionality (projects must be 100% carbon financed). MF assesses projects for activity shifting, market leakage and ecological leakage, requiring projects with significant leakage to account for these	Includes a financial additionality test requiring at least 10% carbon finance, and focuses only on degraded peatlands no longer in agricultural use to avoid leakage.	Legal additional test only. Leakage is not assessed in GDNL projects.

			have otherwise prevented woodland planting (the "barrier test"). Projects have to state any intention to change or intensify land use elsewhere on their holding as a consequence of woodland creation and assess associated GHG emissions.		site – additionality is therefore guaranteed – credits cannot be generated from land already delivering specific biodiversity value. Nor can high quality habitats be converted into other habitats in order to generate credits. Therefore, leakage is not an issue with habitat banks.			barriers would have otherwise prevented peatland restoration (the "barrier test"). Projects have to state any intention to change or intensify land use elsewhere on their holding as a consequence of woodland creation and assess associated GHG emissions.	emissions in their assessment of GHG benefits.		
Permanence	Permanence provided via contractual agreements requiring repayment to buyers if interventions are reversed within the contracted period. Contract lengths are typically short and many of the interventions are easily reversible after the end of a contract, but buyers are aware of this, and primarily procure short-term benefits from the scheme.	No formal mechanisms yet proposed to ensure permanence.	Permanence is provided via contractual agreements and a 15% risk buffer pooled across all projects. Additional protection is provided under the Environmental Impact Assessment (for deforestation) and the Forestry Act (1967) which require a felling licence from the relevant forestry authority to remove trees.	The Blue Impact Fund will offer follow-on investment during the fund's life to further grow and optimise its investments. The investments targeted are operational businesses so will continue deliver impact beyond the funds exit. The fund's exit strategy will be determined after the optimisation phase of the portfolio, which seeks to maximise the operational and portfolio efficiencies, but is likely to comprise either a public listing, which would enable the fund to structure long-term impact objectives within the portfolio structure, or strategic market sale. In each case, the fund will consider permanence within the decision-making.	Provided by mandated 30-year contracts between purchaser/broker or other authority and landowner provider. Environment Bank uses 30-year Conservation Bank Agreements[1] with annual payments to landowners according to delivery of key milestones in the Agreement in association with an agreed payment plan, as verified via regular monitoring and reporting.	Not yet established.	Not applicable.	Permanence is provided via contractual agreements, which require projects to compensate buyers for reversals. Further guarantees can be provided via Conservation Covenants in England and Conservation Burdens in Scotland, which place a requirement to maintain projects on anyone who purchases the land. Permanence is also ensured via a 15% risk buffer and 10% precision buffer of unsold carbon units pooled between all projects.	The permanence of MF projects is provided through contracts, prescribed water levels under the Water Law, entries in the land register to secure permanence of the required water levels and/or the purchase of land for restoration through a Trust that can guarantee the long-term maintenance and management of project sites. Permanence is also ensured via a 30% project buffer of unsold carbon units.	Permanence is included in contracts and increased by only focussing on degraded peatlands that are no longer in agricultural use, but there are no formal measures to guarantee this.	Permanence is not assessed in GDNL projects.
Supply and demand issues	Prices determined through negotiation	Prices determined through negotiation	Prices determined through negotiation	The Blue Impact Fund doesn't foresee any material issues in the supply of projects: the	Prices of conservation credits currently set for habitat	Not yet known.	Not yet known.	Prices determined through negotiation	Prices are fixed on the basis of project costs. Upfront payments	Prices are fixed on the basis of remaining project costs	Prices determined through negotiation

	between buyers and sellers via supply aggregators, based on costs and ecosystem service revenues. Payments made annually via a regional legal entity under development. Prices are based on a bundle of ecosystem services typically including soil function, water quality and biodiversity, but these outcomes are not typically quantified.	between buyers and sellers via supply aggregators, based on costs and ecosystem service revenues. Prices and payment mechanisms have yet to be reached.	between buyers and sellers, either directly or via intermediaries, based on costs and ecosystem service revenues. Upfront payments for woodland establishment followed by annual payments, primarily on the basis of carbon sequestration, though a Wider Benefits Tool enables estimation of co-benefits.	market is fast-growing and the most impactful enterprises are reaching proof-of-concept/scale up phase; particularly within the seaweed sector. COVID has had an impact on the seafood sector and presents an opportunity to bring investment into distressed businesses that demonstrate sustainable growth potential (e.g. through consolidation/expansion).	banks by Environment Bank for establishment and 30-year management. Planning Authorities are key to ensuring demand for developments to to deliver at least 10% Biodiversity Net Gain. A mandated system gives clarity and certainty and reduce planning delays. Range of potential supply issues. Planning Authorities may use their own land but legally challengeable.			between buyers and sellers, either directly or via intermediaries, based on costs and ecosystem service revenues. Upfront payments for restoration capital works, followed by annual payments, primarily on the basis of avoiding GHG emissions, though co-benefits may also be marketed.	for restoration capital works, followed by annual payments, primarily on the basis of avoiding GHG emissions, though detailed guidance is provided to assess co-benefits, which may also be marketed.	after public investment. Upfront payments for restoration capital works are paid from public funds with private investment supporting annual payments, on the basis of avoiding GHG emissions.	between buyer and seller. Payments for units expectedly ex-post, but not regulated. In Q2 2020, a handful of projects were under preparation, using the peatlands methodology but no units issued yet.
Interaction with public funding	Projects are covered entirely by private investment with very limited, indirect Government support for scheme development and operation.	Projects envisaged to be covered by private investment with only limited, indirect Government support for scheme development to date.	Up to 85% of project costs can be publicly funded. Development and operation of scheme is primarily publicly funded.	The Blue Impact Fund is a private equity model but is open to interacting with public sources through match funding, grant and other resource support. The Ocean Recovery Trust, aligned to the Blue Impact Fund, will target engagement with the public sector to leverage additional investment for the ocean economy.	At present Biodiversity Net Gain, whilst already scaling, has failed to attract Government funding.	Local government would be the issuer of the bonds and is therefore a key player as the entity that would take on the risk. Interventions would be funded by private investment.	Impact investors would provide the majority of capital, supplemented by grant funding in the early stages.	Up to 85% of project costs can be publicly funded. Development and operation of scheme is primarily publicly funded.	Projects are covered entirely by private investment, with significant, indirect Government support for scheme development and operation.	Up to 90% of project costs can be publicly funded. Development and operation of scheme is primarily publicly funded.	Up to 85% of project costs can be publicly funded. Development and operation of scheme is primarily publicly funded.

[1] Legal agreements between Environment Bank and the landowner provider

The comparative analysis identified a number of points of commonality between the schemes that were reviewed (see Supplementary Material and Table 1). Common characteristics and challenges across all schemes are:

- Participation in all schemes was voluntary for both buyers and sellers, and the level of payment for interventions was primarily determined by project costs, with negotiation between buyers and sellers possible in some schemes. None based their prices on the price per tonne on the voluntary carbon market, which would typically have been too low to cover project costs. One of the ways that the four peatland schemes justified higher prices (compared to international carbon market prices) was by highlighting additional non-carbon benefits such as water quality benefits of restoration or biodiversity. The marketing of co-benefits was common across all the schemes reviewed, but verification and quantification of co-benefits were limited in nearly all schemes (MF being the exception).
- Most schemes used intermediaries to engage with project developers (e.g. landowners and tenants), or the scheme itself performed this function (e.g. BIF) and LENs used supply aggregators to aggregate sufficient density of supply within a single landscape. However, engagement with suppliers (typically landowners and managers) was a challenge for all schemes except BIF which had created a £90M project portfolio prior to entering its investment phase.
- On the demand side, sensitivities around the willingness of businesses to share financial data were identified as a challenge to the establishment of co-procurement arrangements between buyers in schemes where this was possible. As well as this, additionality was an issue for buyers in some schemes where businesses were reluctant to pay for interventions that landowners/tenants should already be doing to comply with regulation and/or that could be paid for by public finance.
- Across the schemes, consideration of the wider social distribution of ecosystem services was limited, although there was recognition of its importance for buyers with Corporate Social Responsibility goals.
- Permanence was addressed primarily via contractual arrangements in the schemes reviewed, although Conservation Burdens (Scotland) and Covenants (England and Wales) were sometimes proposed by schemes as potential future options to provide additional assurances to buyers in some UK schemes, and BIF provided follow-on funding opportunities to enhance permanence.

In addition to these common characteristics and challenges, the comparative analysis identified a number of important differences between the schemes that were reviewed (see Supplementary Material and Table 1), for example:

- The four peatland schemes and WCC tended to validate and verify outcomes using site visits by independent certification bodies, HB was developing a third-party accreditation system and BIF accredited projects to relevant industry standards. However, validation mechanisms had not yet been developed for NCB and NCPF, and LENs and NIS provided validation in the form of evidence that interventions had been carried out, without requiring independent verification of ecosystem service outcomes.
- Additionality was only assessed formally by the four peatland schemes, WCC and HB, typically via legal (e.g. projects go beyond what would be required by law), financial (e.g. projects would not be possible without carbon finance) and other additionality tests (e.g. application of biodiversity metrics in HB receptor sites). None of the other schemes applied formal additionality tests, relying instead on trusted intermediaries to manage additionality informally as part of the project design process (e.g. LENs) or identifying businesses that had been unable to fund sustainability initiatives via other means (e.g. BIF).

- The peatland schemes and WCC tended to focus on selling (often fungible) climate mitigation benefits via market registries (e.g., the UK Land Carbon Registry run by IHS Markit). While co-benefits, such as biodiversity benefits were used to market these schemes, only MF quantified and "stacked" these benefits as part of a package of ecosystem services for buyers. In contrast, other schemes were designed to sell or finance a wider range of (mainly non-fungible) ecosystem services, including water quality, soil function, biodiversity and animal welfare benefits, in addition to climate mitigation to buyers.
- Investments in the peatland schemes, WCC and HB tended not to be geographically linked to the locations or interests of buyers, who they sourced nationally, and some of these schemes ruled out international investment to avoid double-counting against national emission reduction targets. LENs, NIS, BIF, NCB and NCPF were able to accept funding from national and international buyers (e.g., overseas impact investors). However, LENs and NIS tended to focus on sourcing funding from regional stakeholders, on the basis that this is a scale at which synergies and benefit integration are easier to achieve.
- Schemes relied to varying extents on public funding, both in terms of scheme operation and project financing. The peatland schemes and WCC were significantly more reliant on public funding for project financing and in many cases scheme operation than the other schemes reviewed.
- Payment mechanisms varied significantly across schemes (and in some cases between interventions within schemes) with the use of different legal agreements, payment structures and investment aggregation platforms (ranging from intermediaries acting as demand aggregators to crowdfunding platforms).

4 Discussion

There is a well-known and significant gap between the public funding currently available and the funds that are needed to address the twin challenges of climate change and biodiversity decline[40]. In the UK alone, it has been estimated that it will cost £1.8M to meet Achai biodiversity targets[41], and the cost of reaching net zero GHG emissions by 2050 has been estimated at between £50-70 billion[42]. However, there are significant challenges in delivering emission reductions in the land use sector, where it is estimated that it may cost £247 million to deliver net zero targets from peatlands, woodland and agriculture[43]. This gap is likely to increase as Governments around the world respond to the economic impacts of the COVID pandemic of 2019-20. In the UK land use sector, this is compounded by post-Brexit agricultural policies, which will lead to an overall reduction in public funding for the sector by 2027 as support moves away from direct payments. The upfront costs of many nature-based solutions are prohibitive for owners and managers in the land use and marine sector, and it can be many years before monetizable benefits accrue, further exacerbating the funding gap.

At the same time, members of the UK Investment Association managed £8.5 trillion in 2020[44] and the global bond market was worth $21 trillion in 2019[45]. Within this community is a small but growing group of impact investors who are willing to accept lower than market-rate returns on investment and higher levels of risk[46]. There is also growing recognition in the corporate sector of increasing risks to business from the environment, with climate risks now commonly featuring on company risk registers. Although only 13 percent of US company directors ranked climate change as one of their top five risks for 2020[47], risk assessments over longer time horizons identify multiple risks from climate change, notably risks from extreme weather to infrastructure and supply chains, and "transition risk" as regulation and consumer preferences shift towards a low carbon economy, amplifying other

more traditional risks e.g. being left behind by low carbon technology accelerations and resource scarcity[48].

As a result, demand from the corporate sector is now growing rapidly for ecosystem markets, and there has been a recent proliferation of new schemes and markets, as shown in Table 1. These markets are being stimulated by Government investment, with the goal of using public funding to leverage private investment in natural capital. For example, in the UK, an Investment Readiness Fund was launched in 2021 to support the development of natural environment projects that can generate revenue from ecosystem services and attract repayable investment. The three-year £10 million programme will provide grants which project developers can use to build capacity and consortia to develop projects to an investible level[49]. The UK will issue its first green government bond in 2021, setting an example to other governments on issuing green bonds in the year that the UK hosts the 26th Conference of the Parties to the UN Framework Convention on Climate Change. The UK follows the example of Poland's sovereign green bond (in 2016) and Germany's inaugural green Bund (in 2020).

In this section, we will discuss some of the key differences between the schemes and markets included in the comparative analysis and explore the potential to integrate different types of ecosystem markets. In doing so, we explore the governance issues associated with private market integration and the blending of private and public funding for public goods.

4.1 Types of ecosystem market

Based on the comparative analysis in Table 1 and Supplementary Material, three different types of scheme emerged, based on their modes and geographical scales of operation, funding and outcomes (Table 2):

1. **National carbon markets**, primarily sold verified, validated, additional and (often) fungible climate mitigation benefits (sometimes marketed as offsets), typically to national buyers within a single country, with permanence provided by legislation of long-term contracts and significant Government funding for projects and/or scheme operation;
2. **Regional ecosystem markets** enabled buyers to manage environmental risks to their business by investing in a wider range of non-fungible ecosystem service outcomes (including water quality, soil function, biodiversity and animal welfare benefits), in addition to climate mitigation, typically to regional buyers, with varying levels of validation, verification, additionality and permanence and limited Government funding required for projects and/or scheme operation; and
3. **Green finance** provided risk-adjusted returns on investment for national and international investors (potentially including members of the public via crowdfunding) who were willing to accept lower than market rate returns, and financed the widest range of (sometimes fungible) ecosystem service outcomes, with verification of outcomes (and in one case additionality) using industry or Government agreed metrics and standards, permanence via long-term contracts or follow-on funding and limited Government funding required for projects and/or scheme operation.

Although not included in our sample of UK-based schemes that are operational (or close to market) and peatland schemes in Europe, green finance mechanisms can also include loan-based schemes and insurance products. For example, Scottish Natural Heritage, Scottish Environmental Protection Agency, Scottish Wildlife Trust, RSPB, British Ecological Society and British Marine are developing a scheme based on loans with Lloyds Bank, in which commercial bank loans are be made to groups that can implement biosecurity measures to prevent the arrival or spread of invasive species or help eradicate them. Loans would be

repaid from future savings on the costs of managing invasive species[50]. For example, Willis Towers Watson have a Global Ecosystem Resilience Facility uses the prospect of reduced premiums to encourage investment in projects that reduce climate-related and other environmental risks to clients (e.g., coral reef protection and restoration to protect coastal businesses from storm surges), reducing risks and so making premiums more affordable[51]. Corporate Social Responsibility (CSR) schemes are not included in the typology, as this is one of a range of motives for investing in ecosystem markets, and CSR can motivate investment in all three types of scheme identified above.

The typology in Table 2 provides an evidence-based distinction between the key types of ecosystem markets operating in the UK and Europe on the basis of their modes of operation, funding and outcomes. This may provide useful clarity for decision-makers in policy and practice who wish to expand the role of private investment (ranging from crowdfunding to green investment funds) in conservation and regenerative agriculture. For example, a practitioner may be able to use the typology to identify relevant existing schemes or develop new schemes that target the types of ecosystem services, project developers or investors they are most interested in. Alternatively, a policy-maker targeting climate change mitigation from the land use sector might prioritise the promotion of national carbon markets, whereas a Local Authority seeking to reduce flood risk might prioritise paying for or attracting private investment in natural flood management via LENs and/or investment in sustainable urban drainage systems via green bonds or other green finance mechanisms. A decision-maker interested in providing additional income streams for farmers might focus on a peatland scheme or LENs, and if they wanted to exclude overseas investment to ensure investments counted towards national net zero targets, they might focus on national carbon markets and regional ecosystem markets, rather than green bonds which tend to attract international impact investors. The typology also provides new academic insights into the operation of ecosystem markets in practice, which may challenge traditionally held notions of PES. In particular, regional ecosystem markets do not conform to a number of assumptions underpinning PES and financial markets, in which payments would normally be conditional on, or linked to, ecosystem service outcomes or returns on investment. For this reason, the next section considers the operation of this type of ecosystem market in greater depth.

4.2 Understanding the success of regional ecosystem markets

The emergence and successful early operation of the regional ecosystem market model is particularly noteworthy, given how differently this model operates compared to national carbon markets and green finance (Table 2). What constitutes a PES and how to define it is subject to much debate[52], but generally there is agreement on PES involving individuals or organisations ('buyers') paying other individuals or organisations who manage natural resources ('sellers') to deliver clearly defined benefits or “ecosystem services” from nature[14]. While this definition of PES relaxes Wunder et al.’s [9,10] original stipulation that transactions must be voluntary (they rarely are in publicly funded PES schemes), the conditionality of payments on the delivery of well-defined, agreed outcomes remains central to PES, and is widely assumed to be necessary to engender the necessary buyer confidence to underpin a functional ecosystem market[52]. Therefore, the limited provisions for validation, verification and additionality in the regional ecosystem markets reviewed in this research may either be used to question whether these are indeed PES schemes, or to question how important conditionality is to the success of a PES scheme. Moreover, unlike green finance schemes, regional ecosystem markets are not designed to provide returns on investment.

Table 2: Typology showing the defining characteristics of national carbon markets, regional ecosystem markets and green finance.

Defining characteristic	**National carbon market**	**Regional ecosystem market**	**Green finance**
Main benefits for investors	Climate mitigation benefits, sometimes offsets	Management of environmental risks to the delivery of business objectives	Economically sustainable delivery of public goods from private finance that can deliver returns on investment
Verification and validation of projects and outcomes	Strict procedures governing validation of projects and verification of outcomes by independent certification bodies	More limited verification of outcomes, including by projects themselves and intermediaries	Verification by scheme operators or independent bodies to industry or Government agreed metrics or standards
Additionality	Assessed formally at project scale via legal, financial and other additionality tests with limited consideration of landscape scale effects sometimes via leakage assessments	Assessed informally at landscape scale by intermediaries during scheme design to avoid ecosystem service trade-offs and free-riding	Assessed informally during the construction of the project pipeline or formally via metric-based additionality tests on site
Ecosystem service outcomes	Focus on selling (often fungible) climate mitigation benefits via market registries	Sold a wider range of non-fungible ecosystem services, including water quality and quantity, soil function, biodiversity and animal welfare benefits, in addition to climate mitigation, which were often bundled together in integrated landscape scale propositions	Financed the widest range of ecosystem services, including prevention and removal of invasive species, urban green space, sustainable urban drainage systems and development of peat free composts, some of which were fungible.
Operating scale and market scope	Landscape scale projects typically offered nationally to buyers anywhere in the country, often not allowing international buyers to participate to prevent double counting against national emission reduction targets	Landscape or regional scape projects typically developed for buyers within the same region, although national and international buyers can in theory participate	Landscape or regional business scale projects developed for national and international impact investors and members of the public
Reliance on public funding for projects and/or scheme operation	Significant (up to 85% project costs)	Limited	Limited
Examples (for details, see Table 2)	Woodland Carbon Code Peatland Code MoorFutures max.moor Dutch Green Deal	Landscape Enterprise Networks Natural Infrastructure Scheme	Nature-Climate Bond Natural Capital Pioneer Fund Habitat Banking Blue Impact Fund

As such, it may at first glance seem surprising that the LENs scheme in particular had attracted significant levels of private sector investment and was proliferating across UK landscapes with new international LENs propositions being developed at the time of the analysis. Although prices across the schemes reviewed were dictated primarily by the costs of delivering projects and so varied from project to project, national carbon markets tended to calculate the cost of projects per tonne of carbon as a reference point to guide buyers. In contrast, LENs buyers had no way of knowing the likely climate benefits, let alone the price of these per tonne of carbon. Instead, they took a more risk-based approach to negotiating prices between buyers and sellers on the basis of risks to assets, supply chains or reputational risks, which could be reduced or avoided by paying for interventions in the landscape. In addition to providing a different reference point for buyers in the negotiation, the focus on risk often brought more senior executives responsible for risk management to the negotiation table with access to different budgets, compared to the sustainability and corporate responsibility officers typically involved in decisions around carbon offsetting. In addition, the metrics typically used to assess risk tended to be less precise than those used to assess offsetting, which may explain the willingness to work with trusted intermediaries to deliver risk reduction outcomes without the controls on verification, validation and additionality of projects that were seen in national carbon markets.

This focus on risk management may also explain the broader range of interests captured by regional ecosystem markets, including for example, asset risks from flooding, supply chain risks arising from issues with water quality, soil function or animal welfare, reputational risks arising from threats to biodiversity, and the wider risks to assets, supply chains and reputation arising from climate change. This diversity of interests then drove demand for multiple ecosystem services, which had to be managed in space and time to avoid trade-offs where the delivery of one service (e.g. carbon via conifer plantation) compromised the delivery of another (e.g. biodiversity). However, this diversity of outcomes also increased the likelihood that companies who did not invest in a scheme may benefit from the investments of their competitors (the free-rider effect). The LENs scheme addressed the challenge of avoiding both trade-offs and free-riders by identifying multiple risks across landscapes used by a number of beneficiary organisations who could manage risks by working together at landscape scales. This increased the number of co-investors to reduce the free-rider effect whilst ensuring interventions worked together without generating trade-offs at the landscape scale through the identification of multiple interests across the investor community prior to constructing the landscape scale interventions to deliver against those interests. Aggregating demand for ecosystem services in this way also increased the overall amount of funding (by stacking payments for multiple benefits) and led to perceptions of long-term resilience in funding, as the risks of any individual investor withdrawing funding were reduced with an increased number and diversity of investors. The successful aggregation of demand was in part due to the proactive role of trusted business-to-business brokers, compared to the national carbon markets, which tended to be managed by organisations with very different cultures and language (typically Non-Governmental Organisations, research institutes or Government agencies), who played a more passive role in engaging with investors.

On the supply side, the limited requirements around verification, validation and additionality had the benefit of reducing red tape for land managers who wished to engage with regional ecosystem markets. Indeed, evidence from interviews with farmers working in the LENs scheme in Cumbria have shown widespread satisfaction with the scheme compared to the complexity of public agri-environment schemes[53]. Although farmers still commented on the additional reporting burden, and had other criticisms of the scheme, engagement with the scheme was strong. The two most important drivers for farmer engagement with the scheme, according to a subsequent Delphi survey, were: i) additional, stable income for easily planned and reported, and flexible activities that were compatible with existing

management; and ii) improving environmental outcomes and animal health[54]. In addition to the relative simplicity of the regional ecosystem market model, trusted intermediaries were employed to actively recruit farmers, further reducing barriers to entry. These intermediaries aggregated suppliers of services, and so increased market potential (availability of saleable benefits) while reducing transaction costs (of contracting with multiple landowners/tenants).

In contrast, national carbon markets were less proactive in recruiting land managers to develop projects. Neumann[55] conducted a Social Network Analysis of PC and MF, showing little or no engagement with land management representatives in the two governance networks. Instead, decision-making was primarily taken by scheme co-ordinators in consultation with a small number of key researchers who acted as knowledge brokers, providing access to necessary evidence. There was limited active involvement from members of the policy community, although interviews showed that "weak ties" in the network to these more peripheral actors had played an important strategic role in gaining political support and funding for the two schemes. The role of the most engaged researchers in both networks was multifaceted, acting as trusted intermediaries to members of the policy community as well as providing access to evidence to inform scheme development and management. However, both networks were highly dependent on the knowledge, experience and trust that had been accumulated by a small number of scheme co-ordinators and managers, making the ongoing success of both schemes vulnerable to the impact of staff turnover (indeed, the Peatland Code Manager was replaced soon after the research was conducted). In the case of the Peatland Code, the Director had similarly strong networks, providing a degree of resilience to the management of the network. In the case of MF, despite stronger reliance on a single scheme co-ordinator and additional scheme coordinators in the other participating federal states, a larger number of researchers and practitioners played pivotal roles in the network, which may provide this scheme with more resilience to changes in staffing, compared to the Peatland Code. Despite the relatively informal governance arrangement of MF, compared to the two formal governance structures in the Peatland Code, the day-to-day operation of both schemes was similarly dependent on a small number of active members who regularly exchanged knowledge with others, and who were trusted by their network.

More complex and formalised governance structures may be necessary to ensure accountability and transparency as new regional ecosystem markets develop and seek integration with national carbon markets. However, the successful operation of these schemes needs to mitigate the risk of losing key trusted individuals from the network, if these individuals provide access to expertise, political capital, funding and experience from across their networks. Equally, scheme resilience and delivery of outcomes may be strongly influenced by a small number of key players, which may limit the rate at which new schemes can successfully proliferate, based on their individual capacity.

4.3 Scheme integration

The main reasons for integrating national and regional ecosystem markets that emerged from the stakeholder workshop (see phase 4 in Methods) were to increase levels of investment and drive more multifunctional outcomes from landscapes. National carbon markets have the potential to bring in new investors to regional ecosystem markets from beyond the region, and regional ecosystem markets have the potential to extend the range of habitats, land uses and interventions that can be funded, beyond those currently covered by national carbon markets. There is a danger that single habitat/service schemes, such as woodland carbon schemes may drive certain outcomes (e.g. climate change mitigation) at the expense of others (e.g. biodiversity), but by integrating national carbon markets and regional ecosystem markets, it may be possible to aggregate demand across multiple

habitats and land uses for multiple ecosystem services, and so design schemes that reduce the likelihood of ecosystem service trade-offs.

However, there are a number of governance and technical (e.g., additionality) challenges involved in integrating ecosystem markets. Integrating schemes could generate unwelcome levels of complexity, compared to retaining the status quo of separate schemes, given that these schemes are already operational without integration. There is also a danger that the "commercial force" of carbon markets (as one private sector stakeholder put it) might disrupt regional ecosystem markets that are not currently tapping into this market, leading to a significant refocussing of attention on a single ecosystem service.

The need for schemes to deliver additional outcomes that would not otherwise have been delivered (or legally required) poses a more significant challenge to the integration of national carbon markets and regional ecosystem markets. As described in Section 3.2, regional ecosystem markets were less likely to include formal additionality tests, relying instead on quality assurance of work undertaken to deliver outcomes. However, if income streams for climate mitigation via a national carbon market are integrated with funding for a wider range of ecosystem services via a regional ecosystem market for a package of linked interventions on the same parcel of land, it may be difficult to ensure additionality tests are met. For example, if payments for water quality improvements are stacked on top of carbon payments for a peatland restoration project, it may be difficult to prove that the restoration would not have happened without the carbon finance. One solution to this is for national ecosystem markets to apply financial additionality tests (e.g. the Peatland Code and Woodland Carbon Code require a minimum of 15% carbon finance to be additional). In the case of the Woodland Carbon Code, projects can be de-registered if they integrate additional funding that was not declared prior to validation. Alternatively, although complex and currently untested, it may be possible to apportion credits to different budget contributions within a single project, limiting carbon credits to the proportion of the project funded by carbon finance. The simplest solution however, currently being pursued by UK schemes, would be to spatially separate the delivery of ecosystem services from different schemes, for example integrating peatland restoration and woodland creation in different locations upstream from farm-based projects managing soil carbon or planting hedgerows.

The importance of intermediaries and brokers in achieving integration cannot be understated. In addition to working as supply and demand aggregators (see previous section), they also play an important role in identifying interventions and projects that could deliver monetizable benefits, demonstrating cash flows, evaluating risks and calculating potential return on investment, before presenting opportunities to investors, where relevant accrediting projects to standards (like those developed for national carbon markets) to increase investor confidence[56]. Evidence from the comparative analysis suggested that communication and trust between scheme actors may be as important as the development of formal governance structures. For two of the peatland schemes analysed (PC and MF), there was evidence that researchers may play a more important role than has been previously appreciated[55], as trusted knowledge brokers and advocates rather than simply as providers of knowledge and evidence (c.f. Pielke[57]). Financial brokers have the capacity to work across all three types of ecosystem market, and initiatives like the Broadway Initiative, Green Finance Institute and SRUC's Thriving Natural Capital Challenge Centre in the UK are already connecting many private schemes and working with Government to create an enabling policy environment.

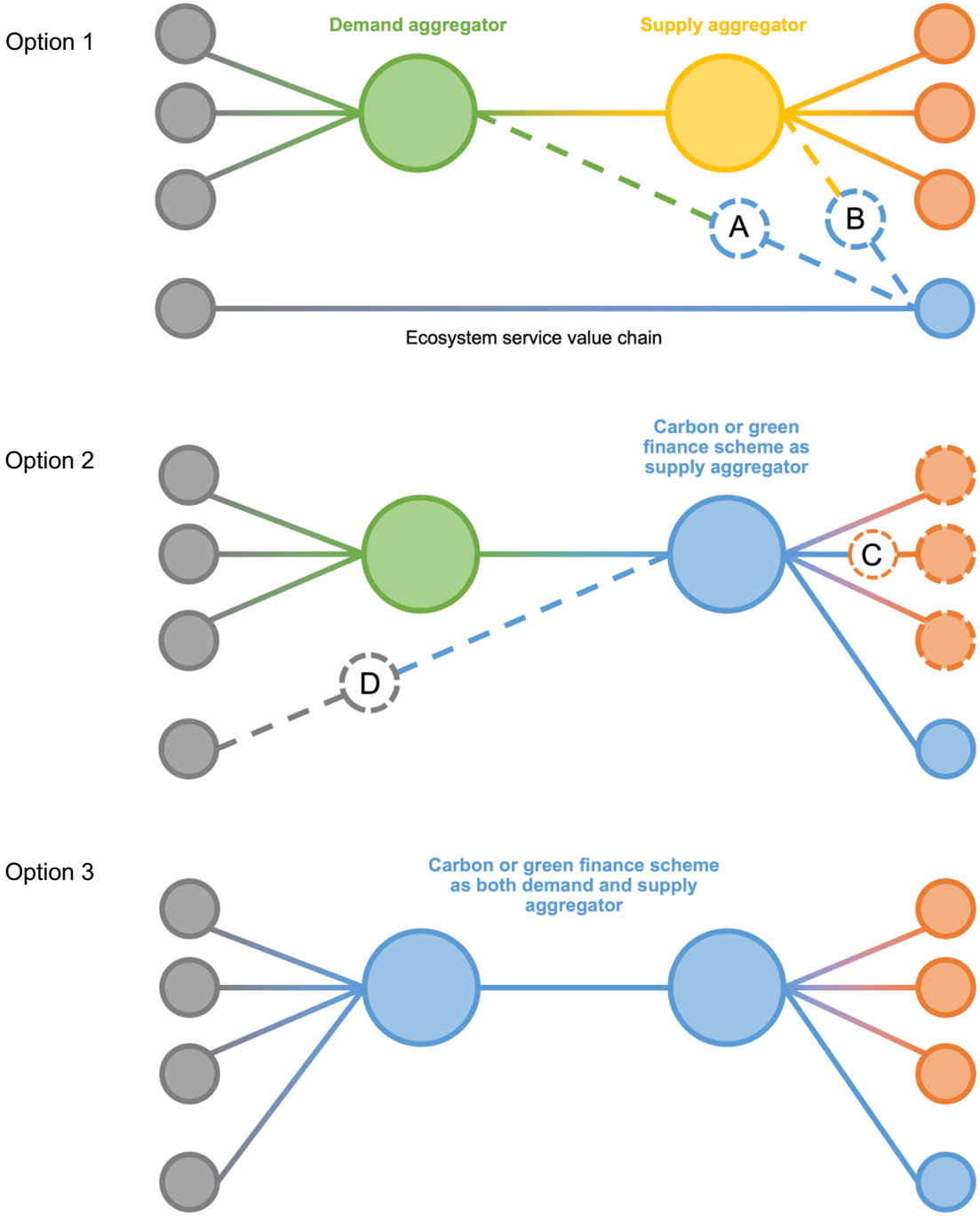

Figure 2: Three alternative options for integrating national carbon markets and green finance schemes with regional ecosystem markets, showing the different roles each type of market could play in the aggregation of supply and demand for ecosystem services. Grey = demand side interests, Green = a demand aggregator, or buyer-group, Yellow = supply aggregators, Orange = individual suppliers (often farmers), Blue = a carbon scheme / operator.

Building this discussion, Figure 2 proposes three ways in which transactions between buyers and sellers could be managed to integrate both national carbon markets and regional ecosystem markets. In **Option 1**, a regional ecosystem market procures climate mitigation benefits from a scheme that is also supplying national carbon markets or green finance markets, either directly via a demand aggregator or intermediary (A), or with the demand aggregator procuring ecosystem services as part of a package of benefits arranged by a supply aggregator/intermediary (B). In **Option 2**, the carbon or green finance scheme acts as the supply aggregator, providing multiple functions from its own scheme with options (C) to source interventions from other supply side entities. The scheme may also supply additional climate mitigation benefits into national markets (D). In **Option 3**, the carbon or green finance scheme provides both demand and supply aggregation functions. Although this is the simplest integration option, it creates a conflict of interest because the same body is negotiating on behalf of both supply and demand side parties to the transaction. An important principle in integrating carbon, or any additional function into a multifunctional landscape trade, is that different income streams should be put together simultaneously to make a trading proposition, and that the full range of ecosystem services to be provided should be agreed prior to the proposition being agreed and implemented. Once implemented, there is typically little incentive for future buyers to pay for outcomes, since those outcomes are already being delivered, and the additionality tests of national carbon markets would not be met, since activities on the ground would demonstrably not be dependent on the additional payment.

Finally, the research highlighted a number of potential areas of conflict between public funding for natural capital and privately funded ecosystem markets. These included the potential for public funds to outcompete private funds (e.g., where public schemes offer more attractive terms including shorter contract lengths and simpler or more familiar application processes), that would otherwise have enabled the market to deliver the public good. Participants noted that when private funds were cancelled out in this way, they did not tend to be redeployed elsewhere in the environment. There was also considerable uncertainty over future public schemes as the UK develops and trials post-Brexit policy over a relatively long time-frame, which could freeze the market, with potential sellers withholding projects until they know whether they will get a better price under existing private schemes versus future public schemes. A lack of integration between public and private schemes may also impact supply of projects to the private sector where those supplying projects consider the terms of public funding preferable to those available from private schemes. However, as summarised in Table 3, it may be possible for grant payments under future public schemes to be designed to incentivise co-investment with privately funded PES schemes. The options described in Table 3 show how public funding might be designed in future to incentivise participation in privately funded PES schemes, rather than funding obligations that could have been provided more cost-effectively through a privately funded approach. Several of these approaches may work best in combination.

Table 3: Mechanisms for integrating public and private peatland payments for ecosystem services in the UK, based on focus group discussions.

Description	Strengths	Weaknesses
1. Funds delineation – *using public investment to fund a discrete menu of 'value-added' components within a package of nature-based solutions*		
The concept here is to break out and use public funds for practical scheme components that are ancillary to privately funded ecosystem function delivery, and for which there is a clear public benefit justification. Designed-in and delivered from the start, these would ideally be spatially defined and discrete within a site.	• Clear 'lines of sight' between sources of funding and outcomes, help with transparency. • Helps boost scale and viability of projects. • Funds multifunctionality.	• May not realise the full potential for 'leverage' presented by more fully integrated payments and action. • Potential for funds to be mis-allocated – for example funding public access infrastructure that realistically will only be used for site management.
2. Trigger funds – *setting up government funding that only 'triggers' when a certain level of private sector funding is achieved*		
'Trigger funds' would be government funds (directed at carbon, and / or other site outcomes) that would only be released once a certain level of private payments was reached. A single universal percentage level could be used, or stepped trigger levels could be used based on site prioritisation (ideally determined regionally)	• Allows Governments to co-fund ecosystem functions, without 'squeezing out' private sector finance. • The effect of private finance triggering public funds could assist in demonstrating additionality.	• Set too low, trigger levels may have the effect of capping the level of private sector funding. • Trigger funds would create organisational complexity
3. Establishing fund-matching / co-investment as a default principle		
An extension of 'trigger funds' in that it establishes a wider default that public funds should only be issued on the basis that a level of private sector funds are already in place for a package of nature-based solutions.	• 'Signalling' to build confidence within the marketplace – avoiding both demand and supply side players being caught in an 'opportunity cost dilemma'.	• Risk that public-benefit oriented projects, where there is little private sector demand, will be disadvantaged.
4. Using a transparent cost-benefit matrix to target public sector funds		
Public funds would be adjusted according to a matrix of public benefit versus private finance potential. Stepped, or differential, rates of funding would need to be guided by a transparent set of tests.	• Creates 'smarter' funding, 'stepping up' funds for more difficult, or public-good oriented schemes or locations. • Provides a 'safety net' to fund valuable projects for which there is no private market	• Adds complexity, and requires a defensible and widely applicable set of tests.
5. Creating integrated systems for public-private implementation		
This is an organisational task; to enable public and private funding mechanisms to interact. It means overcoming mismatches in organisation scales, timelines, terminology, definitions, and metrics. Integration could happen in various ways but is scale dependent; a funding synergy in East Anglia won't be the same as one in Cumbria. Our recommendation is that public funding shapes itself around emerging private sector markets.	• System integration (or at least alignment) will be critical to avoiding public sector funds neutralising potential private sector investment.	• Depending on the level of integration, it could increase bureaucracy, and reduce the agility of private sector delivery.

5 Conclusions

This paper has provided an empirical basis for a new typology of ecosystem markets based on schemes currently operating or under development in the UK and in European peatlands. Each have distinct operational scales of investment and delivery, modes of funding and governance models. Of particular interest are emerging regional ecosystem markets, which are stimulating and meeting demand for ecosystem services by framing demand in relation to business risks and aggregating both demand side interests and the supply of services, overcoming free-rider effects and minimising trade-offs between ecosystem services across a landscape. Contrary to assumptions underpinning traditional PES schemes, taking this approach may lead to strong and resilient demand for ecosystem services in the absence of tight coupling between payments and provision of benefits. However, integration of these regional ecosystem markets with national carbon markets and green finance mechanisms may provide an expanded range of investors and land uses from which a much wider range of services can be provided.

The integration of private schemes may also make it possible to co-ordinate more effectively with public funding for ecosystem services, prioritising public funding towards landscapes and services not paid for by the market, and increasing the diversity and amount of funding for sustainable land management interventions. While the options for integrating private ecosystem markets proposed here are currently theoretical, there are now attempts to apply these integrative governance models in practice. Achieving integration between schemes is increasingly important as private ecosystem markets proliferate around the world. However, as separate schemes proliferate, so does the likelihood of competition and trade-offs between services provided by different schemes. The need to manage these trade-offs and ensure private investment contributes to multifunctional landscapes is therefore a key driver for considering how schemes can more effectively integrate with each other.

As publicly funded schemes also become more PES-like in many countries, there is a risk of perverse outcomes if public funding pays for services that would otherwise have been provided by the market. However, by designing future public schemes to complement private ecosystem services, it may be possible to avoid these markets being crowded out, and even use public funding to leverage private investment, for example via carbon trigger funds (Table 3). As Government budgets come under increasing pressure, stimulating ecosystem markets could help fill the funding gap, contributing to a green post-COVID economic recovery, and increasing the likelihood that ambitious climate and biodiversity targets are met. However, to unlock this private finance, mechanisms need to be developed to ensure public and private funding can be successfully blended in future nature-based projects. Robust standards (akin to those developed for peatland restoration in Europe) are needed to govern the development of new markets in a wider range of land uses and habitats, to provide investor confidence and ensure outcomes are delivered. Public funding may also be used to help these new markets develop investment pipelines with projects that are ready for investment with the associated staff and governance mechanisms to channel investment scale capital into nature-based solutions. In some contexts regulation may be considered, for example the integration of Net Biodiversity Gain in the planning system, requiring developers to make (typically offsite) provisions to compensate for biodiversity losses and provide additional biodiveristy gains. Government funding could also help unlock supply by employing facilitators to explain opportunities to owners and managers of land and marine assets, simplifying and democratising access to private finance. In conclusion, much still needs to be done to stimulate and integrate ecosystem markets, but with the right support and design, it may be possible to integrate multiple sources of private investment with public funding to deliver the levels of funding needed to address the twin challenges of climate change and biodiversity loss.

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Conflicts of interest

Mark Reed is Research Lead for IUCN UK Peatland Programme and sits on the Executive Board for the Peatland Code. Tom Curtis is a founding partner of 3Keel and helped develop Landscape Enterprise Networks. Matthew Hay is a Project Manager and Stephen Prior is co-founder of Forest Carbon Ltd. David Hill is founding owner of Environment Bank Ltd.

References

[1] Nelleman C, Corcoran E. *Dead planet, living planet—biodiversity and ecosystem restoration for sustainable development. A Rapid Response Assessment*. 2010, United Nations Environment Program, GRID-Arendal, Norway.

[2] Crouzeilles R, Curran M, Ferreira MS, Lindenmayer DB, Grelle CE, Benayas JMR. A global meta-analysis on the ecological drivers of forest restoration success. *Nat. Commun.* 2016, 7.

[3] Coase RH. The problem of social cost. *Journal of Law and Economics*. 1960, 3: 1-44

[4] Stigler GJ. Two notes on the Coase theorem. *The Yale Law Journal*. 1989, 99: 631-633.

[5] Engel S, Pagiola S, Wunder S. Designing payments for environmental services in theory and practice: an overview of the issues. *Ecol. Econ*. 2008, 65: 663– 674.

[6] Braat L, de Groot R. *The Economics of Biodiversity and Ecosystems: Scoping the Science*. 2008, European Commission, Cambridge.

[7] Vidal N, Bull G, Kozak R. Diffusion of corporate responsibility practices to companies: the experience of the forest sector. *J Bus Ethics.* 2010, 94: 553–567.

[8] Esteves AM, Franks D, Vanclay F. Social impact assessment: the state of the art. *Impact Assess Proj Appraisal.* 2012, 30: 35-44.

[9] Wunder S. The Efficiency of Payments for Environmental Services in Tropical Conservation, *Conservation Biology*. 2007, 21: 48–58.

[10] Wunder S. Revisiting the concept of payments for environmental services. *Ecol. Econ.* 2015, 117: 234–243.

[11] Sommerville M, Jones JPG, Milner-Gulland EJ.. A revised conceptual framework for payments for environmental services. *Ecol. Soc.* 2009, 14; 34.

[12] Muradian R, Arsel M, Pellegrini L, Adaman F, Aguilar B, Agarwal B, Corbera E, De Blas DE, Farley J, Froger G, Garcia-Frapolli E, Gómez-Baggethun E, Gowdy J, Kosoy N, Le Coq JF, Leroy P, May P, Méral P, Mibielli P, Norgaard R, Ozkaynak B, Pascual U, Pengue W, Perez M, Pesche D, Pirard R, Ramos- Martin J, Rival L, Saenz F, Van Hecken G, Vatn A, Vira B, Urama K. Payments for ecosystem services and the fatal attraction of win-win solutions. *Conserv. Lett.* 2013, 6: 274–279.

[13] Reed MS, Allen K, Attlee A, Dougill AJ, Evans KL, Kenter JO, Hoy J, McNab D, Stead SM, Twyman C, Scott AS. A place-based approach to payments for ecosystem services. *Global Environmental Change*. 2017, 43: 92-106.

[14] Waylen KA, Martin-Ortega J. Surveying views on Payments for Ecosystem Services: Implications for environmental management and research. *Ecosystem Services*. 2018, *29*: 23-30.

[15] Marwell G, Ames RE. Experiments on the provision of public goods. I. Resources, interest, group size, and the free-rider problem. *American Journal of Sociology*. 1979, 84: 1335-1360.

[16] Wunder S, Wertz-Kanounnikoff S. Payments for ecosystem services: a new way of conserving biodiversity in forests. *Journal of Sustainable Forestry*. 2009, 28: 576-596.

[17] de Lima LS, Krueger T, García-Marquez J. Uncertainties in demonstrating environmental benefits of payments for ecosystem services. *Ecosystem Services.* 2017, 27: 139-149.

[18] Ruggiero PG, Metzger JP, Tambosi LR, Nichols E. Payment for ecosystem services programs in the Brazilian Atlantic Forest: Effective but not enough. *Land Use Policy* 2019. 82: 283-291.

[19] Calle A. Can short-term payments for ecosystem services deliver long-term tree cover change? *Ecosystem Services.* 2020, 42: 101084.

[20]Siebert R, Toogood M, Knierim A. Factors affecting european farmers' participation in biodiversity policies. *Sociol. Ruralis* 2006, 46: 318–340.

[21] Ruto E, Garrod G. Investigating farmers' preferences for the design of agri-environment schemes: A choice experiment approach. *J. Environ. Plan. Manag.* 2009, 52: 631–647.

[22] Mills J, Gaskell P, Ingram J, Dwyer J, Reed M, Short C. Engaging farmers in environmental management through a better understanding of behaviour. *Agric. Human Values*. 2017, 34: 283–299.

[23] Reed MS, Chapman PJ, Ziv G, Stewart G, Kendall H, Taylor A, Kopansky D. Improving the evidence base for delivery of public goods from public money in agri-environment schemes. *Emerald Open Research*. 2020a*, 2*: 57.

[24] Reed MS, Kenter JO, Hansda R, Martin J, Curtis T, Saxby H, Mills L, Post J, Garrod G, Proctor A, Collins O, Guy JA, Stewart G, Whittingham M. *Social barriers and opportunities to the implementation of the England Peat Strategy*. Final Report to Natural England and Defra. 2020b, Newcastle University. DOI:10.13140/RG.2.2.23295.23208

[25] Hodge I, Hauck J, Bonn A. The alignment of agricultural and nature conservation policies in the European Union. *Conservation Biology*. 2015, 29: 996-1005.

[26] de Sartre XA, Charbonneau M, Charrier O. How ecosystem services and agroecology are greening French agriculture through its reterritorialization. *Ecology and Society*. 2019, *24*(2).

[27] Bateman IJ, Balmford B. Public funding for public goods: A post-Brexit perspective on principles for agricultural policy. *Land Use Policy* 2018, 79: 293-300.

[28] Bayon R, Hawn A, Hamilton K. *Voluntary carbon markets: an international business guide to what they are and how they work*. 2012, Routledge.

[29] Benessaiah K. Carbon and livelihoods in Post-Kyoto: Assessing voluntary carbon markets. *Ecological Economics.* 2012, *77*: 1-6.

[30] Lang S, Blum M, Leipold S. What future for the voluntary carbon offset market after Paris? An explorative study based on the Discursive Agency Approach. *Climate Policy.* 2019, 19: 414-426.

[31] Defra. *The natural choice: securing the value of nature Natural Environment white paper*. 2011, HMSO, London.

[32] Gosal A, Kendall H, Reed MS, Mitchell G, Rodgers C, Ziv G. *Exploring ecosystem markets for the delivery of public goods in the UK*. Yorkshire Integrated Catchment Solutions Programme (iCASP) and Resilient Dairy Landscapes Report, 2020. DOI: https://doi.org/10.5518/100/48

[33] Olesen AS, Andersen SP, Kenney K. *Carbon farming on organic soils: the case of peatland restoration*. 2021, European Commission, DG CLIMA.

[34] Baumeister RF, Leary MR. Writing narrative literature reviews. *Rev. General Psychol*. 1997, 1:311.

[35] Greenhalgh T, Thorne S, Malterud K. Time to challenge the spurious hierarchy of systematic over narrative reviews? *Eur. J. Clin. Invest*. 2018, 48: e12931.

[36] Braun V, Clarke V. Using thematic analysis in psychology. *Qual. Res. Psychol.* 2006, 3, 77–101. https://doi.org/10.1191/1478088706qp063oa.

[37] Patton MQ. Qualitative research and evaluation methods. *Qual. Inq.* 2002, 3rd: 598.

[38] Crosher I, Gold S, Heaver M, Heydon M, Moore L, Panks S, Scott S, Stone D, White N. *The Biodiversity Metric 2.0: auditing and accounting for biodiversity – User Guide*. 2019a, Natural England.

[39] Crosher I, Gold S, Heaver M, Heydon M, Moore L, Panks S, Scott S, Stone D, White N. *The Biodiversity Metric 2.0: auditing and accounting for biodiversity –Technical Supplement.* 2019b, Natural England.

[40] Johansen DF, Vestvik RA. 2020. The cost of saving our ocean-estimating the funding gap of sustainable development goal 14. *Marine Policy* 112: 103783.

[41] RSPB. *Bridging the finance gap How do we increase financing for conservation?* Discussion paper. 2018. https://www.rspb.org.uk/globalassets/downloads/documents/aboutthespb/bridging-the-finance-gap.pdf

[42] CCC (Committee on Climate Change). Land use: Policies for a Net Zero UK. 2020. file:///Users/MarkReed/Downloads/Land-use-Policies-for-a-Net-Zero-UK%20(5).pdf

[42] CCC (Committee on Climate Change). Net Zero: The UK's contribution to stopping global warming. 2019. www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming

[44] The Investment Association. About us. 2020. https://www.theia.org/about-us

[45] Securities Industry and Financial Markets Association. *Capital Markets Fact Book, 2020*. 2020. https://www.sifma.org/resources/research/fact-book/

[46] Credit Suisse. Conservation Finance From Niche to Mainstream: The Building of an Institutional Asset Class. 2016. https://www.environmental-finance.com/assets/files/research/conservation-finance-en.pdf

[47] National Association of Corporate Directors. *2019-2020 NACD Public Company Governance Survey*. 2020. https://www.nacdonline.org/analytics/survey.cfm?ItemNumber=66753

[48] Bailey R, Clarke L. Climate change is an enterprise risk multiplier. *The Implications for Boards Article Series 2020*. 2020 https://www.oliverwyman.com/content/dam/mmc-web/insights/publications/2020/october/NACD_Climate_Resilience_Compendium_Final.pdf#page=5

[49] Environment Agency. Green finance - funding environmental projects now is essential to tackle climate change in future, 2020. https://environmentagency.blog.gov.uk/2020/12/10/green-finance-funding-environmental-projects-now-and-essential-to-tackle-climate-change-in-future/

[50] SEPA (Scottish Environmental Protection Agency) and SWT (Scottish Wildlife Trust). *The £1 Billion Challenge: Route Map from the Scottish Conservation Finance project.* 2020. https://scottishwildlifetrust.org.uk/wp-content/uploads/2020/05/202001_1-Billion-Challenge-Document_FINAL.pdf

[51] WTW (Willis Towers Watson). Global Ecosystem Resilience Facility. 2020. https://www.willistowerswatson.com/en-GB/Insights/trending-topics/csp-global-ecosystem-resilience-facility

[52] Martin-Ortega J, Waylen KA. PES what a mess? An analysis of the position of environmental professionals in the conceptual debate on payments for ecosystem services. *Ecological Economics*. 2018, 154: 218-237.

[54] Coyne L, Kendall H, Hansda R, Reed MS, Williams DJL A mixed-methods study to explore the role of agri-environmental schemes on the resilience of the English dairy sector. *Land Use Policy. 2020. https://doi.org/10.1016/j.landusepol.2020.105174*

[54] Kendall H, Hansda R, Reed MS (in prep.) UK Dairy Farmer perceptions of and motivations for engagement with Landscape Enterprise Networks: a Delphi study

[55] Neumann RK. *Uptake of peatland ecosystem service knowledge for decision-making*. 2020, PhD thesis, Newcastle University.

[56] Young D, Lockhart-Mummery E, Thompson G, Mansfield J, Speak R, Fitton R, Avery H. *Financing UK Nature Recovery: A proposal for putting nature onto a sustainable financial path in 2021*. 2020. https://www.iema.net/preview-document/financing-uk-nature-recovery

[57] Pielke Jr RA. *The honest broker: making sense of science in policy and politics*. 2007, Cambridge University Press.

[58] Brown P, Broomfield M, Cardenas L, Choudrie S, Kilroy E, Jones L, MacCarthy J, Passant N, Thistlethwaite G, Thomson A, Wakeling D. *UK Greenhouse Gas Inventory, 1990 to 2016. Annual Report for Submission under the Framework Convention on Climate Change.* 2018, HMSO, London.

[59] European Commission. *Introducing the Sustainable Blue Economic Financing Principles*. 2018. https://ec.europa.eu/maritimeaffairs/sites/ maritimeaffairs/files/introducing-sustainable-blue-economy-financeprinciples_en.pdf

[60] TSVCM (Taskforce on Scaling Voluntary Carbon Markets). *Taskforce on Scaling Voluntary Carbon Markets: Consultation Document.* 2020. https://www.iif.com/Portals/1/Files/TSVCM_Consultation_Document.pdf

[61] Couwenberg J, Thiele A, Tanneberger F, Augustin J, Bärisch S, Dubovik D, Liashchynskaya N, Michaelis D, Minke M, Skuratovich A, Joosten H. Assessing greenhouse gas emissions from peatlands using vegetation as a proxy. *Hydrobiologia*. 2011, 674: 67-89.

[62] Joosten H, Brust K, Couwenberg J, Gerner A, Holsten B, Permien T, Schäfer A, Tanneberger F, Trepel M, Wahren A. MoorFutures: Integration of additional ecosystem services (including biodiversity) into carbon credits – standard, methodology and transferability to other regions. BfN-Skripten 207. Federal Agency for Nature Conservation, 2015. https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/Skript407.pdf

[63] Tiemeyer B, Freibauer A, Borraz EA, Augustin J, Bechtold M, Beetz S, Beyer C, Ebli M, Eickenscheidt T, Fiedler S, Förster C. A new methodology for organic soils in national greenhouse gas inventories: Data synthesis, derivation and application. *Ecological Indicators*. 2020, 109: 105838.

[64] VCS (Verified Carbon Standard). *VM0036 Methodology for Rewetting Drained Temperate Peatlands*. v1.0, 2020. https://verra.org/methodology/vm0036-methodology-for-rewetting-drained-temperate-peatlands-v1-0/ (accessed: December 2020).

[65] Bonn A, Reed MS, Evans C, Joosten H, Bain C, Farmer J, Emmer I, Couwenberg J, Moxey A, Artz R, Tanneberger F, von Unger M, Smyth MA, Birnie R. Investing in nature: developing ecosystem service markets for peatland restoration. *Ecosystem Services* 2014, 9: 54-65.

[66] Von Unger M, Emmer I, Joosten H, Couwenberg J. *Design an International Peatland Carbon Standard: Criteria, Best Practices and Opportunities (Final Report)*. German Environmental Agency. Climate Change 42/2019. 2019. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-11-28_cc-42-2019_sca_peatland_standards_0.pdf

[67] Rodgers C. Delivering a better natural environment? The Agriculture Bill and future agri-environment policy. *Environmental Law Review*. 2019, 21: 38-49.

[68] Rodgers C, Grinlinton D. Covenanting for Nature: A Comparative Study of the Utility and Potential of Conservation Covenants. *Modern Law Review.* 2020, 83: 373-405

Supplementary material

Validation and verification of outcomes

The four peatland schemes and WCC tended to validate and verify outcomes using site visits by independent certification bodies, HB was developing a third-party accreditation system and BIF accredited projects to relevant industry standards. However, validation mechanisms had not yet been developed for NCB and NCPF, and LENs and NIS provided validation in the form of evidence that interventions had been carried out, without requiring independent verification of ecosystem service outcomes (Table 1).

Verified Woodland Carbon Units from WCC projects could be used by companies to compensate for their UK-based greenhouse gas (GHG) emissions but could not be traded on voluntary or compliance carbon markets. A registry enabled units to be bought and sold by companies within the UK. Forward selling of Pending Issuance Units[ii] was possible after validation, in addition to the purchase of Verified Carbon Units ex-post. Methods for projecting and verifying carbon sequestration and GHG emission reductions were typically based on or designed to be compatible with methodologies developed for the voluntary carbon market, although none of the schemes currently traded on this market. As a result, GHG benefits were included towards national emissions reduction targets. It was also possible for project developers to make significant savings on verification and auditing compared to the stricter requirements of voluntary market standards like the Verified Carbon Standard. For example, MF and PC allowed the same third-party to carry out both validation and verification and GDNL used a committee of experts to undertake project validation. In the case of the WCC, the methodology for determining carbon sequestration units was initially derived from voluntary carbon market methodologies, and then simplified and adapted to the UK context. Methods for the PC were in turn developed initially on the template of the WCC, but with significant adaptations to enable projects to estimate and then validate GHG emission reductions rather than carbon sequestration. This was done by developing emissions factors based on the analysis of GHG emission data from peatlands of different types and stages of degradation or restoration, in line with the UK's IPCC Tier 2 methodology used to calculate emissions in the UNFCCC National Inventory Report[58]. Within the PC and the WCC during the development stages and at the start of a project, validation was performed via on-site survey visits to assess the quality and condition of the land and inform the assessment of climate benefits that can be obtained, assess risks to the project and confirm the eligibility of the project.

HB took a similar approach to validation of projects and verification of outcomes, using biodiversity metrics[38,39] to assess changes from a baseline condition assessment on site. Although these were conducted by Environment Bank, there were plans to move to an independent certification body for verification and reporting. The BIF verified project outcomes via an investment committee responsible for assessing the impact of each investment. The basis of these assessments was the Sustainable Blue Economy Finance Principles[59], which were developed by WWF to inform private investment into the blue economy. The Blue Impact Fund's investments will comply with relevant ASC/MSC standards and Sustainable Development Goals (in particular SDG 14 – life below water). More broadly, verification of outcomes from green finance schemes is being considered by an international Taskforce on Scaling Voluntary Carbon Markets. The Taskforce has suggested in its "initial recommendations", that satellite imaging, digital sensors and

[ii] A promise to deliver GHG benefits on the basis of projections, which cannot be guaranteed or reported as actual GHG benefits

distributed ledger technology would be appropriate technologies to deploy to aid a verifiable and trustable voluntary carbon market with enough integrity for permanence[60].

For LENs and NIS, price negotiations could be based on data regarding the effectiveness of a given intervention and the value of a given service, based on published evidence of the effectiveness of an intervention (sometimes by proxy on the basis that it is included in agri-environmental schemes). Research is being conducted to determine the effectiveness of some LENs interventions via the Resilient Dairy Landscapes project[iii], which may inform future iterations of LENs. LENs also has the ability to 'adopt in' measures and outcomes certified under independent standards and codes.

All the peatland schemes defined the GHG result as avoided emissions resulting from the (partial) rewetting of drained peatland and integrate both CO_2 and CH_4 using CO_2eq/year. PC, MF and GDNL all used emissions factors to estimate GHG emission reductions after restoration, based on functional relationships between mean annual water table depth, vegetation composition and GHG fluxes[61,62,63]. MF was the first scheme to apply site-specific emission factors (Greenhouse gas Emission Site Types, GEST) to rewetted peatlands. Soon after, the Verified Carbon Standard incorporated this approach into its methodology for rewetting of temperate peatlands on the voluntary carbon market[64]. The approach developed for PC applies the same logic and defines five condition categories based on land degradation and vegetation characteristics. The emissions factors used by the different schemes are not directly comparable as all schemes have stratified eligible peatlands into different condition categories, and then calculated emissions factors for each of these categories. Moreover, the functional relationship underlying vegetation-based GHG emission site types varies with biogeographic region and has to be calibrated for other biogeographical and climatic zones[62]. Experienced surveyors can classify degraded and drained peatlands from field visits, which can be converted to GHG using emission factors in look-up tables. GDNL and PC are the only schemes to use emissions factors for partial rewetting where the land use is not changed, and MF is the only scheme to offer emissions factors for rewetting combined with a land use change to paludiculture. This approach requires sufficient evidence of GHG emissions for different degradation states and peat and vegetation types, restricting the range of peatlands that can be included in schemes (the PC is currently restricted to blanket bogs on this basis). There was insufficient published evidence to construct emissions factors for MM, so it relies instead on an annual peat decomposition rate of 1 cm per year, which it is assumed can be halted by rewetting.

Additionality and leakage

Additionality was only assessed formally by the four peatland schemes, WCC and HB, typically via legal (e.g. projects go beyond what would be required by law), financial (e.g. projects would not be possible without carbon finance) and other additionality tests (e.g. application of biodiversity metrics in HB receptor sites). None of the other schemes applied formal additionality tests, relying instead on trusted intermediaries to manage additionality informally as part of the project design process (e.g. LENs) or identifying businesses that had been unable to fund sustainability initiatives via other means (e.g. BIF) (Table 1).

The principle of additionality is an important requirement for ecosystem markets, ensuring that benefits arising from projects would not have occurred without investment, and would not have occurred anyway without it[65,66]. However, assessing additionality is complex and represents a procedural hurdle to project development. Although the PC allowed for group certification for small projects to lower costs associated with proving additionality,

[iii] https://www.resilientdairylandscapes.com/

interviewees suggested that additionality test could be simplified or externally supported across all the schemes that included formal additionality tests. These schemes typically applied legal and financial tests. Financial additionality requires that a project would not be economically feasible without carbon finance. PC, WCC, MF and MM all used different methods to test for financial additionality, while the PC, WCC and GDNL also accounted for legal additionality, requiring projects to produce emission mitigation beyond what would be achieved by activities or interventions already required by policy and regulation. PC, WCC and MM allowed public and private finance to be combined and considered projects to be additional as long as 15%, 15% and 10% of project costs were from carbon finance respectively. However, MF explicitly excluded the use of public funding in projects. PC and WCC also included barrier tests, enabling a project to be additional if it is unable to meet the financial additionality test if it has overcome other barriers that would have otherwise prevented peatland restoration.

LENs and NIS did not have defined measures for ensuring additionality, with one of the interview respondent for LENs arguing that:

> *"Additionality is less of a concern with landscape outcomes in which the purchaser has a direct technical interest. An example would be businesses interested in reducing their exposure to flood risk or costs relating to water quality, or consortia of businesses and local government interested in regional 'placemaking'. In these instances, the purchaser has a direct interest in the technical outcome of the work they are paying for, and less interest in the attribution of payments. It follows also that if the outcome is already being delivered, then the market for it – the incentive to pay – disappears. The more important test here is quality assurance for the buyer, and the main challenge faced may be that of 'free riders' – i.e. beneficiaries of landscape outcomes who do not pay."*
>
> (Scheme representative, Landscape Enterprise Networks)

Leakage (where damaging activities are displaced to another location by a scheme) was implicitly avoided in LENs projects due to the landscape scale at which they operate, reducing the likelihood that damaging activities are displaced to neighbouring land. The MF provided guidelines on how to minimise leakage by site selection or the provision of alternative income sources to avoid leakage via activity shifting. In the WCC and PC, leakage had to be included in net GHG emission savings estimates for the project. The MM standard concentrated their GHG accounting on degraded peatlands, which were no longer in agricultural usage (so there was no agricultural activity to displace). HB did not allow existing high-quality habitats to be converted into other habitats, but it did not assess whether landowners brought high quality habitats that were not covered by the scheme into production to compensate for reduced production. Leakage was not explicitly considered in the other schemes reviewed.

Permanence

Permanence was addressed primarily via contractual arrangements in the schemes reviewed, although Conservation Burdens (Scotland) and Covenants (England and Wales) were sometimes proposed by schemes as potential future options to provide additional assurances to buyers in some UK schemes, and BIF provided follow-on funding opportunities to enhance permanence.

The permanence of funded land use changes and other interventions, and hence outcomes of schemes was not formally assessed for NIS or GDNL projects, and was provided via

contractual agreements for LENs and MM projects with no protection against reversals outside contract periods. However, in the case of LENs, three measures were taken to increase longevity beyond contractual obligations: (1) selection of measures that are hard to reverse (e.g. capital works), (2) long-term payments to maintain management measures, and (3) selection of multifunctional measures, with multiple rationales and revenue streams associated with maintaining the measure. In the case of MM, the likelihood of reversals was implicitly limited by site selection, focusing on land that had been taken out of agricultural production. The absence of guarantees over the permanence of interventions and associated outcomes did not appear to be a major barrier to investment in these schemes.

The only schemes that provided legal protections around permanence were MF and WCC, which exploited existing national/regional laws or procedures allowing to prescribe water levels (MF) or preventing deforestation (WCC). MF guarantees permanence by ensuring the administrative and legal basis of the project planning and approval process and by securing the permanent availability of the project area, either through acquisition of the land or through registration of servitude with respect to the water table in the land register. In the absence of legal protection, the PC relied primarily on contractual agreements, but was able to provide further assurance via conservation covenants in England and Wales[iv] and conservation burdens in Scotland[v] (some WCC projects had also used these). Covenants and burdens can only currently be agreed by "responsible bodies" who hold the covenant on behalf of the public. In Scotland there are a number of conservation charities and public bodies who hold this status, but in England the National Trust is currently the only body with formal covenanting power.[vi] This will change with the implementation of Part VII of the Environment Bill 2020, which will empower a range of public and charitable bodies to hold the benefit of a covenant as "responsible" bodies. The Bill, when passed into law, will also enable a wider range of ecosystem service buyers to use them to create long term "property" interests (rather than shorter term contracts) under the WCC and PC[67,68].

Under the terms of a mandated regime for biodiversity net gain it is a requirement for the land supplied to generate credits – i.e. habitat banks and bespoke offset sites – to be subject to a 30 year agreement with the payer of the credits. The Environment Bank's HB model involves the issuance of a Conservation Bank Agreement between Environment Bank and the landowner provider which has a term of 30 years. The conservation credits generated by the HB or offset site are sold to the developer under a Conservation Credit Purchase Agreement. The funds generated are used to pay the landowner a) capital costs of the establishment of the specific habitat or habitat mosaic and b) annual management costs with RPI and some income foregone/profit. Environment Bank holds the funds and pays out according to an agreed payment schedule following monitoring visits to ensure that the project is delivering against milestones set out in a Biodiversity Management Plan that accompanies the Conservation Bank Agreement. It is considered that a 30-year term offers a good compromise between encouraging landowner participation and delivering habitat creation and restoration at scale. By year 30 one would expect the majority of habitats to be reaching some form of maturity (woodland excepted). It is highly unlikely that after 30 years a landowner, if selected correctly in the first place, would wish to impact on the landscape and biodiversity enhancements that a habitat bank would deliver to his/her land by its removal and conversion back to agricultural production. In the unlikely event, however, that

[iv] Conservation covenants are private and voluntary agreements between landowners and responsible body (e.g. local authority) who is responsible for monitoring and enforcing the obligations of the covenant.

[v] Conservation burdens were established under the Title Conditions (Scotland) Act 2003. The Act codifies the kinds of restrictions or burdens that can be included in titles to land and property, and establishes conservation burdens as a voluntary instrument that can be used to protect, enhance and maintain aspects of natural and cultural heritage.

[vi] Under National Trust Act 1937, s.8.

there were imperative reasons for needing the land for development, the landowner would need to pay the significant expense of offsetting the impacts of that development. Within 30-years it is likely, in any event, that planning policy will exclude the use of offset sites and habitat banks for development as part of future planning policy compliance.

Supply and demand issues

All schemes were voluntary, open marketplaces and the level of compensation for interventions was primarily determined by project costs, with negotiation between suppliers and buyers possible in some schemes. None based their prices on the price per tonne on the voluntary carbon market, which would typically have been too low to cover project costs. One of the ways that projects justified higher prices (compared to carbon market prices) was by highlighting additional non-carbon benefits. Most schemes used intermediaries to engage with project developers (e.g. landowners and tenants), or the scheme itself performed this function (e.g. BIF) and LENs used supply aggregators to aggregate sufficient density of supply within a single landscape. However, engagement with suppliers (typically landowners and managers) was a challenge for all schemes except BIF which had created a £90M project portfolio prior to entering its investment phase (Table 1).

Four of the schemes (LENs, NIS, WCC and PC) enabled negotiation between buyers and sellers through intermediaries (a single intermediary worked on behalf of LENs and NIS, and multiple independent intermediaries facilitated investments in WCC and PC). WCC determined price on project-by-project basis between suppliers and buyers (except for the Woodland Carbon Guarantee in England, whereby the government offers a contract for the option to sell Woodland Carbon Units to them *via* an auction). Similarly, the PC negotiated prices per project primarily on the basis of costs, which could vary considerably between projects, based on accessibility, level of degradation and other factors. LENs and NIS used a “supply aggregator” (typically a locally trusted organisation contracted to engage landowners/tenants across a landscape in the scheme) as a broker on behalf of the sellers to negotiate deals with demand side actors for the delivery of interventions. Prices were negotiated as a bundle of ecosystem services typically including soil function, water quality and biodiversity with limited quantification of likely risks or benefits. In contrast, negotiation was not possible in MF and MM projects, which were based on cost alone, with fixed prices for buyers. Prices for MF credits are based on the costs of their production, i.e. calculated by deriving the costs of implementation, divided by the total amount of emission reduction units for sale over the project crediting period.

Compensation mechanisms varied significantly across schemes (and in some cases between interventions within schemes) with the use of different legal agreements and payment structures. For example, PC projects may be paid outright by a buyer or by an intermediary who then sells carbon units to multiple buyers, with payments structured in a single on-off payment for the whole project, or with maintenance and revenue payments annualised after an initial lump sum to pay for capital works. All payments go via MF as the issuer and broker of uniquely identified credits, whereas MM and PC do not handle transactions, which take place directly between buyers and sellers, often via intermediaries. GDNL uses a central registry and issuer to keep track of uniquely identified credits which can be traded between buyers, to allow for aggregation and selling of credits from many different sectors alongside peatland restoration.

LENs is currently developing the legal framework to support its delivery at scale. It currently operates on the basis that a group of demand-side players come together to agree to co-procure (via a “demand aggregator”) a certain proportion of ecosystem services or other outcomes and form a memorandum of understanding to achieve this. At this stage this is not

a contract. It is envisaged, however, that in due course LENs arrangements will mature in a process leading to the conclusion of multiple linked contracts between demand side aggregators and supply side aggregators/actors (for example farmers and other land managers delivering ecosystem services). LENs suggest that in the future a regional entity could be established to centrally manage multiple contracts. The legal delivery mechanisms for NIS are under development. Although similar to LENs, they identify a role for a centralised entity to manage contractual arrangements. There was also a recognition that contacts were required to be robust, whilst also being flexible, particularly in the case of long-term landscape interventions where there may be requirements for suppliers and/or the interventions to change over time, for example, in the case of flood risk management to accommodate emerging climate change challenges.

Landowner engagement was a challenge for all schemes. The new General Data Protection Regulation (GDPR) regulation in Europe made it difficult to contact landowners at scale, requiring alternative, often resource intensive means of communication e.g. via trusted brokers. Landowners were not generally willing to self-organise or cooperate with others to develop projects or other proposals for buyers, relying instead on intermediaries to support collaboration and represent their collective interests. There was also a reluctance among the landowning community to enter into long-term agreements. This was particularly problematic for schemes such as the WCC and PC which required permanent commitments for at least 30 years. Moreover, there were concerns from landowners that peatland restoration under the PC could lead to areas of wetland and scrub that would: i) not be eligible for agri-environment payments; ii) not be eligible for Agricultural Property Relief or Business Property Relief, increasing liabilities under Inheritance Tax law; and iii) lead to designation of Sites of Special Scientific Interest, leading to increased statutory obligations and commitments on the land[32]. Similar concerns were expressed by landowners engaging with MF in Germany.

On the demand side, many potential investors were unwilling to share commercially sensitive data to enable the establishment of consortia, making it difficult to establish co-procurement arrangements. For schemes that lacked formal additionality criteria (see section 3.2), investors were reluctant to pay for interventions that they perceived farmers or landowners should be doing as part of compliance with regulation and/or that could be paid for by public finance.

Across the schemes, specific integration and consideration of the wider social distribution of ecosystem services was limited, although there was recognition of its importance for buyers with Corporate Social Responsibility goals. Interviews with businesses during the pilot phase of the PC suggested that companies may be willing to pay a premium for peatland carbon on the basis of project location and co-benefits, with water and biodiversity co-benefits of particular interest[65]. The PC only stipulates the need for a statement of environment in the management plans of projects, which can include the delivery of additional ecosystem services. In contrast, MF provides detailed methodologies for quantifying co-benefits covering improved water, food mitigation, increased groundwater store, evaporative cooling, and increased mire-typical biodiversity[62,63]. MF also makes project areas accessible for buyers to visit, in contrast to more ‘anonymous’ overseas carbon projects. The WCC adopts a ‘Wider Benefits Tool’ to provide a consistent way of evaluating the likely benefits of woodland creation in relation to four aspects; *water, community, biodiversity* and the *economy*. While the tool does not quantify the benefits delivered, it is a consistent way of evaluating the likely benefits and relative merits of each project. By driving multiple investments in multiple landscape functions, LENs seeks to make landscapes more responsive to societal needs, however, the emergent outcomes are not currently measured. Despite limited quantification of wider benefits across the schemes, the potential to further integrate co-benefits was recognised, as long as monitoring costs were not prohibitive.

In relation to HB, prices of conservation credits are currently set by Environment Bank in their model based on known costs of establishment and 30-year management. Credit pricing is positioned in terms of what the market will demand or bear, which varies in terms of location, geology/geography, habitat type, hydrology, soils etc. Planning Authorities are key to ensuring demand by delivering on their (to be) mandated duty to require development to deliver at least 10% Biodiversity Net Gain. Having a mandated system is likely to provide clarity and certainty to developers and reduce planning delays. Supply of sites for HB is limited by a number of factors, including concerns from landowners around inheritance tax rules, contract lengths, risks of land being designated a protected sites for conservation and concerns about engaging with environmental NGOs who have insufficient access to land in the appropriate places. Planning Authorities may use their own land but that is likely to be legally challenged in the future because, in governance terms, regulators must not financially benefit from those whom they regulate.

Interaction with public funding

Schemes relied to varying extents on public funding, both in terms of scheme operation and project financing. The peatland schemes (with the exception of MF) and WCC were significantly more reliant on public funding for project financing and in many cases scheme operation than the other schemes reviewed (Table 1).

LENs, NIS, MF and the green finance schemes were least dependent on public funding for project financing. MF projects had to be fully funded through private carbon finance. LENs projects were financed completely by private finance, and the majority of LENs farmers interviewed by Coyne et al.[54] were not engaged in publicly funded agri-environment schemes. It is not clear to what extent landowners engaging in NIS would supplement scheme payments with public funding via agri-environment schemes, but the scheme was not designed to rely on substantial cross-subsidy from Government. A number of the green finance schemes were being developed in collaboration with Government agencies, as part of a wider route map developed by the Scottish Conservation Finance Project, led by Scottish Environment Protection Agency and the Scottish Wildlife Trust. As a result, each of these relied on a small amount of public funding indirectly via grant-based research funding and in-kind support to develop the pathways to finance. WCC, PC, MM and GDNL were more dependent on public funding for scheme development and operation, and these schemes also relied heavily on public funding for projects, with private contributions only having to account for 10-15% of project costs. In some cases, public funding was used to pay for intermediaries, supply aggregators and other advisors working with landowners. MM is a public-private partnership and bases project implementation on public co-funding with a share of up to 90%, while the remainder of the investment needs come from carbon finance.

Where relevant, this reliance on public funding was a major source of uncertainty for schemes, as changing priorities and lack of public funding in the aftermath of the financial crisis meant that several projects could not get funding for already planned activities. As a result, some schemes also drew on charitable sources to support their activities. There were also concerns about the design of public funding for woodland creation and peatland restoration in the UK. One interviewee explained how the high prices achieved under Woodland Carbon Guarantee auctions had undermined demand for woodland projects being sold by Forest Carbon Ltd. While this interviewee suggested that the design of public schemes should be altered to avoid competition with the private sector, another interviewee suggested that such auctions should drive alternative, more cost-effective and competitive private investment models for financing woodland creation. Similarly, there were reports of NatureScot's Peatland Action programme crowding out Peatland Code projects, given the

relative simplicity of accepting funding for restoration with the aid of Peatland Action facilitators with more familiar, shorter contracts. Given the scale of public spending planned for natural capital investment in the UK, with more than £90 million for the Nature for Climate Fund and an additional £40 million investment in nature recovery through Green Recovery Challenge Fund, these concerns are only becoming more acute.

At present HB, whilst already scaling, has not attracted Government direct funding, but Biodiversity Net Gain is soon to be mandated in the English planning system and is being considered elsewhere in the UK, which is likely to drive demand. Although HB is already offered by a private sector broker, the UK Government is planning to set up its own biodiversity credits scheme and sales platform for developers who cannot find a local market, which one interviewee suggested could inadvertently create competition between public and private HB providers.