THE CONTRIBUTION OF LIMESTONES IN IRELAND TO OUR NATURAL CAPITAL

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ABSTRACT

The natural world we live in underpins human existence. It can be thought of as our stock of natural capital that yields flows of goods and services. These goods and services include the basic requirements of daily living – food, water, clean air, etc. Ensuring those services continue to flow for this generation and future generations is one of the fundamental aspects of sustainable development and the keystone of social and economic welfare as highlighted by global initiatives such as the UN 2030 Agenda for Sustainable Development. The INCASE (Irish Natural Capital Accounting for Sustainable Environments) research project aims to apply NCA at a pilot (catchment) scale in Ireland. Developing natural capital accounts at catchment scale will inform how the accounts (asset extent, condition, supply and use of services, benefits, etc.) can be built using Irish data sources and provide valuable lessons on how best to scale up to the national level. Given that NCA is an emerging discipline, the approach is still in development. This paper serves to highlight the key concepts of natural capital and how NCA may be applied in the context of Limestones and their contribution to Ireland's natural capital.

INTRODUCTION

In the Irish context, the EPA State of the Environment Report (Wall *et al.,* 2016) highlights the need to integrate natural capital accounting (NCA, also referred to as *Green Accounting*) into our measures of prosperity so that we can track and measure our performance alongside related issues such as wellbeing and environmental health. NCA brings a range of data sources together relating to 'nature' – from baseline information on *extent* of natural systems, to data on how well these systems are functioning (referred to as their *condition*). Data behind natural capital accounts, as demonstrated in other countries such as the UK (consider '*the aggregate natural capital rule*[1]) and the Netherlands[2], serve as a standardised data platform that can be used in a multi-disciplinary way.

NCA can be used to identify trends in the quality of the environment, inform trade-offs, identify co-benefits, establish critical links between natural and other capitals (such as built and social capital) as well as identifying knowledge gaps. Such an approach can help us to understand and, combined with the use of other appropriate tools, address the dominant pressures and their impacts - climate change, growth in human population, continued degradation of nature - on Ireland's environment. This paper serves to:

- Introduce the basic concept of natural capital, exploring the term from the perspectives of different assets / stocks (ecosystem, geosystem and atmospheric systems); and flows of nature's services;
- Explore the use of NCA in the context of Limestones and their contribution to natural capital in Ireland; *and*
- Highlight some of the research questions to be addressed by the INCASE project in relation to integrating geo-assets and geosystem services into NCA in Ireland (data sources, condition assessment, valuation etc.).

[1] http://www.dieterhelm.co.uk/natural-capital/
[2] https://www.cbs.nl/en-gb/society/nature-and-environment/natural-capital

NATURAL CAPITAL – KEY CONCEPTS

NATURAL CAPITAL THINKING – DRIVERS

The new European *Green Deal* published at the end of 2019[3] specifically aims to protect, conserve and enhance Europe's natural capital, and protect health and wellbeing from environment-related risks and impacts. The *Green Deal* states that: all EU policies should contribute to preserving and restoring Europe's natural capital. In addition, the development of standardised natural capital accounting (NCA) practices is explicitly mentioned as part of the range of initiatives to pursue green finance and investment. In order to understand the context within which natural capital sits, we first need to understand what capital is and the range of capitals that are considered in thinking about economics and human welfare.

NATURAL CAPITAL – THE FOUNDATION OF ALL CAPITALS

The International Integrated Reporting Council defines the term 'capitals' as referring to any store of value that an organisation can use in the production of goods and services, distinguishing six capitals for reporting purposes as illustrated in Figure 1 (IIRC, 2013). All types of capital are needed to support human welfare, and human capital combines with natural capital to create manufactured and/or financial capital. However, as Figure 1 illustrates, all other capitals *rely* on natural capital. This reflects discussions around the Sustainable Development Goals[4], the nested approach clearly defining the role of nature as that which underpins all else. While this is obvious to those working with and in the Natural Sciences, it is a significant change in thinking for other disciplines, especially political and economic schools of thought.

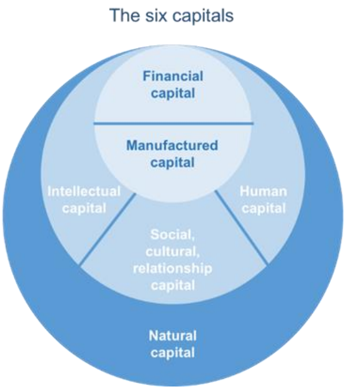

Figure 1. The Six Capitals. Source: https://integratedreporting.org/

DEFINING NATURAL CAPITAL – ASSETS (STOCKS) AND SERVICES (FLOWS)

The term natural capital is now widely used – from academic to business, ecology to economics, international to local levels. The underpinning concepts are nature (everything that occurs naturally – abiotic and biotic components) and capital (stocks or assets). Depending on the perspective of the user and/or the use, for example the desired outcomes of the NCA process (*see later*), the focus may be on biodiversity (e.g. for the purpose of biodiversity under CBD/EU/National targets) or may encompass materials / resources and broader components of nature (e.g. for the purpose of policy and decision making around water/soil resources).

A number of approaches to the classification of natural capital stocks and flows have emerged since the 1990s. These include the Millennium Ecosystem Assessment (MA, 2005), and The Economics of Ecosystems and Biodiversity (TEEB, established in 2008) initiatives which highlighted the importance of recognising the value of natural capital, ecosystem services and the benefits that we receive from nature. In the EU, these initiatives have been built on by the

[3] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[4] https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

EU Mapping and Assessment of Ecosystem Services (MAES) project which has been running since 2011[5] and provides the foundation for the EU approach to classification of ecosystems and ecosystem services (Maes *et al.,* 2013) and subsequent EU approaches to NCA in the form of the EU INCA project (EC, 2019).

For the purposes of the INCASE project, Natural Capital is used in the broadest context as the stock of renewable and non-renewable natural resources, (e.g. plants, animals, air water, soils, minerals) that combine to yield a flow of benefits to people (NCC, 2016)). This reflects the work by van Ree *et al.* (van Ree and van Beukering, 2016; van Ree *et al.,* 2017) (Figure 2) and the work by the UN SEEA-EEA[6] in highlighting the need to broaden the discussion and extend the accounting of natural capital provided by ecosystems to include the role and contributions of geosystems and atmospheric systems (as highlighted in the Catchment Services concept in Figure 3 (Rolston *et al.,* 2017)).

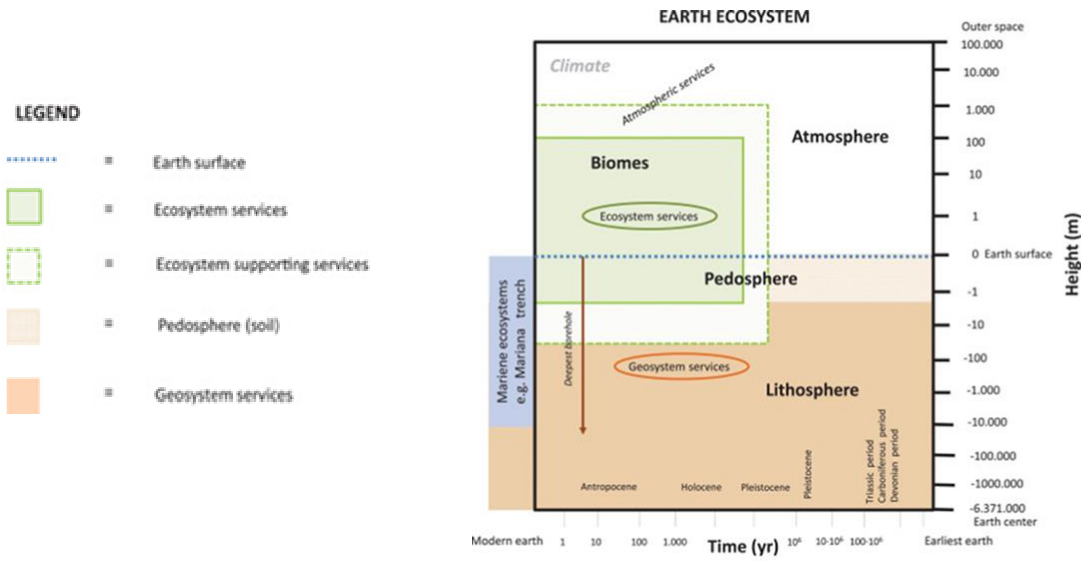

Figure 2: An overview of the temporal and spatial relationships between ecosystems, geosystems and atmospheric systems. The systems are inter-linked and often the boundaries are transitional / not clearly delimited. *Source*: van Ree *at al*. 2016.

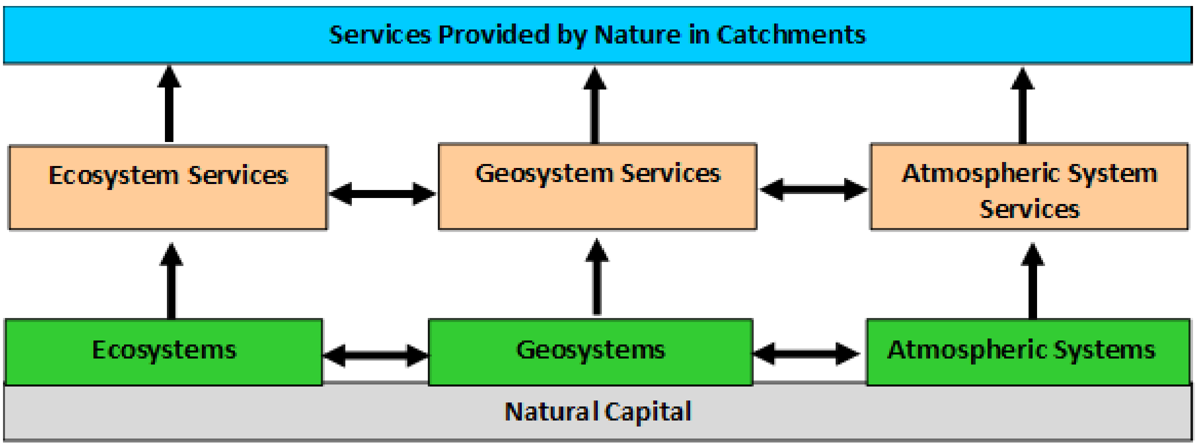

Figure 3. Illustration of the services provided by our Natural Capital and their linkages in a catchment context; adapted from original concept diagram (Daly, 2016).

[5] https://biodiversity.europa.eu/maes
[6] https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision

NATURAL CAPITAL – WELLS OF NATURE'S SERVICES

In a similar way to discussions around natural capital, much of the focus has centred around the role of ecosystems services. Having a clear delineation of the asset, service and benefit is a fundamental requirement for bringing the data into a standardised NCA system and can be challenging in itself given assumptions around services and benefits (*see later*).

There are a number of emerging classifications with the main system in use in Europe being the Common International Classification of Ecosystem Services (CICES) which identifies provisioning, regulating and cultural services at biotic and abiotic levels (Haines-Young and Potschin, 2018). Some services are generally assumed to work within the ecosystem and are not defined as delivering a benefit directly to humans. These are viewed as intermediate, regulating services which are obviously important for the final service delivery. For example, pollination is an intermediate service that leads to the final service of food (provisioning). The main categories of services are outlined as follows:

- *Provisioning services*: services that combine with other capitals to produce food, timber, fish or other 'provisions' such as mineral aggregates;
- *Regulating services* includes those that combine with other capitals to produce flood control, storm protection, water regulation and purification, pollination and climate control. Regulating services are in general less well perceived by humans and include intermediate regulatory services such as pollination, soil formation, primary productivity, and nutrient cycling. These processes and functions are necessary for the delivery of the other services categories[7];
- *Cultural services*: those combined with other capitals to produce recreation, scientific, and other cultural benefits. Landscapes such as the Burren – a product of the interaction of limestone, time, terrestrial ecosystems, atmospheric processes and traditional human management of grazing for agriculture is an example in Ireland . This category is probably the least developed (Chan et al., 2012).

NATURAL CAPITAL ACCOUNTING – TRACKING STOCKS AND FLOWS

SEEA – THE SYSTEM OF ENVIRONMENTAL ECONOMIC ACCOUNTING

From an accounting perspective, defining natural capital as an important and valuable capital or stock brings the discussion around nature into a language more traditionally associated with economics. However, Natural Capital differs from traditional 'capitals', having unique features which relate to the diversity of nature, the complexity of living systems, capacity, condition, non-linearity, feedback loops and resilience. An appropriate asset accounting model is therefore required for the purposes of accounting for natural capital assets and flows; one that can be standardised to allow for comparative and repetitive measurement and reporting at national, regional, catchment, or site/business level.

The main system in development, upon which NCA approaches have formed or have emerged from, is the UN System of Environmental and Economic Accounting, also known as the SEEA[8]. The SEEA is in development since Rio 1992, and works as a set of satellite accounts aligned with the System of National Accounts or SNA, which is collated by the CSO in Ireland and is used to calculate indicators such as Gross Domestic Product (GDP). There are two components of the SEEA: the SEEA-Central Framework (CF) and the SEEA-Experimental Ecosystem Accounting (EEA).

- *The SEEA-CF* covers physical accounts and flows of environmental assets and expenditure with the perspective for measurement purposes on individual environmental assets, such as timber resources, land, mineral and energy resources, and water resources.
- *The SEEA-EEA* is a geospatial approach whereby stocks of natural capital (assets) at a range of scales (e.g. country or catchment scale) are measured. Knowledge of the extent

[7] In general, they are classed as intermediate and not included at an accounting level.
[8] https://seea.un.org/

and condition of natural capital assets allows for integration of the supply and use of services (flows) flowing from nature which are then recorded as benefits to humanity, in an accounting framework.

The SEEA-CF is a statistical standard and reporting is mandatory across the EU since 2011[9]. The SEEA-EEA constitutes an integrated statistical framework for organising biophysical data, complementary to that of the SEEA-CF, although it does not yet have the status of an international statistical standard[10]. Both aspects work together, enabling the tracking of changes in stocks and flows over time.

The SEEA approach, and specifically the SEEA-EEA component, represents initial efforts to define a measurement framework for tracking changes in ecosystems and their outputs, and by extension other natural systems; linking those changes to economic and other human activity by means of the combination of the SEEA-CF and SEEA-EEA accounts. The SEEA-EEA is the main focus of the INCASE project – determining the data requirements and linkages with SEEA-CF accounts being the main focus in terms of establishing and defining the process steps at catchment scale, with a view to scaling up to national level.

ACCOUNTING STEPS IN THE SEEA-EEA

There are four key stages (outlined in Figure 4) in the SEEA-EEA to fully outline geospatial extent, condition and relationships of natural capital assets (*stocks*), as well as accounting for *flows* of services and benefits.

- *Asset extent* – type, range and scale of natural capital assets. The output of this stage is a geo-referenced map, the scale depending on the spatial unit (county, catchment or farm) and an asset register or account (in the form of a table / balance sheet).
- *Asset condition* – quality of the asset. For example, a peatland may be drained, which would be lower condition than one with no drains, which impacts on its capacity to sequester carbon but also its biodiversity. Condition of assets influences the ability of an asset to deliver one or more services and as condition will vary over space and over time, condition mapping is a key spatial component. At this stage, maps showing asset condition and pressures, and a *Risk register* - highlighting areas of degradation - can be developed.
- *Services* – identification of the services, whether within the system or as a product of the system. In the case of a peatland this may be carbon sequestration (a service) or emission (a disservice), and/or water attenuation. Similarly, services may rely on a combination of and the interaction of multiple assets. Mapping services will be a product of the pressures and condition mapping in previous steps, as well as using other relevant geo-spatial data.
- *Benefits* – the benefits to humans and who the beneficiaries are. For example, the benefit may be climate regulation and/or flood control, and the beneficiaries either local or downstream (flood mitigation) or global (reduced carbon emissions to atmosphere). For many services there is a spatial correlation between potential beneficiaries and service availability.

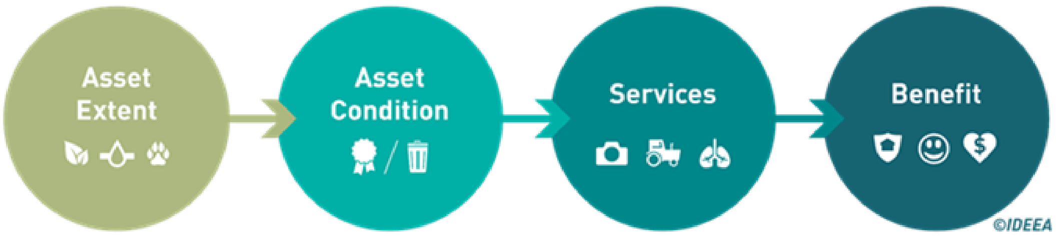

Figure 4. The Core NCA Framework. Source: IDEEA Group.

9 https://www.cso.ie/en/statistics/environmentaccounts/

10 It is anticipated that a revised SEEA EEA will be adopted as an international statistical standard in March 2021.

INCASE – WHAT STOCKS AND FLOWS SHOULD WE CONSIDER?

As part of the INCASE project, we need to map out the different aspects of natural capital present and explore what data sources are available to build the different accounts within the NCA (SEEA) system. For the purposes of the project we will consider all systems – ecosystems, geosystems and atmospheric systems, and determine the feasibility of what can be accounted for with available data over the duration of the project and beyond.

ECOSYSTEMS AND ECOSYSTEM SERVICES

Ecosystems are diverse, depending on the physical environment (consider the contrasting conditions of desert and wetland), and diversity is also a feature within ecosystems (consider two wetlands - a pond and a peatland – comprising different sets of species diversity). Diversity thus is a structural feature of ecosystems, and the diversity among ecosystems is an element of biodiversity (MA, 2005).

Ecosystems are generally defined by characteristic features and/or species and can be variable in size. A range of classification systems exist, and the approach taken to delineate, and map ecosystem units generally depends on the classification system used in a given country and/or region. Work is ongoing in the European Union to develop a common approach to mapping ecosystems for natural capital accounting (EC, 2019). In practice, ecosystems are split into terrestrial and marine ecosystems, with most countries using either Corine Land Cover classes to delineate 'ecosystem asset units' or local classification systems (Maes *et al.,* 2013). In Ireland some work has been carried out by the NPWS in relation to developing a Habitat Asset Register (Parker et al., 2016). For INCASE, building on work in the EU and Ireland, habitats as defined in *The Heritage Council Classification* (Fossitt, 2000) will be most likely used as proxies for the ecosystems.

In regard to ecosystem services, to date a general grouping of 10-12 services have been well developed in terms of their accounting by the EU INCA project. These include food (marine and terrestrial), timber, purification of water, pollination, climate regulation, air purification etc. and largely reflect the availability of data to develop the accounts (EU, 2017). In the SEEA-EEA revision this group has been further developed and a broader range of 25 services are in development in terms of accounting approaches. This provides relatively good coverage of the services of immediate relevance in terms of contribution to human benefits. Note that the contribution of groundwater to ecosystems such as fens, wetlands, turloughs etc. is considered an abiotic component of ecosystems.

GEOSYSTEMS AND GEOSYSTEM SERVICES

Geosystem (van Ree and van Beukering, 2016; van Ree *et al.,* 2017) is defined as the underground environment that consists of subsoil, bedrock, minerals, oil, natural gas and groundwater. Note, it does not include soil and the ecosystem associated with soil, or groundwater that provides the abiotic support to ecosystems such as fens.

Geosystem services are considered as the outputs from geosystems that contribute to human wellbeing specifically resulting from the subsurface, including the flow of natural resources from stocks that have built up over geological time (Figure 2). Examples include aggregates, minerals, energy from fossil fuels, pollutant attenuation provided by subsoils, geological heritage sites, landscape geomorphology including associated cultural values, groundwater used for drinking, geothermal energy (potential) and carbon storage.

ATMOSPHERIC SYSTEMS AND SERVICES

The atmospheric system (Figure 2) is the physical and chemical system in the atmosphere consisting of wind, sunshine and precipitation and the outputs (services) from atmospheric systems that contribute to human wellbeing. Examples of the services include wind energy, solar energy, rainfall.

LIMESTONES AS GEOSYSTEMS

LIMESTONES IN THE IRISH LANDSCAPE

Limestones underlie more than 40% of the land surface of Ireland, including the most populated areas, the main agricultural areas and 75% of the total length of motorway (Drew, 2018). They are a major source of minerals, aggregates and building stone, and they provide some of our outstanding landscapes. Limestone aquifers provide most of the groundwater used for drinking water. Therefore, limestones provide a major component of our geosystem assets and our natural capital.

Applying and developing NCA for geosystem assets requires an understanding of not only the *extent* of limestones in Ireland, but also the *condition* of the limestone asset (pressures and condition indicators), the *services* provided, and the *benefits* received. Following through this logic chain we have developed here a high-level overview with the focus on some of the services or contributions of limestones to Ireland’s Natural Capital, relying on data and discussions in other papers in *these proceedings* and on the Indecon report (IIEC, 2017) to inform the overview. This overview discussion of four geosystem services is a ‘rough cut’ of the approach and will be further developed as part of INCASE.

Services delivered by limestones are discussed briefly here following the outline of asset extent and condition (as relevant to the service), the service itself and the benefit. We outline linkages to other papers in these proceedings and also highlighting further research questions to be answered during the INCASE project work. The services highlighted here[11] are :

- *Provisioning* (groundwater as a drinking source; metallic and non-metallic minerals);
- *Regulatory* (attenuation of pollutants);
- *Cultural* (geological heritage and tourism).

GROUNDWATER AS A DRINKING SOURCE

- *Asset extent*: The extent of limestone aquifers as a drinking source is a key aspect for NCA and is the main indicator for the service (Hunter-Williams, *these Proceedings*).
- *Asset condition*: Service provision will be influenced by pressures such as over-abstraction and contamination by pollutants. For instance, the WFD status results are a possible indicator of asset condition; with 94% of the area of karstic limestone groundwater bodies achieving the good status objective in 2019 (Maher, *these Proceedings*).
- *Services:* A provisioning service – aquifers providing approximately 810,000m^3/d for drinking water. In addition, there are substantial unused resources that have the potential for future use. Unlike in other European countries, there are seldom disservices arising from groundwater abstraction in Ireland due to relatively low level of usage.
- *Benefits*: According to the Indecon Report (2017), more than 160,000 private supplies of drinking water rely on groundwater, over 250 group water schemes (which supply more than 50 people) rely on groundwater and there are over 1,000 public supply wells and springs. The Indecon report puts a price of €0.14 per m^3 used for drinking water, giving a value of €41.3 million annually; while this is for groundwater provided by all aquifers, a high proportion is supplied by limestone aquifers.

METALLIC MINERALS

- *Asset extent*: With the closure of Galmoy and Lisheen mines, Boliden Tara Mines, located in limestones near Navan, is the only remaining lead and zine in Ireland; it is the largest underground zinc mine in Europe (IIEC, 2017).
- *Asset condition*: In the context of minerals, condition is likely to be linked to extent and a quality feature which will be explored during the INCASE project.

[11] More services may be highlighted over the course of INCASE, but in general the services are highlighted because of their obvious contribution to human well-being.

- *Services:* A provisioning service - Tara mines provides a vital source of raw materials. Good management of the mine and the tailing ponds ensure that there are no disservices; the facilities are licensed by the EPA. As part of the INCASE project, consideration will be given to whether potential future services need to be taken into account.
- *Benefits:* The gross added value (GVA) of the lead and zinc sectors was estimated as €230 million (IIEC, 2017)

NON-METALLIC MINERALS

- *Asset extent*: Aggregate potential has been mapped by the GSI and country wide maps are available[12]. In addition, details on the location of active limestone quarries are available in the GSI Quarry Directory[13].
- *Asset condition*: As above – in the context of minerals, condition is likely to be linked to extent and a quality feature which will be explored during the INCASE project.
- *Services:* A provisioning service – limestones provide crushed rock as aggregates and lime (2 million tonnes annually) to improve lime-deficient soils and building stone. Quarries, if not properly managed, can have disservices such as sediment impacting on watercourses and water abstraction impacting on nearby wells and ecosystems.
- *Benefits:* The GVA of the non-metallic extractive industry was estimated at €233 million. (IIEC, 2017). It was not possible to extract the figures for the limestone component for this paper, but undoubtedly it is a substantial proportion to be investigated where relevant by the INCASE project.

GEO-HERITAGE AND TOURISM

- *Asset extent*: The GSI’s Geological Heritage Programme (IGH) in GSI complements other nature conservation efforts by assessing Ireland’s geodiversity, and by producing county reports that include County Geological Sites. Two – the Marble Arch Caves (Cavan/Fermanagh) and the Burren and Cliffs of Moher in Clare – of the three UNESCO geoparks in Ireland are in limestone areas.
- *Asset condition:* As the sites do not yet have a statutory designation, they are not protected, and their asset condition is unknown. Pressures include high visitor numbers in the case of landscapes such as the Burren, pollution of karst springs and damaging of caves.
- *Service:* A cultural service through recreation, tourism, intellectual development, spiritual enrichment, reflection, and creative and aesthetic experiences. In some instances, the geosystem service is closely connected to an archaeological or cultural service, e.g. Hill of Tara and the Rock of Cashel.
- *Benefits:* Research in the UK highlights that the UNESCO label added approx. £2.69 million to the UK economy pa for each UNESCO geopark. The Marble Arch Caves is estimated to generate approximately £17.2 million pa to the surrounding economy. It is estimated that the GVA from geo-heritage (fee-paying and free sites) and geoscience activities such as walking and hiking in Ireland was in the order of €176 million (IIEC, 2017).

SUBSOILS – POLLUTANT ATTENUATION

- *Asset extent:* Subsoils – glacial till, fluvio-glacial sands and gravels, alluvium, peat – cover more than 90% of the Irish landscape and their location, thickness, permeability and groundwater vulnerability have been mapped by the GSI.[14]
- *Asset condition:* As above – in the context of attenuation of pollutants, condition is likely to be linked to extent and a quality feature which will be explored during the INCASE project.
- *Service:* A regulating service – subsoils provide a protecting, filtering layer over groundwater to varying degrees, and this service is encompassed in GSI groundwater vulnerability maps, with vulnerability ranging from ‘extreme’ to ‘low’.

[12] https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=ee8c4c285a49413aa6f1344416dc9956.
[13] https://www.gsi.ie/en-ie/publications/Pages/Quarry-Directory.aspx
[14] https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=7e8a202301594687ab14629a10b748ef

- *Benefits:* There are a range of benefits, for instance, groundwater in high, moderate and low vulnerability areas are less prone to pollution than in extreme areas; and therefore, provides more value in terms of both safe drinking water supplies and the location of infrastructural developments. However, the means of allocating an economic value to this service is unclear and may not be feasible. This will be examined further by the INCASE project.

DISCUSSION

INCASE HIGH LEVEL OBJECTIVES AND RESEARCH QUESTIONS

This paper sets out some of the key concepts around natural capital and the NCA approach. The work is in its development phase in Ireland and the INCASE project will establish the necessary '*learning by doing'* platform and framework from which NCA can be implemented at catchment scale and inform the basis for national scale NCA, either during or beyond the lifetime of the INCASE project as set out in national and EU targets.

Four catchments[15] have been selected for the project and over the course of the research, a number of challenges will be addressed in terms of high-level concepts about NCA. These include discussions around valuation, the efficacy of the approach in general and basic aspects such as data share and data quality. Once the process to build the accounts is established, some of the potential applications of NCA will be explored, including the potential to inform integrated catchment management (ICM) and water quality. The SEEA approach has many parallels in approach to ICM basic principles and they should work well in a complementary way.

NCA AND GEOSYSTEM STOCKS AND FLOWS

With regard to geosystem assets and services, a number of research questions will be addressed through the INCASE project. Input from the geological and hydrogeological community will be necessary to answer these questions, which include:

- How do we classify geosystem assets (extent and type) using best available Irish data? What assets should we include?
- What is the best way to measure condition for different geosystem assets with Irish data? What pressures and/or condition indicators are presently in use? What is used in other countries / studies?
- What are the main geosystem services of focus in the four INCASE catchments and what about nationally?
- What is the best way to determine and measure *flows* (supply and use of services) using available Irish data?
- What are the benefits of focus in four catchments and how do these compare with the national perspective? Who are the beneficiaries? What benefits do they receive? What valuation system (physical, monetary, relative scale) is useful for each flow? What is used in other countries / studies?

CONCLUSIONS

Pioneering methods, tested and refined at catchment level by INCASE, will contribute to scaling up to national level, delivering effective and efficient use of project outputs to be of immediate use to policy makers. Developing a system of NCA fit for purpose will require addressing a range of challenges from high level epistemological ones (can nature fit into accounting methods?) to practical data sharing and quality issues, which requires a multi-disciplinary approach.

[15] https://www.incaseproject.com/catchments

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