The Second State of Natural Resources Report (SoNaRR2020)

Assessment of the Achievement of SMNR Aim 1: Stocks of Natural Resources are Safeguarded and Enhanced.

Natural Resources Wales

Final Report

Mae'r ddogfen hon hefyd ar gael yn Gymraeg

About Natural Resources Wales

Natural Resources Wales's purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales's well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence-informed organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

Title: **SoNaRR2020 Aim 1: Stocks of Natural Resources are Safeguarded and Enhanced**

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The Second State of Natural Resources Report (SoNaRR2020) contents

This document is one of a group of products that make up the second State of Natural Resources Report (SoNaRR2020). The full suite of products are:

Executive Summary. Foreword, Introduction, Summary and Conclusions. Published as a series of webpages in December 2020

The Natural Resource Registers. Drivers, Pressures, Impacts and Opportunities for Action for eight Broad Ecosystems. Published as a series of PDF documents and as an interactive infographic in December 2020

Assessments against the four Aims of SMNR. Published as a series of PDF documents in December 2020:

SoNaRR2020 Aim 1. Stocks of Natural Resources are Safeguarded and Enhanced

SoNaRR2020 Aim 2. Ecosystems are Resilient to Expected and Unforeseen Change

SoNaRR2020 Aim 3. Wales has Healthy Places for People, Protected from Environmental Risks

SoNaRR2020 Aim 4. Contributing to a Regenerative Economy, Achieving Sustainable Levels of Production and Consumption

The SoNaRR2020 Assessment of Biodiversity. Published in March 2021

Assessments by Broad Ecosystem.. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Coastal Margins

Assessment of the Achievement of SMNR: Enclosed Farmland

Assessment of the Achievement of SMNR: Freshwater

Assessment of the Achievement of SMNR: Marine

Assessment of the Achievement of SMNR: Mountains, Moorlands and Heaths

Assessment of the Achievement of SMNR: Woodlands

Assessment of the Achievement of SMNR: Urban

Assessment of the Achievement of SMNR: Semi-Natural Grassland

Assessments by Cross-cutting theme. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Air Quality

Assessment of the Achievement of SMNR: Climate Change

Assessment of the Achievement of SMNR: Energy Efficiency

Assessment of the Achievement of SMNR: Invasive Non-native Species

Assessment of the Achievement of SMNR: Land use and Soils

Assessment of the Achievement of SMNR: Waste

Assessment of the Achievement of SMNR: Water Efficiency

Updated SoNaRR evidence needs. Published in March 2021

Acronyms and Glossary of terms. Published in December 2020 and updated in March 2021

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Introduction to the four aims of SMNR

SoNaRR2020 assesses Wales's progress towards SMNR individually against four aims of SMNR, but it is important to note that they are inextricably linked and should not be seen in isolation (Figure 1). Wales cannot work towards healthy places for people without resilient ecosystems and cannot make our ecosystems resilient without safeguarding stocks of natural resources. The regenerative economy safeguards and restores those stocks and is the route to the transformational change needed to achieve SMNR.

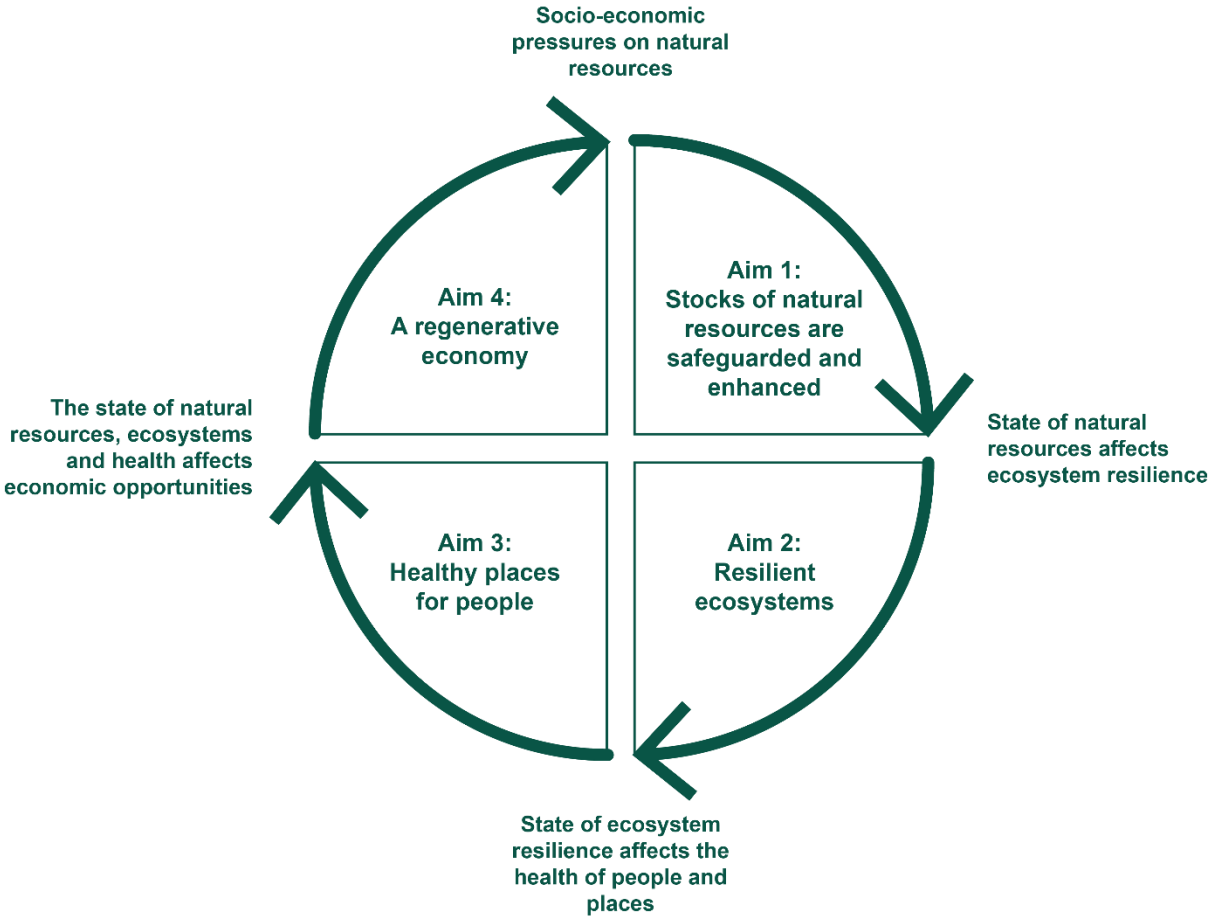

Figure 1 The linkages and cyclical nature of the four aims of SMNR.

SMNR Aim 1: Natural resources are safeguarded and enhanced

Success would see over-exploitation of natural resources tackled to make sure they are regenerated and enhanced to meet the needs of current and future generations. Non-renewable resources such as aggregates and fossil fuels would be used sustainably, and, where that is not possible, substitutes used to meet future needs.

This applies to Wales's use of natural resources and its impact both within Wales and globally.

Here "natural resources" includes (but is not limited to):

- Animals, plants and other organisms
- Air, water and soil
- Minerals
- Geological features and processes
- Physiographical features
- Climatic features and processes

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Summary – natural resources are safeguarded and enhanced

This assessment focuses on the quantity and quality of Wales's natural resources and Wales's impact on global natural resources to assess progress against the first aim of sustainable management of natural resources (SMNR) ensuring natural resources are safeguarded and enhanced.

The Earth's natural resources sustain us as human beings. They include air, water, soil, rocks and minerals, and all living things. They are the basis of our economy: everything we buy, sell or use is either a natural resource or is made from natural resources. Some stocks of natural resources (also known as natural capital) are considered to be critical to human well-being, and so should not be depleted.

If everyone on the planet consumed the same amount of natural resources as we do in Wales, then 2.5 planets would be needed to provide all the necessary resources and absorb the waste. Wales relies on the import of resources from other nations, which not only hampers meeting the well-being goal of securing a "Globally Responsible Wales", but is itself under threat as other nations compete for those resources.

The SoNaRR2020 ecosystem and cross-cutting theme chapters identify the current pressures on these natural resources, both within and outside Wales, summarised in the Natural Resource Registers for each broad ecosystem. Climate change, pollution of air and water, land use change, agricultural intensification and invasive species are all identified as having a significant impact.

Overall, we have concluded that Wales's natural resources, and those we use from other countries, are not safeguarded or enhanced to the degree that we can say we are achieving sustainable management. We are still using resources at an unsustainable rate and SMNR Aim 1 is not yet being achieved.

There are many opportunities for action to safeguard and enhance natural resources used in Wales and to make progress towards achieving this aim. These are summarised into four areas:

- **Decarbonise:** Decarbonisation and carbon sequestration will provide multiple benefits;
- **Improve land management:** Changes in the way land is managed and used for agriculture, forestry and development should be considered to improve sustainability;
- **Recognise biodiversity as an asset:** It needs to be recognised that biodiversity is an asset, or a stock, and that it is declining;
- **Address the impacts of resource use:** As a society, we need to address our over-use of resources and its impact both in Wales and globally.

Introduction: Assessing the sustainability of the stocks of Wales's natural resources

This chapter focuses on the quantity and quality of the natural resources Wales has, also known as natural capital assets. We consider Wales's ecological and material footprints and bring together the findings from the SoNaRR2020 ecosystem and cross-cutting theme assessments. We show where Wales's use of natural resources is threatening the sustainable management of stocks of natural resources.

The first Aim of the Sustainable Management of Natural Resources (SMNR) is to tackle over-exploitation and ensure natural resources are safeguarded and enhanced to meet the needs of current and future generations. This requires exploring how to utilise resources more sustainably and put appropriate substitutes in place where depletion is unavoidable. It is important to remember that Wales's use of natural resources can cause impacts within Wales and globally through imports and exports, pollution and waste. Stocks of natural resources are an important consideration when assessing ecosystem resilience. Ecosystems with diminished stocks will not be resilient.

Over-exploitation of natural resources drives the two main existential threats to humankind. These are elevated levels of species extinction, and human-induced climate change (IPBES, 2019). Although both threats are interconnected because they share common drivers, in some respects the nature crisis is both more complex and less well recognised.

To achieve the sustainable management of natural resources through Aim 1, strong sustainability principles need to be applied to all renewable resources. This seeks to avoid any degradation or depletion of renewable natural capital. However, it does not make sense to apply strong sustainability to non-renewable resources. Here the objective is to ensure that:

- there are sufficient reserves to allow time for substitutes to be found; and
- the depletion is matched by the accumulation of other capital stocks

Taking an 'inclusive wealth' approach (the social value of all of a country's assets, United Nations Environment Programme, 2018) would enable adoption of both strong sustainability principles for renewables and weak sustainability principles for non-renewables, for example applying the concept of *Adjusted Net Savings* (Hamilton and Hartwick, 2017). Adjusted Net Savings considers a country's sustainability by measuring the change in wealth in a specified accounting period. It takes into consideration the consumption of fixed capital, investment in human capital (education), estimates of depletion of natural resources and damage from carbon dioxide and particulate emissions (this is the Wealth Accounting and Valuation of ecosystem services or WAVES approach the World Bank takes).

Consumption of goods and Wales's impact on the rest of the world

People use a range of goods derived from natural resources in Wales. Some of these remain in Wales and others are exported. In addition, Wales imports a range of goods from across the world to keep up with consumer demand. Currently, the balance is wrong. We can see this by looking at Wales's ecological and overseas footprints.

Wales's ecological footprint: the big problems

According to 2015 estimates, if everyone on the planet consumed the same as the Welsh average, 2.5 planets would be needed to provide the necessary resources and absorb associated waste (Welsh Government, 2019a). Despite Wales being a world leader in household recycling, we continue to use up resources faster than they can be replenished (Welsh Government, 2019a) and some resources cannot be replenished at all. This means Wales is not currently living within the limits of the planet. Far more is being consumed than the environment is capable of replenishing or that people can identifiy as sustainable alternatives.

To ensure natural resources will be available for future generations, they must be used sustainably. If depletion of natural resources is unavoidable, substitutes should be put in place to ensure longevity. This applies to Wales's use of natural resources both within Wales and globally. Imports and exports of natural resources, pollutants or waste all contribute to the effect Wales has on the environment.

The planetary boundaries framework (Rockström et al., 2009; Steffen et al., 2015) identified nine "Earth life-support systems" including consumption of water, carbon dioxide (CO_2) levels and biodiversity loss: these systems regulate the stability and resilience of the Earth. Crossing the boundaries increases the risk of large-scale and irreversible environmental changes. Not all of these systems are currently measurable. For those systems that are measurable, Europe already exceeds the planetary boundaries for biogeochemical flows (nitrogen and phosphorus cycles) and land system change, but is within the limits of freshwater use (European Environment Agency, 2020).

Wales's overseas footprint is considered further in the chapter on Aim 4 that looks at a regenerative economy.

Summary assessment of the stocks (extent and condition) of Wales's natural resources

Our ecosystem and thematic technical chapters present the detailed evidence used in the assessment against SMNR Aim 1. This section picks out some relevant key points from those chapters and a brief summary of the evidence they present.

Water

Climate Change is impacting water availability and flow and these impacts are predicted to continue and get worse.

Climate change is projected to increase the frequency and intensity of droughts, fluvial and coastal floods and heatwaves (IPBES, 2019). Climate change scenarios project less water will be available in watercourses and reservoirs due to extended dry weather periods (Freshwater natural resources register). Drier summers could lead to increased pressure on water resources and the natural environment, leading to more frequent droughts (Freshwater natural resources register).

Across the UK, the period 2009-18 has been 1% wetter than 1981-2010 and 5% wetter than 1961-90 with total rainfall from extremely wet days increasing by 17% (Met Office Hadley Centre, 2018). Climate change is expected to restrict the supply of water whilst population growth will add to demand. The population in Wales is projected to increase by 400,000 from the current 3.1m by 2050 (Office for National Statistics, 2020). Despite predicted population growth, Wales currently has a supply/demand surplus in its water supply, and is expected to remain in surplus by the 2050s even under high population and high climate change scenarios (Dŵr Cymru, 2019) (Freshwater natural resources register).

Pollution and physical modification are affecting ecological status of freshwater.

Pollution and physical modification are the major reasons that freshwater ecosystems fail to reach good ecological status under the Water Framework Directive (WFD) (Figure 2) and favourable condition under the Habitats Directive Article 17 reporting (Freshwater natural resources register).

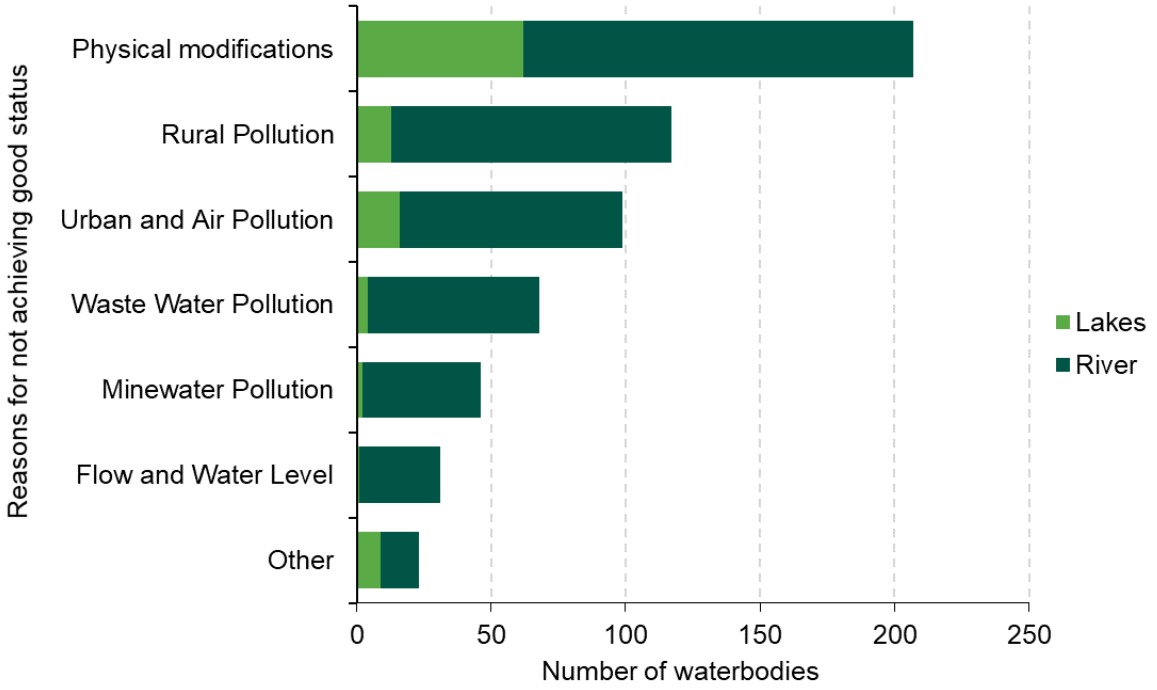

Figure 2 Summary of reasons for not achieving WFD Good status for rivers and lakes (NRW, 2020a).

The two sectors causing the highest number of freshwater pollution incidents in Wales are sewage management and agriculture (primarily the dairy industry) (NRW, 2020b). (Figure 3)

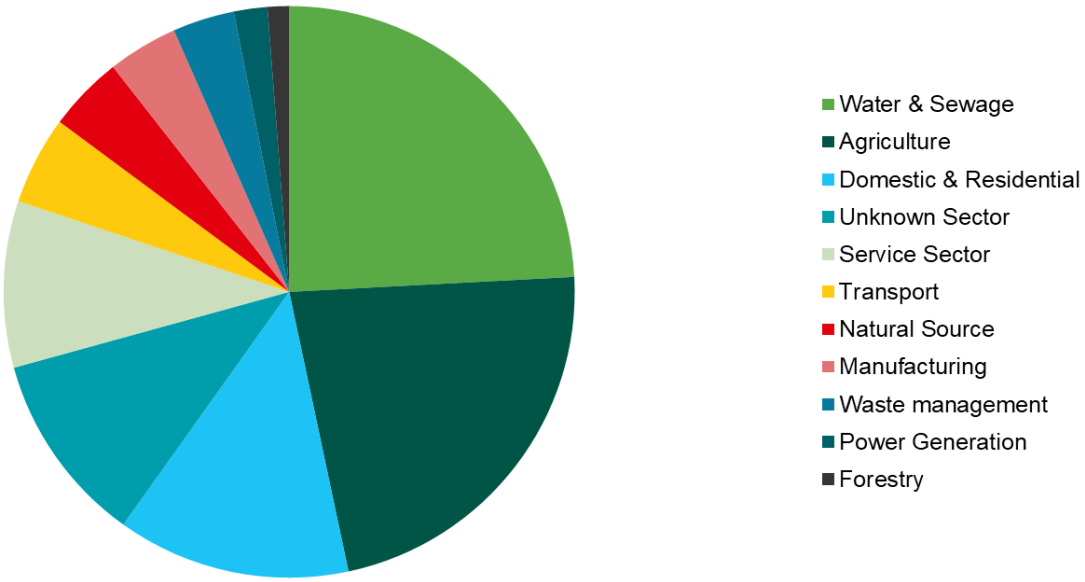

Figure 3 The proportion of pollution incidents by sector, 2014-2019 (NRW, 2020b).

It is important to remember there are also likely to be impacts associated with resource use on ecological status overseas, although this has not been measured in this assessment.

Marine

Marine ecosystems are under pressure from climate change, some human activities, invasive non-native species and inputs from freshwater catchments.

In the marine environment, despite major improvements in water quality in recent years, there continues to be inputs from various sources that affect condition and functioning of habitats and species (Marine natural resources register). Water quality is a priority issue in the marine environment: 28% of Special Areas of Conservation (SAC) habitat features assessed failed to achieve good condition on the basis of one or more nutrient elements of water quality; 38% of habitat features assessed failed to achieve good condition on the basis of chemical elements of water quality, such as mercury, zinc, tributyl tin and brominated diphenyl ethers (NRW, 2018).

Data limitations make assessing the current condition and trends of commercially targeted marine fish and shellfish species at a Welsh level challenging. There is a paucity of stock assessment data for non-quota stocks wholly within Welsh waters. Historical unsustainable fishing practices over the longer term, in the absence of effective management, and other drivers such as pollution and disease are likely to have impacted upon fish and shellfish populations in Wales, for example the decline of native oyster (Woolmer et al., 2011) and crawfish (Seasearch, 2010).

Opportunities to intervene directly to manage the marine environment are limited. Instead, pressures can be reduced or better managed to allow ecosystems to function and recover naturally. The need to act to improve the marine environment has been recognised. A range of legislation, policy and regulation is already in place to manage the marine area that can support the Sustainable Management of Natural Resources, for example site designation. Work needs to continue to ensure compliance and appropriate management of the marine environment.

Land

The total productive land area in Wales has remained stable for many years but there are pressures from other land uses that need to be considered more holistically.

Agriculture accounts for approximately 80% of the land use area in Wales (Welsh Government, 2018). Farmed land comprises of four ecosystems – enclosed farmland, semi-natural grassland, coastal margins and mountain, moor and heath. A smaller proportion of land is used for forestry and woodlands (15%, some of which is within enclosed farmland) (Forest Research, 2019) and urban (approximately 11%) with some integration of use. A small fraction of land can be considered ‘unmanaged’ or ‘abandoned’.

Urban expansion has often been at the expense of the most productive land, although the predicted annual loss of best and most versatile (BMV) agricultural land to urbanisation over the next five decades is expected to be minimal when compared to historical losses (Enclosed farmland natural resources register). An ongoing commitment to tree planting will take land out of agricultural production.

According to Forest Research, in 2017 there were estimated to be 92,700ha of tree cover (urban and rural) outside National Forest Inventory (NFI) defined woodlands (Forest Research, 2017). This is comprised of small woods less than 0.5 hectares in size (49,200ha), groups of trees (33,400ha) and lone trees (10,100ha). The total woodland as a percentage of land cover is 15%. Including trees outside woodland brings the total land cover of woodlands and trees in Wales to 19.4%.

Land utilised for renewable energy development has continued to increase to help meet the target of 70% of Wales's electricity consumption from renewable energy sources by 2030 (Woodland natural resources register). These include wind, solar, hydropower, ground heat sources, energy from waste and bioenergy projects plus the required electricity supply infrastructure.

The way in which land is used is in continual flux. Historically, conversion of arable land to permanent pasture, removal of hedgerows, and land drainage have reduced diversity across the landscape. Up until now, there hasn't been a mechanism to consider this productive resource as a whole.

It is important to consider what current and future generations need from Wales's land resource as a whole, and how Wales is best placed to deliver that in a global marketplace.

Soils

Across Wales there has been a decline in soil biota and organic matter leading to reduced quality and function.

Soil underpins the delivery of a variety of ecosystem goods and services. It determines the land uses and activities that can be supported. People exert pressures on soil resources and supporting services (soil formation, nutrient cycling) through erosion, compaction, sealing, and pollution, primarily through agricultural practices but also through development and other activities.

Soil biota (microorganisms, animals and plants that live in soil) is vital for nutrient cycling and plant growth and accounts for approximately 25% of global biodiversity (George et al., 2019). Across Wales, there has been a decline in soil biota across all land uses from 2013 to 2016 (Emmett et al., 2017). Losses of soil organic matter (SOM) have been associated with a loss in soil quality and function; and reduced resistance and resilience to poor soil management (Welsh Government, 2019b).

Soil structure can be relatively easily damaged by poor land management, which in turn negatively affects soil functions and the provision of benefits, such as biodiversity, agricultural productivity, clean water and flood prevention, and climate change mitigation (Enclosed farmland natural resources register). A short term decline of bulk density (a measure of soil compaction) on improved land is encouraging and may indicate less pressure on these soils (Alison et al., 2020).

The vast majority of carbon in the terrestrial environment is stored in soils rather than vegetation.

Soil is an important carbon store and a better understanding of soil stocks is needed. Accumulation of SOM is important for soil formation as the relatively cool and wet climate of Wales encourages the formation of organic rich soils. Welsh soils are estimated to contain 410 million tonnes of carbon (NRW, 2016; UK NEA, 2011). On the whole, soil carbon contents are close to equilibrium with soil type and land use in Wales (Adams, 2015; Detheridge et al., 2014). Peaty soils have a high carbon (>12%) and organic matter content (>20%).

The total area of deep peat soils in Wales is more than 90,000ha (circa. 4% of Welsh land area). Shallow peaty soils (organo-mineral soils) cover an additional area of 359,200 ha (17.3%) (NRW, 2016). The majority of the peat resource in Wales is in poor condition. As reported in SoNaRR2016, maintaining the carbon content of these soils is a key priority in limiting overall greenhouse gas emissions in Wales as well as managing water resources in the face of inevitable climate change (NRW, 2016).

In 2016, the Office for National Statistics (ONS) published preliminary estimates of carbon stock accounts for geocarbon (coal, oil, gas) and biocarbon. These partial accounts estimated there were 4,266 million tonnes (MtC) of recorded biocarbon in the UK in 2007, of which 94.2% (4,019 MtC) was contained in soil stocks and 5.8% (247 MtC) in vegetation stocks (Office for National Statistics, 2016).

Topsoil carbon concentrations have been monitored across Wales as part of the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP) (Alison et al., 2020). In general, they show a stable trend over the long-term. Recent, more indepth analysis showed topsoil carbon (0-15cm) was stable in woodlands and improved land, while a significant decline in topsoil carbon occurred on habitat land restricted to the uplands from 2007 to 2016 (Alison et al., 2020). Further work is required to investigate the reasons for these changes.

Soil erosion is being exacerbated by land use change and inappropriate land management.

Soil erosion by water is an important degradation process that occurs naturally but is exacerbated by land use change and inappropriate land management. Soil erosion in Wales is mainly attributable to water erosion and upland erosion processes, such as peat shrinkage and oxidation, rilling and gullying of organo-mineral soils, landslips and stream bank erosion (Boardman and Evans, 2006 and Morgan 1985, Rollett and Williams, 2020) (Mountains, moorlands and heaths natural resources register). Whilst erosion effects are evident, little is known about the soil formation rates. However, it is generally accepted that the rate of soil erosion under conventional cultivation tends to be at least one to two orders of magnitude greater than soil formation (Alison et al., 2019). Large areas of Wales are assumed to have low erosion rates due to the predominance of grassland and rough grazing, although this has not been quantified by measurements or observations (Cranfield University, 2016) (Mountains, moorlands and heaths natural resources register).

Biodiversity

Biodiversity is a critical stock of natural resources that is declining in Wales and globally.

The loss of biodiversity is accelerating globally at an unprecedented rate with around 1 million animal and plant species now threatened with extinction, many within the next few decades (IPBES, 2019). There are both winners and losers for different aspects of biodiversity in Wales (all natural resources registers). The overall trend, however, mirrors the global picture and is one of decline. The majority of habitat and species features (those that are endangered, vulnerable, rare and/or endemic) in protected sites in Wales are considered to be in unfavourable condition (NRWs' feature condition monitoring programme for SACs and SPAs, 2018). This means the features are not in a very good state for one or more of parameters such as range, area, structure and function, population andfuture prospects.

There are a variety of pressures and demands affecting biodiversity. The five most important drivers are land and sea use change, direct exploitation of species, climate change, pollution and invasive non-native species.

In the UK, agricultural intensification has been identified as having the single biggest impact on biodiversity.

The farmland birds indicator has shown that since 1970, the abundance of farmland birds has more than halved and similar declines have been seen in many other taxonomic groups (Hayhow et al., 2019) (Enclosed farmland natural resources register). An increase in intensification and specialisation of agriculture is the main risk to biodiversity from the drive to increase profits, efficiency and production.

Climate change is also having a substantial effect on biodiversity. Species are shifting their geographical ranges as the climate warms (Morecroft and Speakman, 2015; MCCIP, 2020), there have been declines in breeding seabird populations attributed to climate change (MCCIP, 2020) and migratory birds are changing their travelling range and arrival times (ASC, 2016). It is predicted that if the world warms by 2°C, one in twenty of all species will be threatened with extinction (IPBES, 2019).

Invasive non-native species

Invasive non-native species (INNS) are increasing and adversely affecting native biodiversity.

Over the period 1960 to 2018, invasive non-native species (INNS) have become more prevalent, increasing the pressure on native biodiversity (all natural resources registers). The rate at which new INNS are establishing in Great Britain has increased dramatically in the last 50 years and this trend is set to continue. Freshwater and marine ecosystems have the highest number of different INNS (already present and yet to arrive in Wales), followed by woodland and semi-natural grassland ecosystems. There are more INNS of interest to Wales (NBN Atlas Partnership, 2018) that primarily impact on supporting and provisioning ecosystem services than on cultural and regulating ecosystem services.

Air

Poor air quality is one of the largest environmental risks to ecosystems and human health in Wales. Air pollution adversely affects biodiversity and has led to widespread changes to species distribution and to the quality of habitats in Wales.

Poor air quality threatens the conservation status of many habitats and reduces the ability of ecosystems to deliver their services such as clean drinking water and timber (Coastal margins, Mountains, moorlands and heaths, Semi-natural grasslands, and Urban natural resources registers). The majority of air pollutants have declined in Wales in recent decades (Figure 4) (Jones et al., 2019). However, concentrations of ammonia are rising and having an impact on sensitive ecosystems.

Ammonia emissions from the UK and Europe continue to be above damage thresholds, resulting in widespread exceedance of critical loads (deposition) and critical levels (atmospheric concentrations) for both acidity and ammonia (Coastal margins, Enclosed farmlands, Mountains, moorlands and heaths, Semi-natural grasslands, and Woodlands natural resources registers). This pollution also contributes to ozone production, which damages not only vegetation but human health (Public Health Wales, 2016) and many human-made materials such as plastic, rubber and metal.

Ammonia and nitrogen pollution from agriculture is affecting 59% of the land area of Wales. In 2018 88% of sensitive habitats exceeded their critical load for atmospheric nitrogen (down from 98% in 2009). It is currently having an adverse effect on 29% of the most sensitive habitats for plants and wildlife (Guthrie et al., 2018).

Particulate matter is of concern to both ecosystems and people, with smaller particle sizes having a greater effect on people as they are easily inhaled. Overall concentrations of PM2.5 (particulate matter 2.5 microns or less in diameter) in most of Wales are low, although hotspots in industrial and densely populated urban areas exist. Non-exhaust road transport emissions, domestic and industrial emissions contribute to local peaks in urban areas (Urban natural resources register). Domestic wood and coal burning also make a significant contribution along the north coast and in urban areas, including for the large urban populations in Swansea and Cardiff. Natural irreducible sources (sea salt, natural rural and urban dusts and biogenic secondary organic aerosols) do however account for around a third of the World Health Organisation (WHO) standard for PM2.5 over areas of South Wales (Urban natural resources register).

Particulate matter impacts on the environment can be wide ranging including reduced visibility (haze), acidification of watercourses, crop damage and effects on ecosystem diversity.

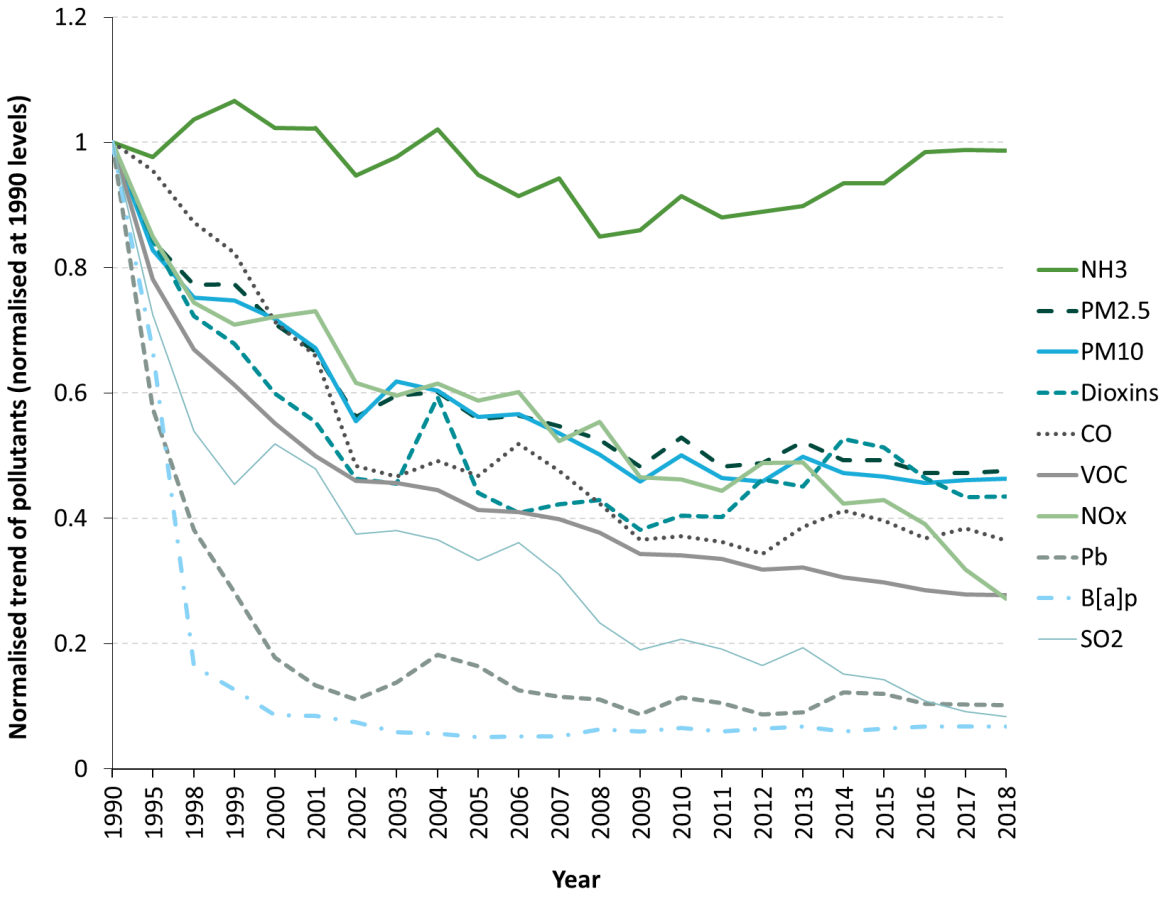

Figure 4 Normalised Trends for all pollutants in Wales (Jones et al., 2019)

Urban areas

Urban areas are responsible for a significant proportion of carbon emissions and resource use and demand is likely to increase.

Urban areas are the main source of human demand on other broad ecosystems, such as food from enclosed farmlands. They are also the areas where impacts of environmental change are felt most by people. In Wales, 83% of people live in built-up areas of more than 2,000 people. These areas occupy just 3.4% of the land in Wales (Office for National Statistics, 2013). It is estimated that between 6,700 and 9,700 additional housing units will be required each year during the period of 2018-19 to 2022-23 (Welsh Government, 2019c) (Urban natural resources register).

Around 40% of the UK's total carbon footprint is from the built environment, primarily energy used in buildings and transport (UKGBC, 2019) (Urban natural resources register). In 2018, road transport contributed around 93% of the Welsh transport carbon emissions (Welsh Government, 2020a).

Transport is also the main source of nitrogen dioxide (NO2), accounting for nearly a third of all NO2 emissions in the UK. Ambient levels of NO2 have generally decreased in Wales over the last 20 years due to decreasing fossil fuel use and improved regulation of fuels (particularly diesel), although levels have remained

broadly similar for the past 5 years. Overall concentrations of fine particulates (particulate matter 2.5 microns or less in diameter known as PM2.5) in most of Wales are low, although there are hotspots in industrial and densely populated urban areas.

The benefits of urban green infrastructure (known as GI) are well understood. Existing green infrastructure is under pressure from development and as a resource could be better managed.

Green infrastructure can help to enhance biodiversity and reduce and mitigate against climate change impacts (Urban natural resources register). Green infrastructure can be defined as a network of natural and semi-natural features in the urban environment (European Commission, 2013) which could include parks, gardens, green roofs, street trees, water bodies and sustainable drainage systems. Garden sizes in new developments are becoming smaller (Thompson and Head, undated) and small gardens cannot normally hold the same number of wildlife habitats such as trees, ponds and hedges. In addition, mature trees are being lost from urban areas. This all implies the green infrastructure stock is being fragmented.

The benefits of green infrastructure are extremely valuable, for example the cooling benefit of Cardiff's green infrastructure is estimated at over £1.4m each year in cost savings from air conditioning and the avoidance of labour productivity loss (Kuyer et al., 2018). The annual monetary benefit of the health effects of noise regulation by urban trees in Wales is estimated at somewhere between £1m and £2.6m (Kuyer et al., 2018).

Green infrastructure alone, however, is not enough to create a sustainable urban ecosystem. Impacts on other ecosystems also need to be considered and minimised.

Energy

The proportion of renewable energy is improving but power generation, heating and transport still account for the majority of greenhouse gas emissions.

Wales consumed around 91 Terrawatt-hour (TWh) of energy in 2018. Electricity consumption represented about 16% of this total consumption; the remaining 76.1 TWh is associated with transport, heating and industry (Welsh Government, 2019d).

Wales generated an estimated 27.9 TWh of electricity in 2019 (Figure 5), while consuming approximately 14.7 TWh. This means that Wales generates almost twice as much electricity as it consumes and is a net exporter of electricity to wider UK and EU (Welsh Government, 2019d). In 2019, 73% of electricity generated in Wales came from fossil fuel plants, and 27% from renewable sources (Welsh Government, 2020b).

In 2017, the Welsh Government announced a target of meeting 70% of Wales's electricity demand from Welsh renewable electricity sources by 2030. As of 2019, Wales achieved 51% (Welsh Government, 2020b). Renewable energy generation in Wales has increased fivefold since 2005. Approximately 70% of the increase in the

last ten years has been due to large-scale onshore and offshore wind (Welsh Government, 2020b). Production of renewable heat was approximately 2.3 TWh in 2019 (Welsh Government, 2020b), which is equivalent to 13% of estimated Welsh domestic heat demand (Welsh Government, 2019d).

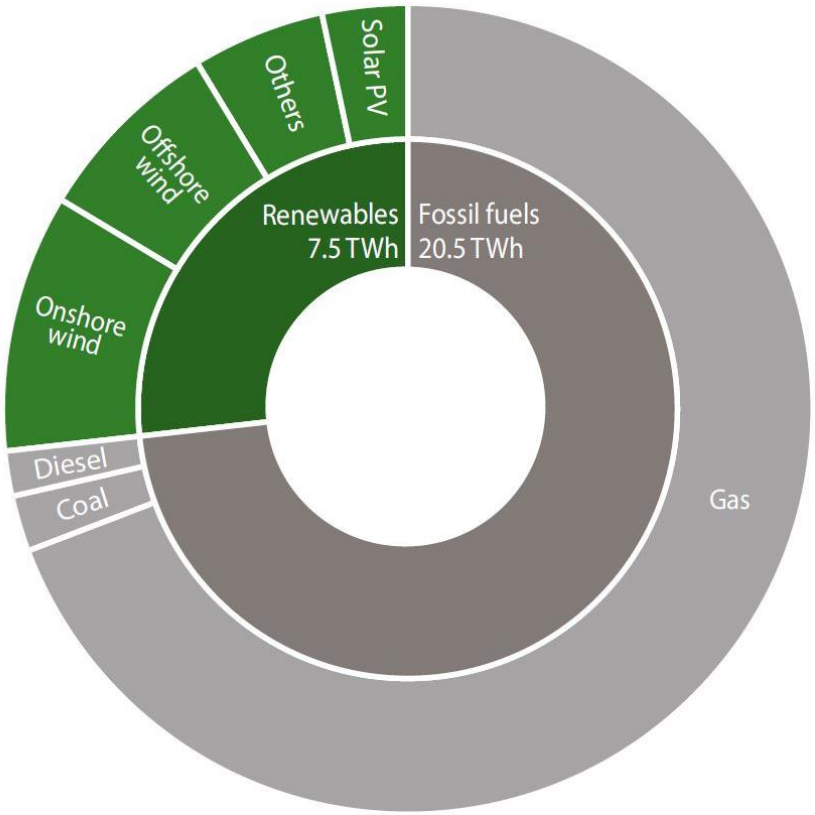

Figure 5 Wales's Electricity Generation Mix 2019 (Welsh Government, 2020b).

Energy generation consumes natural resources (mainly fossil fuels but also water and land use), resulting in emissions that directly and indirectly cause local and global impacts and generates conventional and nuclear waste. The installation of associated infrastructure can cause local impacts including the generation of waste, effluent discharges into local water courses, changes to local air quality (Nerini et al., 2017) and has an impact on biodiversity by modification or loss of natural habitats (Luderer, 2019).

Climate change

Climate change is having a substantial effect on biodiversity and ecosystems.

Climate change is affecting ecosystems through shifting species ranges, localised extinctions, changes to life-cycle events, and sea level rise. It is exacerbating the increase in invasive species including disease vectors. The projected increase in frequency and intensity of droughts, fluvial and coastal floods and heatwaves are all likely to further reduce overall ecosystem resilience.

Climate change is altering the abundance and distribution of biodiversity (IPBES, 2019). Globally, certain groups of species have been found to be more at risk,

including insects and plants (Hoegh-Guldberg et al., 2018). Such change will have knock-on effects for whole ecosystems and impacts will worsen with greater warming (Hoegh-Guldberg et al., 2018).

Where species are unable to disperse, for example due to barriers or where they are unable to respond quickly enough to climate change, they will be at risk of localised extinctions (IPBES, 2019). Localised extinctions may have knock-on effects, particularly for those depending on a limited number of species as a pollinator, disperser or as food.

Engledew (2019) valued the carbon sequestration provided by woodlands in Wales at £109.3 million in 2016. Recent research has also highlighted the significant value of marine and coastal habitats in Wales in sequestering carbon and acting as carbon sinks, also known as “blue carbon” (Armstrong et al., 2020).

Some of the projected impacts of climate change, including sea level rise and coastal erosion, will be irreversible (IPBES, 2019). Mean sea levels around the UK have risen by around 16cm since the start of the 20th century (Met Office Hadley Centre, 2018). Erosion and sea level rise coupled with competing pressures such as development are resulting in loss of habitat such as saltmarsh due to coastal squeeze (Coastal margins natural resources register).

Sea levels will continue to rise even if global warming is restricted to below 2°C (Met Office Hadley Centre, 2018). This will lead to increased flooding across Wales, erosion of coastal habitats and increased salinisation due to ingress of sea water.

How is Wales currently safeguarding and enhancing natural resources?

Overall Wales’s natural resources are not safeguarded or enhanced to the degree that we can say we are achieving sustainable management. The evidence and examples provided in this chapter and elsewhere in SoNaRR, supported by international reports such as those of the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), indicate that we have a considerable way to go until that aim is achieved. Whilst Wales is rich in natural resources and the diversity of its ecosystems, we are still using resources at a rate that is unsustainable. Therefore, Aim 1 is not yet being achieved.

Achievement of this aim cannot be seen in isolation; without achieving Aim 1 we are unable to improve the resilience of our ecosystems (Aim 2) which is essential for providing healthy places, protected from environmental risks (Aim 3). Central to achieving these three aims is achieving Aim 4. Moving towards a regenerative economy from the existing unsustainable one will be the transformative change needed to address the climate and nature emergencies.

Opportunities for action

To enable Wales to safeguard and enhance natural resources we have identifed the following opportunities for action:

Decarbonise

Decarbonisation and carbon sequestration will provide multiple benefits.

Wales needs to consider and implement ways to reduce itsenvironmental and carbon footprints, building on the Low Carbon Delivery Plan published in 2019 (Welsh Government, 2019e). This includes focusing on sectors that use the most resources to reduce consumption and on sectors where there may be greater potential for re-use and recycling, such as vehicles, plastics, construction and water industries. Making buildings energy efficient and low carbon is one example of reducing overall energy use, and therefore greenhouse gas emissions, whilst also helping towards the behavioural changes needed in society to address many of the issues Wales is facing.

Reducing greenhouse gas emissions is crucial. Removing carbon from the atmosphere and maintaining long-term storage of it also needs to be considered, for example through peatland restoration and increased tree cover in the right places with the right species.

Improve land management

Changes in management and land use for agriculture, forestry and development should be considered to improve sustainability.

This could include improved production efficiency and nutrient management; management to deliver habitat restoration, improving connectivity of habitats across whole landscapes (for example an increase in woody elements within farmland systems); and improve environmental impact of changes in land use. Sustainable agriculture and woodland management can be delivered by working with farmers and land managers and offering incentives and support. Similarly, management of urban trees provides multiple local benefits to people and biodiversity. Catchment management solutions reduce flood and drought risk by storing and slowing water. Supporting protected site management would help to achieve good condition, and landscape scale restoration would help to restore ecosystem resilience.

Recognise biodiversity as an asset

It needs to be recognised that biodiversity is an asset, or a stock, and that it is declining.

Biodiversity underpins the social and economic systems we rely on in Wales and despite a more integrated policy framework, we struggle to find ways to measure it as a *stock.* Biodiversity is made up of the first group of natural resources, “animals, plants and other organisms”, listed in the Environment (Wales) Act. The resilience of

biodiversity is obviously linked to management of other natural resources in Wales and needs managing in a holistic way. Clear information is needed to show where declines in biodiversity and other natural resources are leading to impacts on well-being. If biodiversity was viewed as part of Wales's wealth in the same way that other assets are treated, the importance of replenishing its stocks would be recognised.

In SoNaRR we are building a mechanism for accounting for biodiversity, including the impact outside Wales, through the natural resource registers. Wales needs to find ways of using this approach effectively to support businesses, planners, and decision makers to take long-term biodiversity investment decisions.

Address resource use and its impacts

As a society, we need to address our over-use of resources and its impact in Wales and globally

Our society relies on ecosystems as a source of natural resources and to dispose of wastes and emissions. Wales's global footprint makes it clear that our systems of production and consumption are putting too much pressure on the environment. We need to reduce our use of natural resources and the pollution and waste we generate, in order to have an economy which regenerates ecosystems, instead of degenerating them.

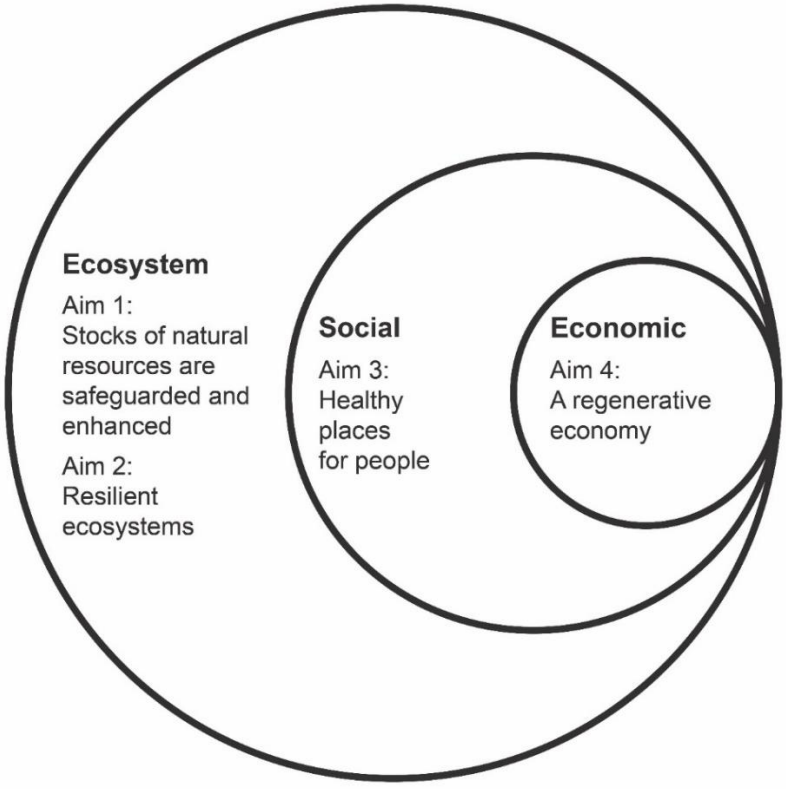

Figure 6 Economy is a subsidiary of the Environment

In the Interim Review of the Economics of Biodiversity (Dasgupta, 2020) Sir Partha Dasgupta makes clear the need to recognise that our society and the economy are nested within the environment (Figure 6) The economy cannot be looked at separately to the environment: “The economy is a wholly owned subsidiary of the environment, not the reverse” (quote by Herman E. Daly in Clark, 2007).

“This conclusion is in sharp contrast to the assumptions underlying contemporary growth and development economics, and by extension the economics of climate change. Whereas that literature sees humanity as external to the biosphere, the Review sees us as embedded.” (Dasgupta, 2020).

Aim 4 (considering a regenerative economy) looks at some of the ways in which these systems can be reimagined which will contribute to safeguarding and enhancing natural resources.

References

Adams, W.A. 2015. Carbon storage and dynamics in soils and ecosystems in Wales and potential for change in CO2 sequestration. Welsh Soil Discussion Group, British Society of Soil Science. 12pp

Alison J, Thomas A, Evans CD, Keith AM, Robinson DA, Thomson A, Dickie I, Griffiths RI, Williams J, Newell-Price JP, Williams AG, Williams AP, Martineau AH, Gunn IDM, Emmett BA. 2019. Technical Annex 3: Soil Carbon Management. In Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP): Sustainable Farming Scheme Evidence Review. Report to Welsh Government (Contract C210/2016/2017). Centre for Ecology & Hydrology Project NEC06297. Available from: https://erammp.wales/en/r-sfs-evidence-pack [Accessed October 2020]

Alison J, Maskell LM, Smart SM, Feeney C, Henrys PA, Botham M, Robinson DA, Emmett BA. 2020. Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP). ERAMMP Report 30: Analysis of National Monitoring Data in Wales for the State of Natural Resources Report 2020. Report to Welsh Government (Contract C210/2016/2017). UK Centre for Ecology & Hydrology Project 06297. Available from: https://erammp.wales/en/gmep-data-analysis [Accessed December 2020]

Armstrong, S., Hull, S., Pearson, Z., Wilson, R. and Kay, S. 2020. Estimating the Carbon Sink Potential of the Welsh Marine Environment. NRW, Cardiff, 74pp.

ASC. 2016. UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Wales. Adaptation Sub-Committee of the Committee on Climate Change, London.Boardman J, Evans R. 2006. Britain. In Soil Erosion in Europe. Edited by J. Boardman and J. Poesen

Clark T. 2007. Stick this in your memory hole. p19.

Cranfield University. 2016. An analysis of the extent and severity of soil degradation in Wales. Cranfield Soil and Agrifood Institute. Dasgupta, P. 2020. The Dasgupta Review – Independent review on the economics of biodiversity, Interim Report, April 2020.

Detheridge A, Scullion J, Griffith G, Gwynne-Jones D. 2014. Soil organic carbon in Wales. What is it and why is it important? Report co-funded by the Welsh Government Land Use and Climate Change Committee and the Seren programme. 14pp. Available from: https://www.flexis.wales/grc-engineering/reports/wales-soil-carbon-report-fact-sheets/. [Accessed December 2020]

Emmett BE, Abdalla M, Anthony S, Astbury S, August T, Barrett G, Beckman B, Biggs J, Botham M, Bradley D, Brown M, Burden A, Carter H, Chadwick D, Cigna F, Collier R, Cooper D, Cooper J, Cosby BJ, Creer S, Cross P, Dadam D, Edwards F, Edwards M, Evans C, Ewald N, Fitton A, Garbutt A, Giampieri C, Gooday R, Grebby S, Greene S, Halfpenney I, Hall J, Harrison S, Harrower C, Henrys P, Hobson R, Hughes P, Hughes S, Illian J, Isaac N, Jackson B, Jarvis S, Jones DL, Jones P,

Keith A, Kelly M, Kneebone N, Korenko J, Lallias D, Leaver D, Lebron I, Malcolm H, Maskell L, McDonald J, Moxley J, Norton L, O'Hare M, Oliver T, Owen A, Parkhill KA, Pereira M, Peyton J, Pogson M, Powney G, Pritchard N, Pritchard S, Prochorskaite A, Prosser M, Pywell R, Rawlins B, Reuland O, Richards M, Robinson DA, Rorke S, Rowland C, Roy D, Scarlett P, Scholefield P, Scott A, Scott L, Scott R, Sharps K, Siriwardena G, Smart S, Smith G, Smith P, Stopps J, Swetnam R, Taft H, Taylor R, Tebbs E, Thomas A, Todd-Jones C, Tordoff G, Turner G, Van Breda J, Vincent H, Wagner M, Waters E, Walker-Springett K, Wallace H, Watkins J, Webb G, White J, Whitworth E, Williams B, Williams P, Wood C, Wright S. 2017. Glastir Monitoring & Evaluation Programme. Final Report to Welsh Government - Executive Summary (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Projects: NEC04780/NEC05371/NEC05782).

Dŵr Cymru. 2019. Water resources management plan 2019. Available from: https://www.dwrcymru.com/en/My-Water/Water-Resources/Final-Water-Resources-Management-Plan-2019.aspx [Accessed October 2020]

Engledew M, Maclean K, Thomas T, Fitch A, Robinson DA, Jones L. 2019. ERAMMP Year 1 Report 24: Welsh National Natural Capital Accounts - Ecosystem Service Accounts for Woodland, Farmland and Freshwater Habitats. Report to Welsh Government (Contract C210/2016/2017) (CEH NEC06297)

European Commission. 2013. Green Infrastructure (GI) — Enhancing Europe's Natural Capital - COM(2013) 149. Available from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013DC0249 [Accessed December 2020]

European Environment Agency. 2020. Is Europe living within the limits of our planet? An assessment of Europe's environmental footprints in relation to planetary boundaries. EEA report no. 01/2020. Joint European Environment Agency (EEA) and Federal Office for the Environment (FOEN) report. ISBN 978-92-9482-215-6.

Forest Research. 2019. Forestry Facts & Figures 2019 [online]. Available from: https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/ [Accessed November 2019]

George PBL, Lallias D, Creer S, Seaton FM, Kenny JG, Eccles RM, Griffiths RI, Lebron I, Emmett BA, Robinson DA, Jones DL. 2019. Divergent national-scale trends of microbial and animal biodiversity revealed across diverse temperate soil ecosystems. Nature Communications 10 (1107) doi:10.1038/s41467-019-09031-1. Available from: https://www.nature.com/articles/s41467-019-09031-1 [Accessed January 2020]

Guthrie S, Dunkerley F, Tabaqchali H, Harshfield A, Ioppolo B, Manville C. 2018. Impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis. 10.7249/RR2695.

Hamilton K, Hartwick J. 2017. Wealth and sustainability. Chapter 15 pp 343-363. In Hamilton K, Hepburn C (eds.). 2017. National Wealth: What is missing and why it matters. Oxford University Press. Hayhow DB, Eaton MA, Stanbury AJ, Burns F, Kirby WB, Bailey N, Beckmann B, Bedford J, Boersch-Supan PH, Coomber F, Dennis EB, Dolman SJ, Dunn E, Hall J, Harrower C, Hatfield JH, Hawley J, Haysom

K, Hughes J, Johns DG, Mathews F, McQuatters-Gollop A, Noble DG, Outhwaite CL, Pearce-Higgins JW, Pescott OL, Powney GD, Symes N. 2019. The State of Nature 2019. The State of Nature partnership.

Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, Diedhiou A, Djalante R, Ebi KL, Engelbrecht F, Guiot J, Hijioka Y, Mehrotra S, Payne A, Seneviratne SI, Thomas A, Warren R, Zhou G. 2018. Impacts of 1.5ºC Global Warming on Natural and Human Systems. In: Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M, Waterfield T (eds.) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. In Press.

IPBES. 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Díaz S, Settele J, Brondízio ES, Ngo HT, Guèze M, Agard J, Arneth A, Balvanera P, Brauman KA, Butchart SHM, Chan KMA, Garibaldi LA, Ichii K, Liu J, Subramanian SM, Midgley GF, Miloslavich P, Molnár Z, Obura D, Pfaff A, Polasky S, Purvis A, Razzaque J, Reyers B, Roy Chowdhury R, Shin YJ, Visseren-Hamakers IJ, Willis KJ, Zayas CN (eds.). IPBES secretariat, Bonn, Germany. Available from: https://doi.org/10.5281/zenodo.3553579 [Accessed December 2020]

Jones L, Claxton R, Thistlethwaite G, Raoult J, MacCarthy J, Karagianni E, Kilroy E, Misselbrook T, Otto A, Passant N, Pearson B, Richardson J, Wakeling D, Walker C. 2019. National atmospheric emissions inventory: Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 1990-2017. Prepared by Ricardo Energy & Environment for the Department for Environment, Food & Rural Affairs, The Scottish Government, The Welsh Government and The Northern Ireland Department for Agriculture, Environment and Rural Affairs.

Kuyer J, Cryle P, Dickie I, Jones L, Morton D, Thomas A, Fitch A. 2018. Scoping UK Urban Natural Capital Account - Noise Extension. Final Report for Defra. Eftec. Available from: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=20027. [Accessed December 2020]

Luderer G, Pehl M, Arvesen A, Gibon T, Bodirsky BL, Sytze de Boer H, Fricko O, Hejaki M, Humpenöder F, Iyer G, Mima S, Mouratiadou I, Pietzcker RC, Popp A, van den Berg M, van Vuuren D, Hertwich EG. 2019. Article in Nature Communications: Environmental Co-Benefits and adverse side effects of alternative power sector decarbonisation strategies. Available from: https://www.nature.com/articles/s41467-019-13067-8 [Accessed December 2020]

MCCIP. 2020. Marine Climate Change Impacts: Marine Climate Change Impacts Report Card 2020. In: Stoker B, Turrell WR, Robinson KA, Howes EL, Buckley P, Maltby K and Matear L, (eds.) Summary Report. Lowestoft: MCCIP.

doi:10.14465/2020.arc00.000-000 Available from: http://www.mccip.org.uk/impacts-report-cards/full-report-cards/2020/ [Accessed December 2020]

Met Office Hadley Centre. 2018. UKCP18 Global Projections. Available from: https://ukclimateprojections-ui.metoffice.gov.uk/ui/home [Accessed December 2020]

Morecroft MD, Speakman L. 2015. Biodiversity Climate Change Impacts Summary Report. Living with Environmental Change. ISBN 978-0-9928679-6-6.

Morgan RPC. 1985. Assessment of soil erosion risk in England and Wales. Soil Use and Management, 1, 127-131.

NBN Atlas Partnership. 2018. Species list: INNS of interest to Wales July 2018. Available from: https://lists.nbnatlas.org/speciesListItem/list/dr1832 [Accessed November 2020]

Nerini FF, Tomei J, To LS, Bisaga I, Parikh P, Black M, Borrion A, Spataru C, Broto VC, Anandarajah G, Miligan B, Mulugetta Y. 2017. Mapping Synergies and Trade-off between energy and the Sustainable Development Goals. Nature Energy 3, 10–15 (2018)

NRW. 2016. The State of Natural Resources Report (SoNaRR): Assessment of the Sustainable Management of Natural Resources. Annex Technical Annex for Chapter 3. Available from: https://naturalresources.wales/evidence-and-data/research-and-reports/the-state-of-natural-resources-report-assessment-of-the-sustainable-management-of-natural-resources/?lang=en. [Accessed December 2020]

NRW. 2018. Indicative feature condition assessments for European marine sites [online]. Available: https://naturalresources.wales/guidance-and-advice/environmental-topics/wildlife-and-biodiversity/protected-areas-of-land-and-seas/indicative-feature-condition-assessments-for-european-marine-sites-ems. [Accessed December 2020]

NRW. 2020a. Reasons for not achieving WFD Good status for rivers and lakes. Internal database.

NRW. 2020b. NRW pollution incidents data 2014-2019. Internal database.

Office for National Statistics. 2013. 2011 Built-up Areas - Methodology and Guidance. Version: 2013 v1 June 2013. Available from:https://geoportal.statistics.gov.uk/datasets/f6684981be23404e83321077306fa837_0 [Accessed December 2020]

Office for National Statistics. 2016. UK Natural Capital: Experimental carbon stock accounts, preliminary estimates. Statistical Bulletin. Available from: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/experimentalcarbonstockaccountspreliminaryestimates [Accessed December 2020]

Office for National Statistics. 2020. Population estimates for the UK, England and Wales, Scotland and Northern Ireland: mid-2019. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/pop

ulationestimates/bulletins/annualmidyearpopulationestimates/mid2019estimates [Accessed November 2020]

Public Health Wales. 2016. Estimating the Mortality burden of air pollution in Wales. in National Assembly for Wales.Ricardo, Department for Environment, Food and Rural Affairs (DEFRA), The Scottish Government, The Welsh Government, The Northern Ireland Department for Agriculture, Environment and Rural Affairs. 2019. National Atmospheric Emissions Inventory: Air pollutant inventories for England, Scotland, Wales and Northern Ireland: 1990-2017. ED 62689, Issue 1.0, 14th October 2019.

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS III, Lambin E, Lenton TM, Scheffer M, Folke C, Schellnhuber H, Nykvist B, De Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley J. 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14 (2), 32. Available from: http://www.ecologyandsociety.org/vol14/iss2/art32/ [Accessed December 2020]

Rollett A, Williams J. 2020. Assessment of Welsh Soil Issues in Context. Welsh Government Soil Policy Evidence Programme 2018-19/01.

Seasearch. 2010. Seasearch Wales Crawfish *Palinurus elephas* historical diver records.

Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, Biggs R, Carpenter SR, de Vries W, de Wit CA, Folke C, Gerten D, Keinke J, Mace GM, Persson LM, Ramanathan V, Reyers B, Sörlin S. 2015. Planetary boundaries: guiding human development on a changing planet. Science 347 (6223), p. 1259855 (DOI: 10.1126/science.1259855).

Thompson K, Head S. Undated. Gardens as a Resource for Wildlife. Wildlife Gardening Forum. Available from: http://www.wlgf.org/garden_resource.html [Accessed December 2020]

UK NEA. 2011. The UK National Ecosystem Assessment - Technical Report. Chapter 20: Status and Changes in the UK's Ecosystems and their Services to Society: Wales. Cambridge: UNEP-WCMC. Available from: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx [Accessed December 2020]

United Nations Environment Programme. 2018. Inclusive Wealth Report 2018. Available from: https://www.unenvironment.org/resources/report/inclusive-wealth-report-2018 [Accessed December 2020]

Welsh Government. 2018. *Brexit & Our Land: Securing the Future of Welsh Farming* [online]. Available from: https://gov.wales/sites/default/files/consultations/2018-07/brexit-and-our-land-consultation-document_0.pdf [Accessed November 2019]

Welsh Government. 2019a. Well-being of Wales Report 2018-19. Report by Statistics for Wales. Available from: https://gov.wales/well-being-wales-2019 [Accessed December 2020]

Welsh Government. 2019b. Farming facts and figures. Report by Statistics for Wales. Available from: https://gov.wales/farming-facts-and-figures-2019 [Accessed October 2020]

Welsh Government. 2019c. Estimates of Housing Need in Wales by Tenure (2018-based), Statistical Article. Statistics Wales. Available from: https://gov.wales/estimates-housing-need-tenure-2018-based. [Accessed December 2020]

Welsh Government. 2019d. Energy Generation in Wales 2018. Available from:https://gov.wales/energy-generation [Accessed June 2020]

Welsh Government. 2019e. Prosperity for all: A low carbon Wales. The Low Carbon Delivery Plan. Available from: https://gov.wales/low-carbon-delivery-plan [Accessed November 2020]

Welsh Government. 2020a. 2018 Wales Greenhouse Gas Emissions. Available from: https://gov.wales/greenhouse-gas-emissions-infographic. [Accessed December 2020]

Welsh Government. 2020b. Energy Generation in Wales 2019. Available from: https://gov.wales/energy-generation-wales-2019 [Accessed December 2020]

Woolmer AP, Syvret M, FitzGerald A. 2011. Restoration of Native Oyster, Ostrea edulis, in South Wales: Options and Approaches. CCW Contract Science Report No: 960, 93 pp.