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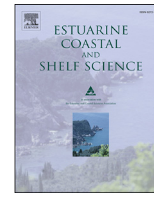

The value of carbon sequestration and storage in coastal habitats

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ABSTRACT

Coastal margin habitats are globally significant in terms of their capacity to sequester and store carbon, but their continuing decline, due to environmental change and human land use decisions, is reducing their capacity to provide this ecosystem service. In this paper the UK is used as a case study area to develop methodologies to quantify and value the ecosystem service of blue carbon sequestration and storage in coastal margin habitats. Changes in UK coastal habitat area between 1900 and 2060 are documented, the long term stocks of carbon stored by these habitats are calculated, and the capacity of these habitats to sequester CO_2 is detailed. Changes in value of the carbon sequestration service of coastal habitats are then projected for 2000–2060 under two scenarios, the maintenance of the current state of the habitat and the continuation of current trends of habitat loss. If coastal habitats are maintained at their current extent, their sequestration capacity over the period 2000–2060 is valued to be in the region of £1 billion UK sterling (3.5% discount rate). However, if current trends of habitat loss continue, the capacity of the coastal habitats both to sequester and store CO_2 will be significantly reduced, with a reduction in value of around £0.25 billion UK sterling (2000–2060; 3.5% discount rate). If loss-trends due to sea level rise or land reclamation worsen, this loss in value will be greater. This case study provides valuable site specific information, but also highlights global issues regarding the quantification and valuation of carbon sequestration and storage. Whilst our ability to value ecosystem services is improving, considerable uncertainty remains. If such ecosystem valuations are to be incorporated with confidence into national and global policy and legislative frameworks, it is necessary to address this uncertainty. Recommendations to achieve this are outlined.

1. Introduction

Ecosystem services are commonly defined as “the outputs of ecosystems from which people derive benefits” (NEA, 2011). The ecosystem service of carbon sequestration and storage, linked to the provision of an equable climate, is a rapidly growing research field (Chung et al., 2011). Whilst there is extensive literature regarding the role of terrestrial habitats as a source and sink of greenhouse gases, the role of marine and coastal habitats is comparatively unknown. Recent research has shown however that ‘blue carbon’, that is carbon sequestrated and stored by marine and coastal habitats (Nellemen et al., 2009), could play a significant role in the global carbon budget (McLeod et al., 2011; Chung et al., 2011). At present, an estimated one third ($\sim$2 Gt C yr^{-1}) of anthropogenic CO_2 emissions are sequestered by the oceans (Orr, 2001; Takahashi et al., 2002). In addition, coastal habitats such as mangroves, sand dunes and saltmarsh have the capacity to sequester carbon at a rapid rate (Chmura et al., 2003; Jones et al., 2008; Alongi, 2012) and, on accreting coasts, this may occur to considerable depth or lateral extent (Chmura et al., 2003). The relative carbon storage potential of coastal habitats is now considered to play a significant role in the regulation of both local and global climate (Nellemen et al., 2009; Irving et al., 2011; Pendleton et al., 2012).

Coastal habitats are at risk and in decline across the world (French, 1997; Martinez et al., 2004). Drivers of this decline include urban and industrial development, aquaculture, agriculture, tourism, forestry, coastal erosion and sea level rise (Jones et al., 2011). For example, ‘reclamation’ of coastal land for agricultural or industrial use alone, here termed ‘land claim’, has accounted for an estimated 25% loss of intertidal land in estuaries worldwide (French, 1997). In the UK, coastal margin habitats have been subject to considerable land use change over the last 100 years (French, 1997; Delbaere, 1998), with land claim through draining occurring on an industrial scale since the 1700s (Hansom et al., 2001).

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With conversion, degradation or loss comes a decline in their potential to sequester and store carbon. Pendleton et al. (2012) estimate that 0.15–1.02 Pg (billion tons) of CO_2 are released annually through the conversion of vegetated coastal ecosystems resulting in economic damage, estimated to be in the order of $US 6–42 billion annually (£ 4–27 billion).

The social and economic significance of this ecosystem service in coastal systems is however poorly represented in policy and management decisions, and rarely features in global climate change mitigation discussions or documentation. In the context of coastal management, it is critical to recognise that any change in type, functioning and area of these ecosystems has the potential to influence carbon sequestration and storage (Everard et al., 2010). In addition to policy at a global scale, this capacity is also of importance for local scale ecosystem service accounting, for example when making decisions on coastal flood defence options such as managed realignment (Andrews et al., 2006).

Global level studies have raised awareness of coastal carbon (Pendleton et al., 2012), yet there is a continuing need for methodological development regarding the calculation of carbon sequestration rates, carbon stocks, and the valuation of this ecosystem service. In addition there is an on-going requirement for site specific data to support meaningful national and local scale policy. It is the aim of this study to address these issues using the UK as a case study.

The UK is selected as a case study partly because few studies have been published in this area. For example, published carbon sequestration rates in saltmarsh rely predominantly on US studies of saltmarsh (Kirwan and Mudd, 2012) which are geomorphologically different from European saltmarshes. Sequestration rates in saltmarsh have been estimated from extrapolation of sedimentation rates and carbon content of established saltmarsh sediments (Cannell et al., 1999; Adams et al., 2012) but do not quantify carbon stocks. In sand dune grasslands and dune wetlands, chronosequence approaches have been used to estimate carbon sequestration rates (Jones et al., 2008). However, no study has yet attempted an inventory of carbon stocks in these habitats and the implications of coastal change for carbon stocks are largely unquantified.

This paper is organised in three sections. Firstly, carbon sequestration rates and stocks are calculated. This study provides the first comprehensive inventory of carbon stocks and sequestration for the principal UK coastal margin habitats of saltmarsh, sand dune and machair dune grassland, including change over time from 1900 to 2060. Information is collated from published sources, the grey literature and unpublished data to calculate C stocks, and estimate the impact of future change. Given the rate of conversion of coastal habitats to other land uses globally and within Europe, the implications of this decline, both for the carbon stocks held and for future carbon sequestration, are explored. It is essential to understand the extent and stability of those carbon stocks and therefore to understand the permanence of storage.

Secondly, a valuation of the ecosystem service of carbon sequestration is undertaken. ‘Carbon stock’ is used to define the carbon stored in the given ecosystem, often shown in static units of g/m^2 or g/m^3. This is different to an ‘ecosystem service stock’, which in the case of carbon storage and sequestration is the ecosystem structure and processes (Luisetti et al., 2013), sometimes known as the natural capital. Neither stock is valued here. The carbon stock currently stored in coastal ecosystems is not valued as although stand-alone environmental values are valuable in raising awareness (Costanza et al., 1997; Beaumont et al., 2008), they do not aid the decision making process with regard to balancing trade-offs and selecting between different development options.

From the ecosystem service stock flows a variety of ecosystem services, one of which is carbon sequestration, or the rate of carbon uptake, which is generally measured in dynamic units such as $g\ m^{-2}\ yr^{-1}$. The carbon stock has the potential to increase, via the ecosystem service of carbon sequestration (a positive flow of this ecosystem service), or decrease via habitat destruction and an accompanying release of CO_2 (which could be interpreted as a negative flow of this ecosystem service, or dis-service). It is the net carbon sequestered which is valued here, and both aspects, the potential service and dis-service, are explored. The third and final section discusses the significance of these figures in terms of global coastal management and future recommendations are made. This approach will provide information to policy makers and coastal managers, and an improved methodology which will be transferable to coastal habitats elsewhere.

2. Carbon sequestration and storage by UK coastal margin habitats

Sand dune habitats and sandy beaches, saltmarsh and machair dune grassland comprise 93% of the UK coastal margin habitat, the remainder consisting of vegetated shingle and shingle beaches, saline lagoons and maritime cliffs and slopes and small islands. In this study the focus is on the first three habitats, henceforth termed sand dunes, saltmarsh and machair since very little is known about the carbon stock or sequestration rates in vegetated shingle, maritime cliff grasslands or saline lagoons, and they occupy less than 10% of the UK coastal margin area. However, it is acknowledged that further work needs to be done to study carbon sequestration and storage in these habitats. Sand dune systems contain a variety of vegetation types, from mobile sand dunes to fixed dune grassland, scrub and dune slacks, and seasonal wetland habitat. Saltmarsh comprises vegetated inter-tidal habitat in a range of communities defined primarily by the frequency of tidal inundation. Machair systems are unique to the UK and Ireland and typically consist of a cordon of mobile sand dunes bordering fixed machair grassland which is occasionally cultivated and fertilised with seaweed. Machair may also contain seasonal wetlands and may grade to peaty wetlands inland.

2.1. Trends and drivers of change in coastal margin habitat area

There is a reduction in the area of all UK coastal margin habitats (Jones et al., 2011). In sand dunes this decline is mainly due to urban expansion, forestry planting, agricultural improvement, tourism and leisure (e.g. golf and caravan parks), and sea level rise. Decreases in saltmarsh area are primarily a result of land claim from agriculture and industry, and coastal erosion. The downward trend in machair area is due to infrastructure development, coastal erosion and sea level rise. Increased statutory protection over the last few decades has slowed the rate of loss of coastal margin habitats, but coastal erosion and sea level rise continue to pose a significant threat. Changes in habitat quality, and natural successional development within existing areas, will also alter rates of carbon sequestration (Jones et al., 2008). Table 1 summarises habitat area by country, and changes in their extent over time.

Current sand dune area (Table 1) is ca. 71,000 ha (JNCC; Dargie, 2000), of which 71.4% is in Scotland (Angus et al., 2011). Since 1900 some 30% of the UK dune area has been lost, including 9127 ha of the Scottish resource (Delbaere, 1998; Angus et al., 2011). Prior to 1945 losses were mainly due to urban expansion and forestry planting, in the period 1945–1970 losses were primarily due to agricultural improvement and continued infrastructure development for tourism, while between 1970 and 2000 losses decreased due to statutory protection of most large sites, however smaller or