Integrating ecosystem service flows with economy wide modelling

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Executive summary

The Scottish government invests significantly in environmental protection and conservation including support for research to understand how its natural assets can contribute to sustainable economic growth. While casual observation confirms the economic contribution of natural assets, there is less agreement on why and how this contribution should be consistently measured. Growth accounting in a sustainable economy requires closer scrutiny of the status of capital stocks and associated service flows. This in turn implies a planned interface and coordination between (a)what ecosystem scientists are measuring providing the data available for accounting; (b) economic and social science methods to reflect changing status and values and crucially, (c) local, national and global feedback loops. To date this interface has been limited, but the Scottish Government Strategic Research Programme provides a context for exploring the scope and limitations of better integration. This deliverable maps the existing methods for data integration and highlights some of the gaps in existing knowledge and its application to policy. The document provides a route map to guide RESAS and CAMARAS partners in terms of the current status of (environmental) wealth and wellbeing measurement and potential future policy directions.

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Glossary

Ecosystem services (ES)	Natural process and the goods and services they provide which provide benefits to people
Natural asset	The stock of assets from nature e.g. trees, soil from which ecosystem services potentially flow
ONS	Office of National Statistics
Natural capital	Used interchangeably with natural asset
Revealed preference	Non-market valuation methods that infer the value of environmental goods from the value of property (hedonic pricing) or cost of time and travel to recreational sites (travel cost). Also known as surrogate markets.
SEEA	United Nations System of Environmental-Economic Accounting are internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics on the environment and its relationship with the economy.
SRP	Strategic Research Program
Stated preference	Non-market valuation methods (e.g. contingent valuation or choice experiments) that ask survey respondents their willingness to pay for changes in provision of environmental goods in hypothetical markets.
TEEB	The Economics of Ecosystem and Biodiversity (http://www.teebweb.org/)
WAVES	Wealth Accounting and the Valuation of Ecosystem Services https://www.wavespartnership.org/

Background & aims

Natural capital is one of a range of capital assets (e.g. financial, human and social) that combine to produce the flows of goods and services that are consumed actively or passively across our economies and societies. The Natural Capital Committee and the UK National Ecosystem Assessment identify that the impact on the performance of the UK economy of changes in natural capital both in the UK and internationally is poorly understood. There is at the very least a research agenda to reconcile models for measuring natural capital with models, frameworks and metrics that describe economic performance and national wellbeing. This deliverable outlines some of the latter, providing an interface between research being undertaken in Strategic Research Programme (SRP, mainly but not uniquely Theme 1 on Natural Assets) and the broader economic growth objectives of the Scottish Government. The deliverable considers some of the key approaches for mainstreaming environmental and ecosystems services in macroeconomic (i.e. growth and wellbeing) metrics and reflects on progress made over the last decade of integrative research. The deliverable accompanies two further reports developed by Fraser of Allander Institute (Comerford 2017a, 2017b), which develop some of the most promising approaches covered here.

Natural Capital and the wider economy

Natural capital (NC) is the stocks of natural assets, and encompasses those elements of nature that directly or indirectly produce value for people, including ecosystems, species, freshwater, land, minerals, air and oceans, as well as natural processes and functions. Ecosystem services (ES) are the flows of benefits that are generated by these natural assets. Conceptualising nature in stock and flow terms is analogous to accounting protocols for measuring conventional (i.e. monetary) capital at different scales (e.g. country, region, business or household), and permits use of further analogous metrics including gross and net capital accumulation, depreciation, saving and interest rates, capital substitutability (for maintaining wellbeing and resilience) and income and employment multipliers. The links between growth and wellbeing are also debated in this context; specifically any correspondence or misalignment between (monetary) economic growth and wellbeing.

Once confined to economists and national accountants, this rhetoric has gained traction in the ecological and conservation communities with the formulation of an Ecosystem Approach or framework that provides a way of examining the interaction between ecosystems and human well-being. Over the last two decades these metrics have become more mainstream in environmental planning and policy arenas including the Millennium Ecosystem Assessment (MEA), UK National Ecosystem Assessment (UKNEA), UK Natural Capital Committee, TEEB and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES). While Scottish and UK governments have addressed elements of adjusted growth accounting, efforts at consensus on what to measure is largely lacking.

The MEA and the UKNEA highlighted the relevance of economic valuation to the Ecosystems Approach, and (in the UK) non-market valuation methods have been applied extensively to ES categories to inform microeconomic decision-making in the context of cost-benefit analysis (or Regulatory Impact Assessment), and in some cases the design of market-based instruments. However, there is a conspicuous gap in knowledge between ES modelling and formal numerical macro models of economic performance (Anger et al. 2014). Despite various national (e.g. ONS 2012) and international initiatives (e.g. SEEA 2013, WAVES, TEEB), inadequate progress has been

made in developing the interface between ES values and economy-wide modelling that can be used to inform macroeconomic decision-making at national and regional scales.

Moreover, there are still fundamental gaps in knowledge about how ES are provided, the magnitude of their benefits, and how human activities affect their provision. Many of these knowledge gaps arise because previous studies have treated the components of the NC system independently, thereby ignoring important feedbacks and interactions (e.g. Zulian et al. 2013). Such interactions are important since changes in one system component can affect another, either directly, e.g. changes in land use affect regional hydrology or biodiversity; or indirectly through policy, e.g. measures designed for coastal flood defence also impact on coastal habitat (Harrison et al. 2013; 2015; Holman et al. 2014).

Other more subtle interactions are even more poorly understood and documented. For example, investment in landscapes and clean air generates non-market value that might be measured in terms of started or revealed preferences, values that can have an identifiable monetary value. However, improving these capitals may also improve labour productivity and mental wellbeing, values that are less explicitly identified as service flows in national growth metrics. It is important to clarify at least in theory how formal economic approaches might seek to accommodate these flows.

NC is under threat from many pressures, particularly climate change, population growth, and changing societal expectations for quality of life and wealth, which lead to increasing pressure on resources. Such pressures also interact with each other and the NC system in potentially complex non-additive ways. Furthermore, as noted they impact directly and indirectly on economic sectors both increasing and reducing the explicit and implicit costs of production. Ignoring such interactions and feedbacks can lead to either over- or under-estimation of the effects of policy interventions on both the value of ecosystem services themselves and their contribution to economic performance.

Research should ideally aim to bridge the gap between the science of ES provision on the one hand and the development of growth metrics on the other, with the ultimate goal of developing an interface through integrated models that can dynamically couple the multiple components that influence growth. For example, to understand agricultural natural capital systems subject to multiple external stressors needs a clear pathway to link capital stocks, service flows to all measureable outputs from a defined unit of provision (e.g. a farm or region). An appropriate model could enable policy and decision makers to quantitatively evaluate the response of that system to actual or hypothetical changes in the external stressors.

Currently this ambition is not widespread and the number of practitioners that span both areas of interest is small. The current state of the art in this area is disjointed. On the one hand we have a community of scientists studying ecosystem models and the generation of services that can have an economic or social value. On the other hand a community of economic modellers are seeking ways to incorporate this (largely non-market) information into formal models of economic growth and performance. This represents a compelling science policy interface for which there is considerable demand from government. Agriculture is a sector that has a big influence on the flow of ecosystem services and it would be a valuable advance to include them more systematically in economic models.

Mainstreaming and policy

The UK experience in environmental valuation and mainstreaming this globally advanced with the Treasury Green Book, and work of the ONS setting out robust approaches on the use of non-market data in official appraisal and growth accounting methods.

The importance of the natural environment and ecosystem services for sustainable economic growth was recognised in the UK Government's White Paper on "The Natural Choice: securing the value of nature" (2011). It also acknowledged the economic and social benefits of a healthy natural environment and committed to putting natural capital at the centre of economic thinking. Moreover, the formation of the Natural Capital Committee has led to closer scrutiny of methodologies to integrate ecosystem services with economic models that measure growth and related economic variables. Reports on the state of natural capital and ecosystem services (albeit in England) have further emphasised the need to:

- halt the decline in species and habitats and to properly value our natural capital[1];
- use natural capital sustainably and improve it in order to maximise economic benefits, while having a long-term plan which will deliver well-being and economic growth[2];
- foster better economic valuation of natural capital for decision-making, identify the natural assets and benefits at greatest risk, and develop a new 25 year strategy[3].

Similar aims are evident in devolved administration documents, such as the Welsh Government's Natural Environment Framework[4] and the Scottish Government's Natural Capital Index and its Biodiversity Strategy to 2020[5]. More generally the UK Government has indicated an ambition to be the first generation to leave the natural environment of England in a better state than it inherited; a sentiment that is in line with work in Wales and Scotland, as well as achieving sustainable economic growth.

Previous key events such as the Stern Review of the Economics of Climate Change (2006) showed that the UK is willing to test the limits of environmental economic analysis at a global scale, thereby playing an important advocacy role in addressing both market and information failures. This is noteworthy since it is important that any sustainability metrics seek to incorporate the UK's international footprint from trade.

The UK Natural Capital Committee has stressed the need for more research on coupled modelling linking ecosystem service values and economic performance. Further, The UK National Ecosystem Assessment follow on project (Anger et al 2014) reviewed previous work exploring the interface between ecosystem services and the macro economy aggregates and observed the need to map and substantiate the links between key resource using sectors. It also notes that no one existing approach is adequate to deal with the complex interactions between ecosystems and the macro

[1] https://nebula.wsimg.com/17ce16211194bfe53215bb754444686d?AccessKeyId=68F83A8E994328D64D3D&disposition=0&alloworigin=1
[2] Op.cit.
[3] Op.cit.
[4] http://www.werh.org/natural-environment-framework.php.en
[5] http://www.gov.scot/Publications/2013/06/5538/5

economy but that "greening the existing macroeconomic (and in some cases micro) techniques is probably the way forward". The objective here is to clarify these techniques as a basis for further exploration of options to link Theme 1 with the input of the HEI partner Fraser of Allander Institute and to undertake further exploratory projects in this area both nationally and internationally.

Arguably this ambition can only be fulfilled by qualitative and quantitative monitoring and the development of appropriate metrics discussed here.

Options for mainstreaming

There is a large literature detailing both the theoretical and applied experience with non- market valuation and its role in macroeconomic mainstreaming, and separately the developing economy wide impact assessment. The joint literature is more limited. Rather than review these sources Annex Table 1 provides a technical chronology of the state of the art as it applies in Scotland (i.e. existing work and applications), or as proposed internationally as part of the recognised approaches to mainstreaming. The Table represents an ambition for future research in Scotland to further the use of integrated environmental-economic modelling. It offers a trajectory of ambition that progresses from highly static and partial reflection of environmental stock and service/flow value through to more dynamic in terms of economy wide inter linkages and spatial/inter temporal feedbacks. A general conclusion is that this needs to go beyond existing CGE models to incorporate the flexibility offered by bespoke model integration allowing for the ability to reflect environmental change in factor (e.g. labour) productivity. One option is to develop more agent based rules for understanding how environmental change feed back into resource use decisions. Such models have been proposed and imply increasing sophistication in the way we integrate biophysical functions into economic models. They also imply and can exploit increasing computational power to address both stochastic and uncertainty in key relationships.

Route map

As a way forward we suggest developing a framework for stress prioritising endogenous or exogenous shocks that can affect natural capital stocks and service flows in in Scotland. In other words we would seeks to establish (possibly with RESAS staff and other private sector stakeholders) a hierarchy of scenarios that are likely to influence the main capital stocks over a plausible time horizon for modelling economic data. These environmental change scenarios could focus initially on the agricultural sector (Figure 1) and would then provide a basis for quantities economic modelling of the direct and indirect effects of stock and flow changes on economic growth building

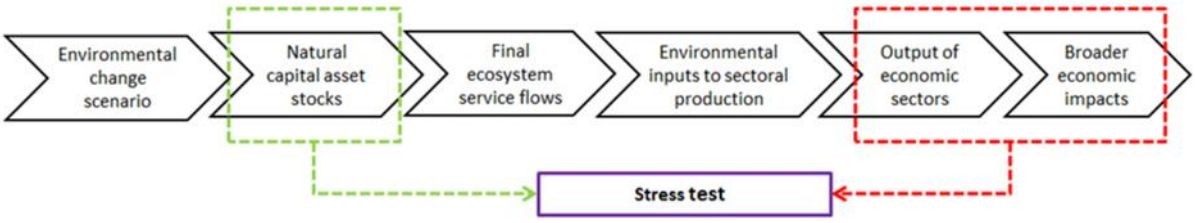

Figure 1 Dynamic recursive model would develop feedback from domestic land use decisions

Figure 2 depicts a structure for a bespoke model of relevant interfaces between the ecosystem services and economic modelling. In the latter we include both non-market valuation and economy-

wide modelling, which in turn provides direct and indirect drivers to land use, i.e. change decision makers who can be assumed to behave as economically rational agents or according to alternative behavioural rules and heuristics modelled using agent-based or other Bayesian methods. Making the model recursive - representing the relationship between land use and ecosystem services as a series of time steps - allows for the more general set of feedbacks to be captured through time.

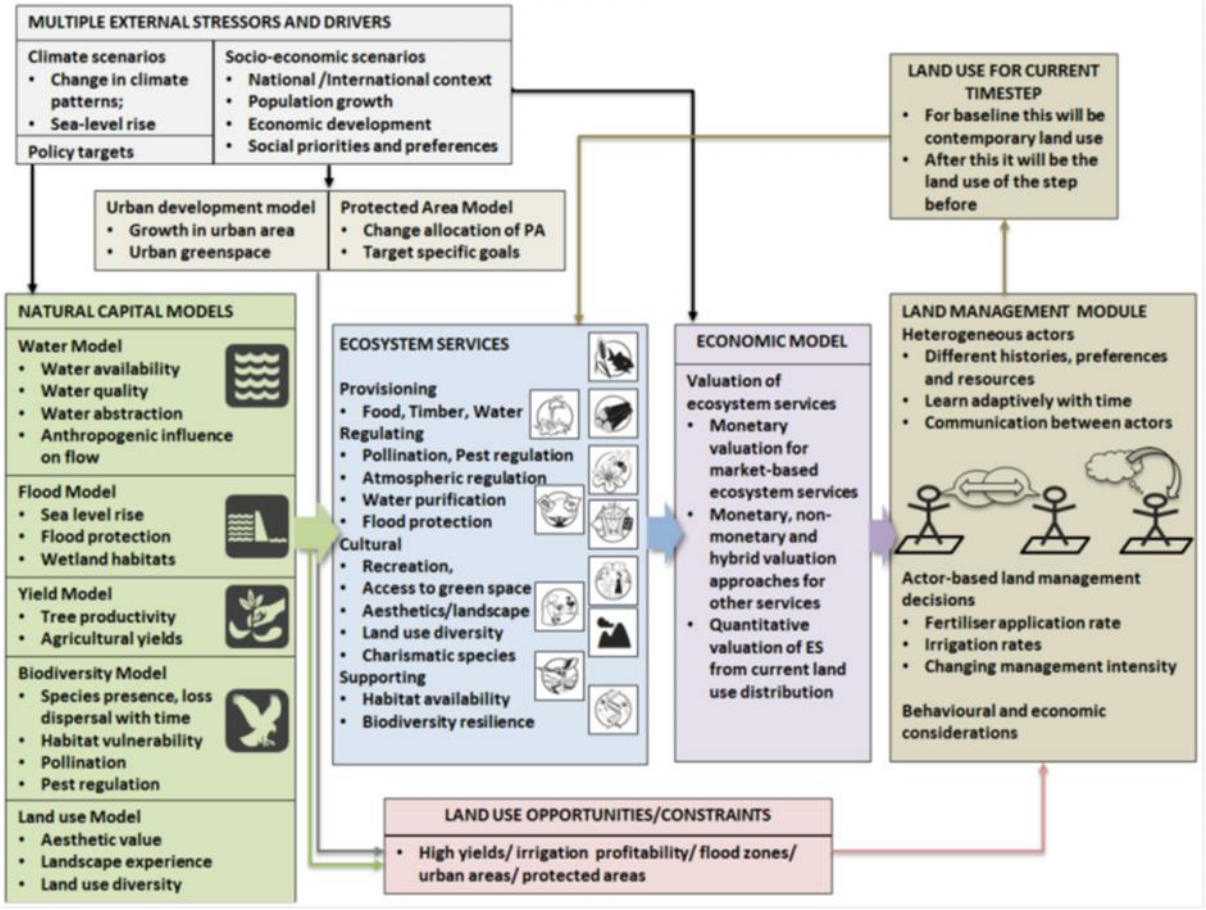

Figure 2 Combining modelling components for a bespoke representation of natural capital in growth.

Subjective wellbeing

Alongside adjusted growth there has been more recent interest in the use of self-reported subjective wellbeing and its link to both valuing environmental change and as complementary to growth reporting.

Using a life satisfaction approach (e.g. Frey et al 2009) subjective wellbeing scores can serve as an empirical approximation to individual welfare. If this interpretation of subjective well-being measures is accepted, it becomes straightforward to value environmental goods: Environmental conditions can be taken into account in micro-econometric life satisfaction functions along with income and other covariates. While wellbeing research can arguably improve valuation approaches the use of subjective scores can also potentially side step the modelling complexities of seeking to

detect indirect environmental impacts in say labour productivity data. Instead, it may simply be more straightforward to elicit information from respondents directly. To date however, there have not been any empirical exercises attempting this. Nor has there been any investigation of how subjective wellbeing data might be used directly to adjust conventional growth metrics.

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TABLE A1

Indicator/model	Purpose	Application in Scotland	Comment
Qualitative/quantitative indices	Monitoring capital stocks and implicitly flows Nationally or internationally to account for global impacts of domestic consumption	Scotland's Natural Capital Asset Index http://www.snh.gov.uk/docs/B814140.pdf Variants of (static) global footprint estimates - see also under I-O below Often based on Common International Classification of Ecosystem Services (http://cices.eu/)	As with all indices weighting is key and Previous review of index http://www.snh.org.uk/pdfs/publications/commissioned_reports/751.pdf Some limitations in terms of policy relevance (i.e. often does not seek to clarify drivers).
Satellite physical accounts	Physical data sitting alongside monetary accounts. Year on year monitoring of opening and closing stocks plus service flows where measurable	Existing data sets of different resolution - particular strengths in soil monitoring, land cover and class. Existing environmental accounting frameworks for agriculture (Jacobs and SAC, 2008 and ONS environmental accounts for farmland) https://www.ons.gov.uk/economy/environmentalaccounts/articles/uknaturalcapitalfreshwaterecosystemassetsandservicesaccounts/2015-03-20 Coastal accounts: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/scopingukcoastalmarginecosystemaccounts	May be constructed from index data sources. Enable further measures of capital accumulation/ depreciation and further questions on capital substitutability.
Monetary valuation	Revealed and stated preference approaches applied to key capital stocks and value flows	A large body of valuation studies particularly in relation to agri environmental landscapes/impacts and water bodies. The Defra Environmental Look-up (EVL) tables being considered for use in SRP 1.4	Aside carbon valuation (shadow price), limited attempt at systematic coverage/prioritisation or the development of a national inventory to address key questions on valuing marginal changes and trade-offs linked to land use change scenarios including those related to climate change
Integrated monetary accounts	Combining satellite accounts with monetary valuation. Static monetary accounts at corporate, sector or national scale adjusting economic bottom line (e.g. adjusted GDP or net corporate revenue.	Regional variants of various UK exercises conducted by ONS and E.g. Jacobs/SAC (2008), National parks: http://sciencesearch.defra.gov.uk/Document.aspx?Document=13496_TheBroadsNationalParkSummaryReport.pdf Vellinga et al (2014)	Updating but static information but do not accommodate direct/indirect feedbacks and international impacts
Augmented Input-Output /Social	Economy (nation or region)-wide Leontief matrix	Several applications based on I-O tables developed by Fraser of Allander Institute (FAI) - e.g. to	Natural capital sectors (e.g. forestry) explicitly or implicitly included in matrices but to date only exploratory work on

Accounting Matrices	coefficients showing sector by sector exchange relations in terms of key economic metrics of income, output and expenditure. Can be augmented for carbon or water exchange but as yet no other environmental services	evaluate carbon intensity of domestic Scottish production compared to the same for overall consumption	adding other environmental "sectors".
Partial or (computable) General Equilibrium modelling	Dynamic economy-wide modelling. Economy-wide extensions of I-O to include more global impacts - e.g. price responses in response to supply demand shocks	Best example is AMOSENVI - 25 sector CGE model of the Scottish Economy http://www.gov.scot/Publications/2008/11/13110942/4 Developed by FAI See also Bosello et al (2011) for exploratory work	Can be used to consider environmental shocks interpreted as exogenous shifts in productivity, changes in endowments, international income transfers or variations in demand structure, technology and preferences. Interesting questions on which other environmental drivers can influence productivity or consumption behaviours. Can be used to understand the direct and indirect effects of international trade (hence changes in global prices and quantities)
Bespoke model integration	Linking changes in capital stocks to wellbeing including direct and indirect effects not capturable through I-O or CGE architectures	None as yet – likely to be augmented partial or general equilibrium analysis relaxing behavioural assumptions most likely use to augment indirect effects not captured in Some suggestions in Binner, A et al (2017)	Could relax neoclassical models using Agent-based elements
Subjective wellbeing research	Self-reported wellbeing data generated by mixed quantities and qualitative surveys	Gilbert et al (2016) Regionalised data for UK-wide surveys e.g.	Essentially side-steps data and empirical modelling The Life Satisfaction Approach to valuation Opens up the issue of production versus consumption???