Carbon and Ecosystem accounting

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Author: Michael Vardon[1]

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[1] *The views and opinions expressed in this report are those of the author and do not necessarily reflect the official policy or position of the United Nations or the Government of Norway.*

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Contents

1 Introduction

1. This note summaries conceptual and methodological material related to carbon in the context of the development and application of the System of Environmental-Economic Accounting– Experimental Ecosystem Accounting (SEEA-EEA). The SEEA-EEA was presented to the United Nations Statistical Commission at its 44th Session in 2013. The report of the 44th Session "welcomed" the SEEA-EEA and "encouraged its use by international and regional agencies and countries"[2].

2. This note provides countries and agencies embarking on a program of ecosystem accounting with a starting point for the development of accounts relating to carbon. Carbon has an important place in the ecosystem, many other environmental processes and economic activity. The extensive role of carbon in the environment and the economy requires a comprehensive approach to measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon from the perspectives of the geosphere, the biosphere, the atmosphere, oceans and the economy.

3. While much progress has been made with carbon accounting and the SEEA-EEA provides a clear and effective starting point, carbon accounting is still in its infancy. As such, those wanting to produce carbon accounts will have to confront a variety of theoretical and practical issues. Carbon accounting is specifically mentioned in the SEEA-EEA research agenda and a number of issues are highlighted in this note under the heading "Issues for Resolution" (Section 7). One function of this note is to make potential users and compilers of carbon accounts aware of these issues so that through their work they may be addressed and part of the on-going development of both carbon and ecosystem accounting.

4. The London Group on Environmental Accounting[3] has provides a forum for the development of carbon accounting. Over the past few years a range of papers have been presented (e.g. Muukkonen 2010; Van Rossum and Schenue 2011; Weber 2011; Obst 2012; Comisari et al. 2013, Ajani and Comisari 2014; Ivanov 2014). In additions, the meetings leading up to the publication of the SEEA-EEA, which involved many members of the London Group, also provided a forum for discussion of carbon accounting (e.g. Ajani 2011; Gundimeda 2011; Ivanov et al. 2011; Muukkonen 2011).

1.1 The carbon cycle

5. Figure 1 presents the main elements of the carbon cycle. It is these stocks and flows that give the underlying context for carbon accounting. Of particular relevance are the qualitative differences between the different stores of carbon. For example as a gas (e.g. carbon dioxide and methane), liquid (e.g. oil) or solid (e.g. coal, timber or diamonds) forms as well as in living and inert forms. Accounting for carbon in the context of ecosystem accounting must take these differences into account.

6. The SEEA-EEA includes carbon accounting in three contexts:
   - Carbon as an asset (Section 4.4 and Table 4.6, pp 92-96)
   - Carbon related ecosystem services - sequestering of carbon and carbon storage (Table 3.2 p. 59, Paragraphs A3.16 to A3.19 and Figure A3.4, pp. 70-71)

[2] UN Statistical Commission Report of the forty-fourths session (26 February-1 March 2013), Page 10. http://unstats.un.org/unsd/statcom/doc13/2013-Report-E.pdf

[3] See London Group on environmental Accounting: http://unstats.un.org/unsd/envaccounting/londongroup/

- Carbon as a characteristic of ecosystem asset condition (Section 4.3 and Tables 4.3 and 4.4)

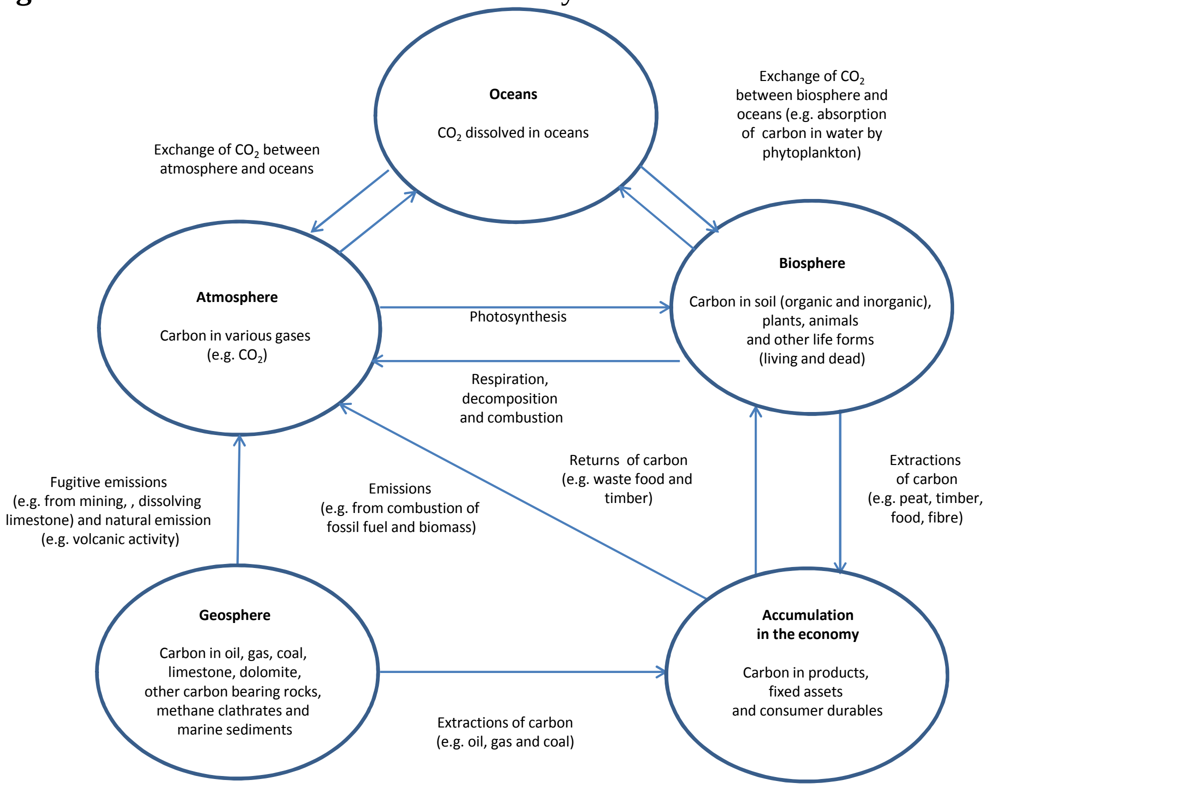
7. This note outlines the basic concepts of carbon in the SEEA-EEA and provides information on data sources and methods as well as a link to additional material to aid in the construction of accounts for carbon.

1.2 Carbon accounts – applications

8. Accounting for carbon can assist in a wide range of analytical and policy situations at any point in the carbon cycle shown in in Fig. 1. For example, carbon stock accounts can complement the existing flow inventories developed under the UNFCCC (UN Framework Convention on Climate Change) and the Kyoto Protocol with information on the stocks of carbon and how they are used and managed. Carbon accounting has been directly linked to policies aimed at climate change mitigation (see Ajani et al. 2013)

9. Carbon stock accounts provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems (i.e. maintaining carbon stocks in the biosphere). Combined with measures of carbon carrying capacity[4] and land use history, carbon stock accounts for the biosphere can be used to:
   - Investigate the depletion of carbon stocks due to the conversion of natural ecosystems to other land uses;
   - Prioritise land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration or improved land management with their differing trade-offs against food, fibre and wood production, and;
   - Identify land uses that result in temporary carbon removal and storage.

Figure 1. The main elements of the carbon cycle



[4] The mass of biocarbon able to be stored in the ecosystem under prevailing environmental conditions and disturbance regimes, excluding human disturbance (Gupta and Rao 1994).

Source: SEEA-Experimental Ecosystem Accounting, Figure 4.1 (p. 93)

10. The carbon accounts of the SEEA-EEA can also support many international initiatives. For example, accounts for stocks and flows of biocarbon (the carbon occurring in the biosphere as living and dead biomass) align with the accounting approach of REDD (Reducing Emissions from Deforestation and Degradation[5]). They also enable physical and monetary measures of carbon to be integrated with the System of National Accounts and the Strategic Plan for Biodiversity 2011-2020[6] and in particular contributing to Target 2.

11. Various indicators can be derived directly from carbon stock accounts or in combination with other information, such as land cover, land use, population, and industry value added. The suite of indicators can provide a rich information source for policy makers, researchers and the public. For example, comparing the actual carbon stock of different ecosystems with their carbon carrying capacities can inform land use decision making where there are competing uses of land for food and fibre production.

12. An important indicator that can be derived from the carbon stock account is the 'net carbon balance'. This indicator relates to the change in the stock of carbon in selected reservoirs (carbon stores) over an accounting period. The focus of net carbon balance measures is usually on biocarbon. However, depending on the analysis the net carbon balance may also include parts of geocarbon, carbon in the economy and other reservoirs.

1.3 Terminology

13. The terminology used in this note is the same as that found in the SEEA-EEA. These terms are defined in the text below as appropriate. In some cases terms are used before they are defined, as in the introduction. This is done to make the document as easy as possible to read. Reference should be made to glossary of the SEEA-EEA[7].

14. Two terms used in relation to carbon accounting that deserve special mention are *net carbon balance* and *net primary production*. Neither term is used in the SEEA EEA carbon stock account. The terms are however are often used elsewhere where "net" is the total additions minus the total reductions. Both terms apply to biocarbon stocks and indicate the net amount of biomass accumulated by plants in a given period of time, usually a year. It should be noted that total carbon stocks for the globe are fixed and any changes that occur are between the various stocks (i.e. geocarbon, biocarbon, atmosphere, oceans and the accumulations in the economy).

1.4 Structure of this note

15. This note is composed of 8 Sections and an Annex. Section 1 is the introduction. Section 2 is on accounts for carbon stocks (or assets), Section 3 is on the ecosystem services related to carbon – sequestration of carbon and carbon storage. Section 4 is on the treatment of carbon in the SEEA Central Framework as well as on carbon as an indicator of ecosystem condition. Carbons role in assessing ecosystem condition and capacity is dealt with only briefly, with the broader issue of ecosystem condition and capacity dealt with in a separate note.

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[5] See UN-REDD Programme. http://www.un-redd.org/

[6] See Convention on Biological Diversity (http://www.cbd.int/sp/) and Target 2 Quick Guide. http://www.cbd.int/sp/targets/rationale/target-2/

[7] See SEEA-EEA, pages 159-169, http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf

16. Section 5 is on data sources and methods that can be used to populate accounts for carbon and in particular the carbon stock account. Section 6 provides additional reference material and links to other ecosystem accounting initiatives. Section 7 is a summary of the issues in relation to carbon accounting which require further testing and ultimately resolution. The note concludes with Section 8, the references. Referencing is by author date and where they exist links to publically accessible websites are provided. Annex 1 is an excerpt from the SEEA-EEA providing additional detail on the definitions of the entries and classifications used for the SEEA-EEA carbon stock account.

2 Carbon Stock Account

17. The carbon stock account of the SEEA EEA is a basic resource account following the general structure of the natural resource accounts for the SEEA Central Framework[8]. Carbon stock accounts record the stock changes due to human activities (e.g. extraction of oil, felling of timber) and natural causes (e.g. volcanic eruptions) in the geosphere, biosphere and various anthropogenic stocks (e.g. inventories of oil in storage; concrete in fixed assets; wood and plastic in consumer durables; solid waste – i.e. residuals that remain in the economy in controlled land fill sites; imports and exports). The accounts include the residual flows to the environment, including carbon dioxide emissions to the atmosphere.

18. The structure of a carbon stock account in the SEEA-EEA is show in Table 1. The row entries in the account follow the basic form of the asset account in the SEEA Central Framework: opening stock, additions, reductions and closing stock. Opening and closing stocks of carbon are recorded with the various changes between the beginning and end of the accounting period. These are recorded as either additions to the stock or reductions in the stock due to natural causes (natural expansion or contraction), human activities (managed expansion and contraction) as well as changes in knowledge (discoveries, upwards and downwards reappraisal and reclassifications). Additional rows for imports and exports are also included, making the table a stock account. Details on the types of additions and reductions described in the carbon stock accounts are included as Annex 1 of this document.

19. Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils). Geocarbon is further disaggregated into: oil, gas, and coal resources (fossil fuels); rocks (primarily limestone); and minerals (e.g. carbonate rocks used in cement production, methane clathrates and marine sediments). Biocarbon is further classified by the type of ecosystem that it occurs in, which at the highest level these are terrestrial, aquatic and marine ecosystems. These higher level classifications can be further disaggregated (e.g. terrestrial ecosystems could be further divided in to forests, grassland, cropland, etc.). Within the ecosystems the carbon can be found in above and below ground in biomass, include soil carbon.

20. The reservoirs of carbon in the geosphere and biosphere differ in important ways, namely in the amount, their capacity to be restored and the time required for restoration. Different reservoirs therefore have different degrees of effect on atmospheric carbon dioxide levels (Prentice et al. 2007). Carbon stocks in the geosphere are generally stable in the absence of human activity but once extracted cannot be returned except in geological timescales. For example coal and oil take millions of year to form.

21. The stability of the carbon stocks in the biosphere depends significantly on ecosystem characteristics. In natural ecosystems, biodiversity underpins the stability of carbon stocks by bestowing resilience and the capacity to adapt and self-regenerate (Secretariat of the Convention on Biological Diversity 2009). Stability confers longevity and hence the capacity for natural

[8] See SEEA Central Framework, pages 139-142, including Table 5.2.
http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf

ecosystems to accumulate large amounts of carbon over centuries to millennia, for example in the woody stems of old trees and in soil (Ajani and Comisari 2014). Semi-modified and highly modified ecosystems are generally less resilient and less stable (Thompson et al. 2009). These modified ecosystems therefore accumulate smaller carbon stocks, particularly if the land is used for agriculture where the plants are harvested or grazed regularly.

22. A key aspect for carbon accounting is understanding the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, for example, natural ecosystems, semi-natural ecosystems, and agricultural ecosystems. Such detail is important for linking to potential policy mechanisms for particular industries, such as agriculture and forestry. Details on how these types of ecosystems may be defined is found in Annex 1.

3 Ecosystem services –carbon sequestration and carbon storage

23. The SEEA-EEA describes the ecosystem services of carbon sequestering and carbon storage (Annex A3.1, paras A3.16 – A3.19, pp 70-71). These two services are the most common types of services included in academic papers on ecosystem services. For example, in a review of 70 papers on ecosystem services by Martinez-Harms and Balvanera (2012), carbon storage was the most common service included and was measured in 13 studies (or 19%) while carbon sequestration was the equal next most measured service being in 11 studies (or 16%). Similar results were found in reviews by Crossman et al. (2013) and Egoh et al. (2012).

24. The release of carbon stored in biomass whether it be above ground (in trees and other vegetation) or in below ground stocks, such as peatlands, is an important source of greenhouse gas emissions worldwide. It is also the subject of much debate in the international arena, in particular with regards to the REDD (Reduced Emissions from Deforestation and Degradation) payment mechanism. The sequestration of carbon is the ongoing accumulation of carbon due to ecosystem processes which remove carbon dioxide from the atmosphere via photosynthesis.

25. The sequestering of carbon and carbon storage are service flows that can only have positive values. In both cases the flows are expressed as tons of carbon (equivalent) per year for spatially defined areas. The service of sequestering of carbon is equal to the net accumulation of carbon in an ecosystem due to growth of the vegetation and due to accumulation in below ground carbon reservoirs.

26. Figure 2 shows the ecosystem service of sequestration of carbon. Ecosystem management generally affects the level of sequestration and/or the storage of carbon in the soil. The enabling factor for this service is the occurrence of climate change, which causes carbon sequestration and storage to provide benefits resulting from avoided damages, both now and in the future.

27. As noted in the SEEA-EEA, the services of sequestering of carbon and carbon storage are often combined in presentations and are usually identified as a single service of carbon sequestration. However, it is important to recognise that these are different, albeit linked, services and both are important for ecosystem management and ecosystem accounting.

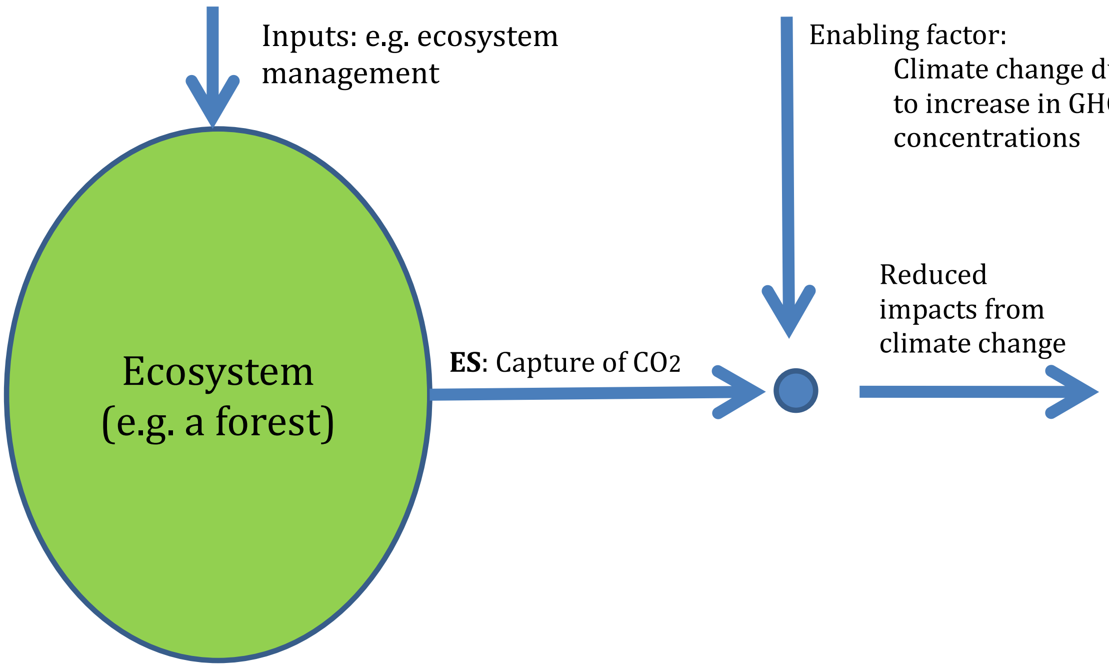
28. The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of above ground and below ground carbon sequestered in the ecosystem. As such it is necessary to calculate the avoided flow needed to measure the carbon storage ecosystem system. The avoided emissions only relate to the part of the stored carbon that is at clear risk of being released in the short term due to land use changes (conversion of forest to agricultural land, natural processes (e.g. fire) or other factors. No ecosystem service flow is recorded if the carbon stocks at risk of being released are actually released, but positive service flows are recorded where carbon stocks at risk remain in storage.

Table 1. Carbon stock account

Gigagrams carbon (GgC)		Geocarbon					Biocarbon			Atmosphere	Water in Oceans	Accumulation in economy				TOTAL
		Lime stone	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories *	Fixed assets	Consumer durables	Waste	
Opening stock																
Additions to stock																
	Natural expansion															
	Managed expansion															
	Discoveries															
	Upwards reappraisals															
	Reclassifications															
	Total additions to stock															
Reductions in stock																
	Natural contraction															
	Managed contraction															
	Downwards reappraisals															
	Reclassifications															
Total reductions in stock																
Imports and exports																
	Imports															
	Exports															
Closing stock																

*Excludes inventories included in biocarbon (e.g. plantation forests, orchards, livestock, etc)

Figure 2. Sequestering of carbon



Source: SEEA-EEA, Fig. A3.4, p. 71

4 Carbon in the SEEA Central Framework and as a characteristic of ecosystem condition

29. In addition to the carbon stock accounts and the ecosystem services of carbon sequestration and carbon storage, carbon is a characteristic of ecosystem condition, while the SEEA-Central Framework includes carbon related accounts (e.g. in subsoil asset accounts for oil and coal). These aspects of carbon accounting are not the primary focus of this note but are summarised briefly below for completeness.

4.1 Carbon in the SEEA Central Framework

30. In addition to the carbon specific aspects of assets and services covered in the SEEA-EEA, there are important links to the accounts of the SEEA Central Framework for:
- Energy;
- Carbon dioxide emissions;
- Subsoil assets and;
- Land cover and forests.

31. Reference material on the concepts and structure of these accounts can be found in the SEEA Central Framework, while a range of additional reference material relating to the theory practice of producing accounts exists or is in development (Table 2).

Table 2. Reference material for accounts and statistics related to carbon in the SEEA Central Framework

SEEA Central framework account	**Reference material**
Energy	SEEA Energy http://unstats.un.org/unsd/envaccounting/seeae/ International Recommendations for Energy Statistics http://unstats.un.org/unsd/energy/ires/default.htm Energy Statistics Compilers Manual. http://unstats.un.org/unsd/energy/ESCM.htm Key Energy Statistics 2014 http://www.iea.org/publications/freepublications/publication/KeyWorld2014.pdf UN Energy Statistics Yearbook. http://unstats.un.org/unsd/energy/yearbook/default.htm
Carbon dioxide emissions	IPCC Reporting http://www.ipcc.ch/report/ar5/ Emissions Database for Global Atmospheric Research (EDGAR) http://gcmd.nasa.gov/records/GCMD_EDGAR_RIVM.html See also Section 5 below
Subsoil assets	European Commission (2000). Accounts for subsoil assets. http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-00-853/EN/KS-31-00-853-EN.PDF European Commission (2003). Subsoil asset accounts for oil and gas - Guidelines for the set of standard tables. http://unstats.un.org/unsd/envaccounting/ceea/archive/Energy/Eurostat_Guidelines_Jan2003.PDF BEA (2000). Accounting for Subsoil mineral resources. http://www.bea.gov/scb/pdf/national/niparel/2000/0200srm.pdf
Land cover, forests ad timber	FAO-Forestry http://www.fao.org/forestry/en/ Forest Accounting for Development. https://www.wavespartnership.org/sites/waves/files/documents/Forestry-Brochure.pdf Improving the Forests Database to Support Sustainable Forest Management http://profor.info/sites/profor.info/files/docs/Forest%20Wealth_WEB_08%2005.pdf

4.2 Carbon and ecosystem condition and capacity

32. Ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics. Measures of ecosystem condition are generally combined with measures of ecosystem extent (e.g. in ha or km^2) to provide an overall measure of the state of an ecosystem asset. Ecosystem condition also underpins the capacity of an ecosystem asset to generate ecosystem services and hence changes in ecosystem condition will impact on expected ecosystem service flows.

33. Ecosystem capacity is not defined from a measurement perspective in SEEA Experimental Ecosystem Accounting but it is linked to the general model of ecosystem assets and ecosystem services that are described. In general terms, ecosystem capacity refers to the ability of a given ecosystem asset to generate a set of ecosystem services in a sustainable way into the future. While ecosystem capacity is relevant to assessments of ecosystems, measurement of ecosystem capacity requires the selection of a particular basket of ecosystem services. Measures of ecosystem capacity are more likely to relate to consideration of a range of alternative ecosystem use scenarios than to a single standard basket of ecosystem services.

34. Carbon is used as one of the indicators of the characteristics of ecosystem condition. For example, the net carbon balance carbon or primary productivity. The amount of carbon in soil can also be an indicator of soil condition which, along with vegetation, biodiversity and water are all possible measures of ecosystem condition (Table 3)(see SEEA-EEA p. 35).

Table 3. Measures of ecosystem condition for particular areas.

	Ecosystem extent	**Characteristics of ecosystem condition**				
		Vegetation	Biodiversity	Soil	Water	Carbon
	Area (proportion of EAU)	Indicators (e.g. Leaf area index, biomass index)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil fertility, soil carbon, soil moisture)	Indicators (e.g. river flow, water quality, fish species)	Indicators (e.g. net carbon balance, primary productivity)
Type of LCEU						
Forests						
Agricultural land						
Urban areas						
Inland water bodies						

Source: SEEA-EEA, Table 2.3, p. 35

5 Data sources and methods

35. This section provides information on the data sources and methods for producing carbon stock accounts as well as for measuring the ecosystem services of carbon sequestration and carbon storage. A range of specific data sources and methods are provided as an introduction to compilation. Additional material is briefly described and linked in Section 7 Additional Reference Material.

36. In order to be able to produce accounts for carbon there is a need to have access to suitable technology. In addition to the standard software used for databases and statistical procedures, access to a Geographic Information System (GIS) and the expertise needed to use it are essential. It is beyond the scope of this paper to provide information on the technical characteristics of the hardware and software or technical expertise needed and agencies investigating the production of carbon accounts should check with specialist areas either within their own agencies (e.g. a geography unit) or external agencies (e.g. Department of Forestry or land planning agencies).

37. The focus of this section is primarily on the carbon in the biocarbon. Estimation of geocarbon and its rates of extraction are important but are covered in detail in other documents, for example,

the International Recommendations for Energy Statistics and various documents produced by the International Energy Agency (see Table 2).

38. The basic approach for estimating biocarbon stocks is to start with a land cover or vegetation map and to estimate the stocks of carbon and occurring in the different land cover or vegetation types using information about the height, density and species that occur in the vegetation and the known relationships of these too volumes of carbon. This type of information is usually only available for a small percentage of total area and this information is coupled with standard statistical techniques (e.g. extrapolation) to generate an estimate for the total area.

39. Data bases containing information on the carbon content of different vegetation known as "look-up tables" (e.g. Gibbs 2006), are often used because of the paucity of primary data on the carbon content of different types of vegetation. Similarly for soil carbon, soil maps are used along with measurements of soil carbon and basic statistical techniques.

40. The stock of atmospheric carbon can be estimated from the concentration of carbon dioxide and other carbon based gases in the atmosphere (and crudely this is using the concentration expressed in parts per million and multiplying this by the total volume of the atmosphere). However, the stocks of atmospheric carbon are excluded (i.e. out of scope) of the carbon stock account described in the SEEA EEA. Similarly the stock of carbon dissolved in the oceans and seas could be estimated, but is also excluded.

5.1 Data sources

41. Table 4 provides a list of data sources and methods specific to carbon accounting. This is for both carbon stocks and the ecosystem services of sequestration of carbon and carbon storage. Land cover or vegetation maps are available for the globe (e.g. GLOBCOVER GLC2000,) and more detailed or higher resolution data are usually available at the continental CORINE land) or national levels. These data sources are covered in another technical and are mentioned here and in Table 4 for completeness.

42. A particular issue with the land cover or vegetation maps is the resolution of data contained within them. In this resolution refers to the spatial resolution (i.e. size of the grid), the technical equipment making the measurements in terms of spectral or radiometric resolution and the frequency with which data is collection (i.e. every 5 days, every 24 days). The spatial resolution of the information is particularly important to understand. This can range from of $1km^2$ to $2.5m^2$. If comparing data from two different sources, with different spatial resolutions, then at least some of the differences will be apparent rather than real. There are methods to account for these differences (e.g. upscaling) but these are beyond the scope of this paper.

Table 4. Specific data sources for carbon stock accounts and the ecosystem services of carbon sequestration and carbon storage.

Name of data source or reference	**Agency responsible for data source or reference**	**Web link**
Land cover and forests		
Global Land Cover Data Sets	NASA Goddard Institute of Space Studies	http://data.giss.nasa.gov/landuse/
GLOBCOVER	European Space Agency	http://due.esrin.esa.int/globcover/
Global Land Cover (GLC) 2000	European Commission Joint Research Centre	http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php
CORINE Land Cover	European Environment Agency	http://www.eea.europa.eu/publications/COR0-landcover
Global Forest Resource Assessment (FRA)	FAO	http://www.fao.org/forestry/fra/en/
State of the World's Forests	FAO	http://www.fao.org/forestry/sofo/en/
Carbon stocks		
Terrestrial Carbon Management Data Sets and Analyses	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/carbonmanagement/
Land use and ecosystems	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/land_use.html
Global carbon biomass look-up table	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_tables.pdf
National Biomass and Carbon Dataset	Woods Hole Research Centre	http://www.whrc.org/mapping/nbcd/
Project Carbon Sequestration	Forestry Commission (UK)	http://www.forestry.gov.uk/forestry/INFD-8JUE9T
Carbon sequestration and storage		
Carbon and biodiversity calculator	CBD Secretariate, LifeWeb and UNEP-WCMC	http://carbonbiodiversitycalculator.unep-wcmc.org/
UNEP-WCMC Ecosystem Services Toolkit	Climate regulation	UNEP-WCMC, 2011
Envision	Oregon State University	http://envision.bioe.orst.edu/Default.aspx
InFOREST	Virginia Department of Forestry	http://inforest.frec.vt.edu/
REDD+ (Reduce Emissions from Deforestation and forest Degradation).		https://www.forestcarbonpartnership.org/
Guidelines for National Greenhouse Gas Inventories Vol. 4. Agriculture, Forestry and other Land Use (AFOLU)	IPCC (Intergovernmental Panel on Climate Change). 2006. (Also known as Eggleston et al. 2006)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html
Greenhouse gas emissions from Agriculture, Forestry and other Land Use	FAO	http://faostat3.fao.org/faostat-gateway/go/to/download/G2/*/E
Soils		
Global Soil Map		http://www.globalsoilmap.net/
European Soil Portal	European Commission Joint Research Centre	http://eusoils.jrc.ec.europa.eu/
Harmonized world soil database	FAO	http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

5.2 Populating the carbon stock account for biocarbon

44. The main heading for the row entries for carbon stock account (see Table 1) are:
    - Opening stocks
    - Additions to stock
    - Reductions in stock
    - Imports and exports
    - Closing stock

45. The biocarbon stocks are disaggregated by terrestrial, aquatic and marine ecosystems. Included in the biocarbon stocks are plantation forests, orchards and livestock which in the System of National Accounts and SEEA Central framework are included in the inventories within the economy.

46. As noted above, land cover or vegetation maps are the usual starting point for developing estimates of biocarbon. The classification used in these maps should be used as the starting point for estimates of biocarbon. For example, the land Cover Classification System (LCCS, Version 3) of the FAO. Table 6 shows the LCCS classification as adapted for the purpose of land cover accounting in the SEEA Central Framework (see Table 5.12, p. 170) and the construction of a biocarbon stock account for terrestrial, aquatic and marine ecosystems, including inland water bodies.

47. The opening and closing stocks for the biocarbon in the terrestrial and aquatic ecosystems can be calculated using land cover or vegetation maps and information about the carbon content of each land cover or vegetation type. While local or national information is preferable, global data sets can provide this information. For example, the Global Land Cover (GLC) 2000 or GlobCover for 2005 and 2009. Data sources for the carbon content of different vegetation types are again best sourced from field measurements taken within the vegetation occurring within countries, but a first approximation can be found using the information in the look-up tables available from the FAO Forest Resource Assessment or the IPCC Good Practice Guidelines on Land Use, Land Use Change and Forestry (Annex 3 of Eggleston et al. 2006). Table 4 provides links to these information sources.

48. The information for the rows on additions and subtractions to particular reasons for change (e.g. natural, managed or reappraisal) can come from a variety of sources. In some cases it is obvious. For example, any increase in the area of artificial surfaces, woody or herbaceous crops is almost certainly due human management and hence, “managed expansion” of these areas (and a corresponding reduction in other areas). A starting point for these more obvious changes as well as some of the less obvious changes is the construction of a land cover change matrix, as described in the SEEA Central Framework (see table 5.14, page 181).

49. Changes in the areas of grassland, tree and shrub covered areas could be due to natural or human causes. In this changes in land zoning or use may provide an indication of the reason for change. For example, if an area went from being herbaceous crop to shrub covered area and it is also known that it when from private land used for agriculture to public land established as a national park, then this would be a managed expansion of shrub covered area and conversely a managed contraction of herbaceous crop. Information from agricultural surveys or censuses may be able to assist with identifying the changes related to the various crop lands as well as the grassland used for livestock. The entries for the upwards and downwards reappraisals are due to changes in information sources. This could be the source of the information (e.g. different satellite imagery for land cover) or new or updated information on the carbon content of particular vegetation types (e.g. collected from field surveys).

Table 5. Biocarbon stock account for terrestrial, aquatic and mangrove ecosystems.

Tonnes of carbon		**Terrestrial ecosystems***									**Aquatic ecosystems**		**Marine ecosystems****	
		Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Sparsely natural vegetated areas	Shrubs and/or herbaceous vegetation, aquatic or regularly flooded	Inland water bodies	Coastal water bodies and intertidal areas	Other (e.g. sea grass and coral reefs)
Opening stock														
Additions to stock														
	Natural expansion													
	Managed expansion													
	Upwards reappraisals													
	Reclassifications													
	Total additions to stock													
Reductions in stock														
	Managed regression													
	Natural regression													
	Catastrophic losses													
	Downwards reappraisals													
	Reclassifications													
	Total reductions in stock													
Closing stock														

*not shown are the categories terrestrial barren land, permanent snow ice and glaciers. Mangroves could be shown as marine ecosystems

**The other category for marine ecosystems has been added

6 Additional reference material

50. A variety of material relating to carbon accounting are available for generating estimates of stocks of carbon in the biosphere as well as the ecosystem services of sequestration on carbon and carbon storage. This includes:
    - *Ecosystem Natural Capital Accounts: A Quick Start Package* (Webber 2014)
    - *Carbon Accounting in Australia* (Ajani and Comisari 2014)
    - The guidelines developed to support reporting for the UN Framework Convention on Climate Change (UNFCCC) and for the Kyoto Protocol (Penman et al. 2003)
    - REDD+ (*Reduce Emissions from Deforestation and forest Degradation*)(COFC_GOLD 2013)
    - Various academic papers on ecosystem services
    - Other international ecosystem accounting initiatives

51. The main features of these and how they relate to the SEEA EEA are outlined in general below. Most of the material has not been developed specifically for the purpose of ecosystem accounting but the methods in these documents appear suitable for producing accounts of carbon stocks and carbon storage and sequestration. The exception to this are the documents by Weber (2014) and Ajani and Comisari (2014) which both specifically address accounting for carbon in the context of the SEEA EEA and for this reason these papers are considered first.

6.1 Quick Start Package

52. *The Ecosystem Carbon Account* is Chapter 5 of the Quick Start Package. The package provides information on how existing and accessible data can be used to populate a set of ecosystem accounts, with special attention given to carbon. It follows the principles of the SEEA EEA and outlines 4 tables for compilation:
    - Table 1. Summary Ecosystem Carbon Basic Balance (with 2 supporting tables)
    - Table 2. Accessible Resource Surplus
    - Table 3. Total Uses of Ecosystem Bio and Geo-Carbon
    - Table 4. Indexes of Intensity of Use and Ecosystem Health

53. The structure of Ecosystem Carbon Balance Account (Table 1) is similar to the Carbon Stock Account of the SEEA EEA but omits geocarbon from its scope. Imports and exports of carbon based products are captured through the column titled “supply and use system”. Geocarbon is considered in Table 3 of the QSP “Total Uses of Ecosystem Bio and Geo-Carbon”. A separate account for the ecosystem services of carbon sequestration and storage is not provided.

54. Data source and method for calculating table entries are provided along with examples. The Quick Start Package was trialed in Mauritius (Weber 2014) where a table showing a simplified carbon balance (with a structure like the Ecosystem Carbon Basic Balance) is show for the years 2000 and 2010.

6.2 Carbon Accounting in Europe

55. Spatially explicit carbon accounts for Europe (the “EU28”) were developed by the European Environmental Agency using the Experimental Framework for Ecosystem Capital Accounting in Europe (Weber 2011). First estimates were produced in 2011 and more comprehensive carbon accounts were competed in 2014, although the results and details of the methodology are not expected to be published until 2015.

56. In general, the recently completed accounts were produced using accounting principles, remotely sensed data a combination of statistical and estimation procedures from the IPCC and others. These are broadly described in the Quick Start Package (see Section 6.1).

57. Various remote sensing, geographical and statistical data sources were tested for the purpose of estimating carbon stocks and flows. These included:
    - Statistical data
        - Forest biomass (FRA, 2000, 2005, 2010)
        - Crops harvest (EUROSTAT 2000 – 2010)
        - Timber harvest (EUROSTAT 2000 – 2010)
        - Livestock (EUROSTAT 2000 – 2010)
    - Remote sensing information
        - Land cover (CORINE LC 2000, 2006);
        - Vegetation (SPOT vegetation NDVI 1999 – 2010);
        - Primary production (GPP) and Ecosystem respiration (TER), (NASA, 2000 – 2010);
    - Soil and other geographic data
        - Soil organic carbon (Global map, JRC, Hiederer and Köchy, 2012);
        - NUTS administrative divisions.

58. Downscaling techniques were applied to allocate the national or regional statistics (e.g. on forest biomass, crops, timber and livestock) to a 1 x 1 km grid, using factors derived from land cover and/or the vegetation indices. For parameters for which no data were available, such as biomass in wetlands and grasslands), studies of particular sites published in the scientific literature were used to derive factors that were applied more generally based on land cover information.

59. Opening carbon stocks were estimated for year 2000. These stocks included estimates of soil organic carbon and above-ground biomass, both dead and alive. The biomass stocks were mapped using the categories: forest; agro-forestry; arable crops; complex crops; pastures; permanent crops; grasslands, moors, heathlands, sclerophyllous vegetation, shrublands, sparse vegetation, inland marshes, peat bogs and salt marshes.

60. The flows of carbon were mapped for each year for the decade 2000 – 2010 and included primary production (or carbon sequestration) and the carbon release of carbon (via ecosystem respiration) as well as carbon exports (through harvest of crops, timber, fibre and animal products) and carbon imports (including deposition of dry sludge and manure in the fields). Carbon exports were further broken down to harvest of timber, crops and animal products (which are also the main provisioning services). The crops were individually mapped for the following types: cereals, citrus fruit, industrial crops, oilseed, olives, rice, root crops and grapes.
61. The quality of the European carbon accounts was assessed using independent data from published studies and measurements of carbon exchanges between the ecosystems and the atmosphere (FLUXNET) in Europe.

6.3 Carbon Accounting in the USA

62. The United States Geological Survey Organisation has published a method for assessing carbon stocks and carbon sequestration (Zhu et al. 2010). The method uses the concepts and definitions from the IPCC reporting and takes remotely sensed data on land cover along with climatic data information to estimate current and future stocks and flows of carbon. Below ground biomass is included as in the carbon in aquatic ecosystems. The method also examines the capacity of ecosystems to store more carbon under different land use scenarios.

63. The report highlights the need for collaboration between government and non-government organisations to enable the method to be implemented. Specifically the report says: "*The sharing or developing input data will be critical to the assessment*" (see p. 2 of the executive summary).

6.4 Carbon Accounting in Australia

64. Ajani and Comisari (2014) compiled a preliminary carbon stock account for Australia based specifically on the concepts and structure of account described in the SEEA EEA. The publication includes the results, details on the data sources and methods as well as information on the process used to develop the accounts.

65. A key feature of the process was the collaborative approach used. This approached involved as partners an academic institution (Australian National University), the policy agency (Department of Climate Change and Energy Efficiency) and the national statistical office (Australian Bureau of Statistics).

66. For the production of the accounts, Appendix C of Ajani and Comisari (2014) provides a list by source and methods for each type of ecosystem within Australia (e.g. rangelands, woodlands, rainforests and agricultural crops), while Appendix D is a list of the main information providers in Australia. The tabular approach used in Appendix D to organise information may be suitable as a template for other countries.

6.5 UNFCCC and IPCC guidance

67. The *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (Penman et al. 2003) and the *Guidelines for National Greenhouse Gas Inventories Agriculture, Forestry and other Land Use* (AFOLU) Requirements (Eggleston et al. 2006; VCS 2013) provide information for countries preparing inventories for submission to the UNFCCC as well as additional steps relevant to the Kyoto Protocol.

68. While the term used is land use, it is applied generally and refers to both to land cover and land use (and the differences and linkages between land cover and land use are recognized within these guidelines).

69. The six broad categories of land use indented in the UNFCCC/IPCC report are: forest land; cropland; grassland; wetlands; settlements and; other land. The document provides detailed guidance for how to estimate the area of land in each category of land use as well as the method for estimating carbon stocks. Detailed methods for estimating carbon stocks and changes (carbon sequestration) are described for each land use category in the documents of the UNFCCC (Penman et al 2003) and IPCC (Eggleston et al. 2006).

70. The tables presented in Chapter 2 of the guidance document for land use change (Tables 2.3.2, 2.3.4, 2.3.5) are essentially the same as the SEEA Central Framework's physical account for land cover (Table 5.13) and the land cover change matrix (Table 5.14). Chapters 3 and 4 of the guidance document provide information on how to estimate emissions and removal estimates of greenhouse gases for each land use category. Chapter 5 includes information on data quality description and assessment.

71. The IPCC inventory has developed a software tool that does not require any additional software or internet access. It covers all inventory categories but can also be used for the management of specific industries. It allows different parts of the inventory to be developed simultaneously and has data entry in worksheets following 2006 IPCC Guidelines for ease-of-use. The tool provides default data from 2006 IPCC Guidelines but

allows users to use their own country-specific information when available. The tool and guidance material can be found at: http://www.ipcc-nggip.iges.or.jp/software/

6.6 REDD (Reduce Emissions from Deforestation and Forest Degradation)

72. The Forest Carbon Partnership Facility aims to assist countries to reduce emissions from deforestation and forest degradation. It does this by providing financial and technical assistance to countries. The partnership currently has 47 developing countries and uses a performance-based payment system.

73. Guidance for REDD is provided in a Sourcebook of Methods and Procedures for Monitoring Measuring and Reporting (GOFC-GOLD 2013). This report draws on material from the UNFCCC and IPCC reports and is restricted to consideration of forests. It provides information on the selection and use of satellite imagery.

6.7 Various academic papers

74. A large number of academic papers have been produced on carbon and ecosystem services. Many of these include information on carbon sequestration and storage, although they are sometime described using different terms (e.g. atmospheric regulation).

75. Three papers have reviewed the ecosystem service studies. These are:
    - Martinez-Harms and Balvanera (2012)
    - Egoh et al. (2012)
    - Crossman et al. (2013)

76. Another review by Bagstad et al (2013) examined the use of modeling tools that produce estimate of multiple ecosystem services, including carbon sequestration and storage. Two tools that included carbon sequestration and storage were InVEST and ARIES.

77. A large body of literature relating to carbon accounting has developed to support the IPCC reporting and the understanding of climate change. A range of this literature is included in the reference section, although not all is cited in this document.

6.8 International initiatives related to ecosystem accounting

78. There are a number of initiatives advancing ecosystem servicers or natural capital accounting underway around the world that can be related to ecosystem accounting. In addition to the ones mentioned above specifically in regards to carbon accounting there is the following activity related to either accounting or ecosystem services:
    - ProEcoServe (Project for Ecosystem Services) http://www.proecoserv.org/
    - WAVES (Wealth Accounting and Valuation of Ecosystem Service) https://www.wavespartnership.org/en
    - MAES (Mapping and Assessment of Ecosystems and their Services) http://biodiversity.europa.eu/maes
    - The Ecosystem Services Partnership http://www.es-partnership.org/esp/82222/9/0/50

79. In addition to this is the work of the London Group on Environmental Accounting, which holds annual meetings, and the 20th Meeting held recently (October 2014) in New Dehli had a session specifically on ecosystem accounting (see http://unstats.un.org/unsd/envaccounting/londongroup/). More broadly the UNSD maintains a Searchable Archive of environmental accounting publications which is added to regularly (see http://unstats.un.org/unsd/envaccounting/ceea/archive/).

7 Issues for resolution

80. In the work on carbon accounting, and ecosystem accounting more generally, a number of theoretical and practical issues need to be resolved in order to bring the accounts to the level of an international statistical standard (i.e. and sit alongside the System of National Accounts and SEEA- Central Framework). Indeed a key part of the SEE-EEA is the research agenda in which carbon is specifically mentioned:

    "Developing specific topics of research on measures related to biodiversity and carbon in the context of ecosystem accounting"[9].

81. This section outlines a number of issues that could be addressed by countries and agencies compiling or seeking to compile accounts for carbon. A general issue for resolution is the definition of ecosystem capacity and in this work on carbon accounting may provide some useful information. For example, how the capacity of particular ecosystem to sequester carbon could change given different management scenarios.

7.1 Terminology and classification of ecosystem services

82. The range of material reviewed in the development of this note show that there were a range of terms being used in carbon accounting and in particular to describe the ecosystem services termed sequestration of carbon or carbon storage in the SEEA-EEA (and in this note). The SEEA-EEA adopts the Common International Classification of Ecosystem Services (CICES)[10]. However, the CICES does not define either the service of sequestration of carbon or carbon storage.

83. The CICES is a three level classification, with the "1-digit" level being the highest level of aggregation.
    - Section Regulating (1-digit)
    - Division Regulation of physic-chemical environment (2-digit)
    - Group Atmospheric regulation (3-digit). Examples, provided include capture of carbon dioxide; climate regulation

84. Future versions of the CICES or of an alternate classification used by the SEEA-EEA should identify and define the services sequestration of carbon or carbon storage.

7.2 Spatial units, classification and boundary issues

85. The identification, delineation and classification of the spatial units are general issues for ecosystem accounting. There are a number of specific issues highlighted in the development of carbon accounts.

86. In this note the carbon stock account is built from land cover/ecosystem functional units (LCEU) aggregated to a country level. The LCEU are classified according the FAO Land Cover Classification System (LCCS Ver. 3). This is primarily a terrestrial classification although parts of the marine ecosystem are included (e.g. mangroves and coastal water bodies) but others are apparently not (e.g. coral reefs, sea grass beds). A comprehensive classification of marine ecosystems needs to be identified and tested.

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[9] SEEA-EEA, Annex 1 Research Agenda. Pages 155-157.
http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf

[10] SEEA-EEA, pages 54-55, Table 3.1.
http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf

87. Related to this is the definition and boundary of marine ecosystems. The LCCS Ver. 3 includes mangroves and coastal water bodies which are probably best described as marine ecosystems. However, the boundaries between marine, aquatic and terrestrial ecosystems probably need to be more clearly defined.

88. The SEEA-EEA defines ecosystem accounting units (EAU). These are areas that aggregate the data from the LCEU in areas suitable for analysis or management. The country level is the highest level EAU but it may be that within countries smaller nested EAU may be appropriate for subnational analysis or management. For example, the management of particular river basins or provinces or states within countries.

7.3 Scale, measurement methods and data quality

89. Combining information from different information sources invariably means that data from different spatial scales (or resolution) and different measurement methods (e.g. satellite images and field surveys) are being combined. The effects of spatial resolution are relatively well known and there are techniques to address these. The combination of different measurement methods is a more difficult problem and is not unique to ecosystem accounting.

90. A recurring theme in reviews of ecosystem services is that the broad scale data available from global remotely sensed sources is not as accurate as information from local sources, often obtained from field surveys (see for example, Egoh et al. 2012). Furthermore the errors involved from using multiple data sources and things like look-up tables for the carbon content of particular vegetation types, are compounding and are difficult to quantify (see Eigenbrod et al 2010a a&b).

91. Robust statistical techniques are needed to merge data from different sources and scales and these methods should attempt to quantify of errors. Descriptions of data quality are needed and existing frameworks, like the Statistics Canada (2002) Quality Assurance Framework.

7.4 Policy uses

92. A range of potential uses of carbon accounts were identified earlier in this note. Exploring how carbon accounts can be applied to particular decisions or decision-making processes will be an important driver for adoption of accounts for carbon by a broad range of countries and international agencies.

93. A particular issue which might be useful is consideration of what headline indicators could be drawn for the accounts and related information.

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ANNEX 1

Section A4.1 of the SEEA-EEA, pp. 102-105.

Additional detail concerning accounting for carbon

A4.1 The rationale for carbon accounting in the context of ecosystem accounting is discussed in Section 4.4. This annex provides some additional details on the structure and accounting entries related to the carbon stock account presented in Table 4.5.

A4.2 The carbon stock account presented in Table 4.6 provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and in particular the differences in the nature of particular carbon reservoirs. Opening and closing stocks of carbon are recorded with the various changes between the beginning and end of the accounting period recorded as either additions to the stock or reductions in the stock.

A4.3 Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils). Geocarbon is further disaggregated into: oil; gas; and coal resources (fossil fuels) and rocks and minerals (e.g. carbonate rocks used in cement production, methane clathrates and marine sediments). For accounting purposes where the information generated from the accounts is policy focussed, the priority should be to reporting those stocks that are being impacted by human activity (e.g. fossil fuels).

A4.4 Biocarbon is classified by type of ecosystem. At the highest level these are terrestrial, aquatic and marine ecosystems, as shown in Table 4.6. This high level classification can be further broken down, but at present there is no internationally agreed classification of ecosystems. In the absence of this, compliers may chose to use the land cover classification of the SEEA Central Framework, noting that the primary purpose of this classification is not for ecosystem accounting, but for understanding production, consumption and accumulation from an economic perspective, not the ecosystem perspective. In this it should also be noted work on land cover classifications is part of the SEEA Central Framework research agenda.

A4.5 A key aspect for carbon accounting is to understand the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, for example:

- Natural ecosystems: which are largely the product of natural and ongoing evolutionary, ecological and biological processes. The key mechanism of 'management' in natural ecosystems is natural selection operating on populations of species which has the effect over time of optimizing system level properties and the traits of component species. System-level properties which are naturally optimized with respect to, among other things, environmental conditions include canopy density, energy use, nutrient cycling, resilience, and adaptive capacity. Natural processes dominate natural ecosystems within which human cultural and traditional uses also occur. Natural ecosystems include terrestrial and marine ecosystems.

- Semi natural ecosystems: which are human modified natural ecosystems. Natural processes, including regenerative processes, are still in operation to varying degrees. However, the system is often prevented from reaching ecological maturity or is maintained in a degraded state due to human disturbance and land use. Thus, the vegetation structure may not reflect natural optima, and the taxonomic composition may be depauperate.
- Agricultural ecosystems: which are human designed, engineered and maintained systems on agricultural lands that grow animals and crops mainly for food, wood and fibre and as feedstocks for biofuels and other materials. Plantations of trees for timber or fruit production (e.g. orchards) are included in the agricultural ecosystem. Note that these stocks in the SEEA Central framework and SNA would be included as inventories of the economy and hence must be removed from this category.
- Other ecosystems: including settlements and land with infrastructure.

A4.6 The atmosphere and ocean are the receiving environments for carbon released from primary reservoirs and accumulations in the economy. In this, the atmosphere and oceans may be viewed in a way similar to the way the rest of the world is treated in physical supply and use tables in the SEEA Central Framework, since they are not under the control of a particular owner. Oceans may be split into shallow and deep ocean reservoirs.

A4.7 Accumulations in economy are the stocks of carbon in anthropogenic products and are further disaggregated into the SNA components: Fixed assets (e.g. concrete in buildings, bitumen in roads); Inventories (e.g. petroleum products in storage, but excluding those include in agricultural ecosystems); Consumer durables (e.g. wood and plastic products); and Waste. Accounting for waste follows the SEEA Central Framework where waste products (e.g. disposed plastic and wood and paper products) stored in a controlled land fill sites are treated as part of the economy.

A4.8 Carbon stored through geosequestration (i.e. the managed injecting of gaseous CO_2 into the surface of the Earth) is similarly treated as being a flow within the economy (increase in accumulations). Any subsequent release of carbon to the environment is treated as a residual flow with a reduction in accumulations in economy matched by corresponding increase in carbon in the atmosphere.

A4.9 Although not shown in the table, these ecosystem types could be disaggregated further into marine and terrestrial ecosystems. Marine ecosystems include mangroves, saltmashes and seagrass beds. Peat stocks and flows align with the biocarbon sector with peatland vegetation associated with a variety of ecosystems, including forests, grasslands, mossbeds, mangroves, saltmashes and paddies. There is potential to disaggregate Geocarbon and Biocarbon further.

A4.10 The row entries in the account follow the basic form of the asset account in the SEEA Central Framework: opening stock, additions, reductions and closing stock. Additions to and Reductions in stock have been split between managed and natural expansion. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account.

A4.11 There are six types of additions in the carbon stock account.

- Natural expansion: These additions reflect increases in the stock of carbon over an accounting period due to natural growth. This will be effectively only for biocarbon and may arise from climatic variation, ecological factors such as reduction in grazing pressure, and indirect human impacts such as the CO2 fertilisation effect (where higher atmospheric CO2 concentrations cause faster plant growth).
- Managed expansion: These additions reflect increases in the stock of carbon over an accounting period due to human-managed growth. This will be for biocarbon in ecosystems and Accumulations in economy, in inventories, consumer durables, fixed assets and waste stored in controlled land fill sites including the injection of greenhouse gases into the earth.
- Discoveries of new stock: These additions concern the arrival of new resources to a stock and commonly arise through exploration and evaluation. This applies mainly, perhaps exclusively, to geocarbon.
- Upwards reappraisals: These additions reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.
- Reclassifications: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example increases in carbon in Semi-natural ecosystems by the establishment of a national park on an area used for agriculture would be equalized by an equivalent decrease in Agricultural ecosystems. Here, it is only the land use that has changed; that is, reclassifications may have no impact on the total physical quantity of carbon.
- Imports: A line for imports is shown to enable accounting for imports of produced goods (e.g. petroleum products). Imports are show separately from the other additions so that they are presented with exports.

A4.12 There are six types of reductions recorded in the carbon stock account:

- Natural contraction: These reductions reflect natural, including episodic, losses of stock during the course of an accounting period. They may be due to changing distribution of ecosystems (e.g. a contraction of Natural ecosystems) or biocarbon losses that might reasonably be expected to occur based on past experience. Natural contraction includes losses from episodic events including drought, some fires and floods, and pest and disease attacks. Natural contraction also includes losses due to volcanic eruptions, tidal waves and hurricanes.
- Managed contraction: These are reductions in stock due to human activities and include the removal or harvest of carbon through a process of production. This includes mining of fossil fuels and felling of timber. Extraction from ecosystems includes both those quantities that continue to flow through the economy as products (including waste products) and those quantities of stock that are immediately returned to the environment after extraction because they are unwanted, for example, discarded timber residues. Managed contraction also includes losses as a result of a war, riots and other political events; and technological accidents such as major toxic releases.
- Downwards reappraisals: These reductions reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The reassessments may also relate to changes in the assessed quality or grade of the natural resource. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.
- Reclassifications: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example decreases in carbon in Ecosystems agriculture by the establishment of a national park on an area used for agriculture would be equalized by an equivalent increase in Semi-natural ecosystems. Here it is only the land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon.
- Exports: A line for exports is shown to enable accounting for exports of produced goods (e.g. petroleum products). Exports are shown separately from the other reductions so that they are presented with imports.

Catastrophic losses, as defined in the SNA, are not shown as a single entry but are allocated between Managed contraction and Natural contraction. Managed contraction would include fires deliberately lit to reduce the risk of uncontrolled wild fires. Also for the purposes of accounting, reductions due to human accidents, such as rupture of oil wells, would also be included under managed contraction. Catastrophic losses could, however, be separated.