A carbon asset accounting framework and data population

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A. Introduction

1. The SEEA Central Framework states that the SEEA Experimental Ecosystem Accounts will discuss 'a complete articulation of carbon accounting' and that 'an ecologically grounded accounting approach is required to fully account for stocks and flows of carbon and provide information for policy in this area' (UN Statistical Commission 2012, para 5.393). The Technical Expert Meeting on ecosystem accounts, London 5-7 December 2011 determined that 'Carbon accounts should, in principle, incorporate stocks and flows of the carbon cycle comprehensively, building on the methods used by UNFCC and IPCC for compiling statistics on emissions.' (Technical Expert Meeting on Ecosystem Accounts 2012).

2. A range of carbon accounting approaches were presented at the Technical Expert Meeting on Ecosystem Accounts, London 5-7 December 2011 (papers are available at http://unstats.un.org/unsd/envaccounting/seeaLES/egm/lod.htm) with the meeting concluding that 'A comprehensive approach around carbon is crucial including links to other systems and the work of IPCC and UNFCCC.' (Technical Expert Meeting on Ecosystem Accounts 2012). The Discussant noted that, given the widespread interest in climate change, agreement was needed on the scope and purpose of carbon accounts. In advancing carbon accounting, the Discussant also encouraged the avoidance of duplicating effort; working with the IPCC to build consistency; and, where appropriate, drawing on the same data sources as other monitoring work (Roy Haines-Young 2012).

3. The aims of this paper are to:
   a) articulate the core underpinnings for carbon stock accounts from an ecological perspective,
   b) clarify the core information and policy need for carbon stock accounts,
   c) present a carbon asset accounting framework that is ecologically grounded and consistent with the SEEA Central Framework, and
   d) present recommendations for advancing data population.

4. The Technical Expert Meeting on Ecosystem Accounts also discussed the separate issue of the potential to link carbon accounts and ecosystem accounts. On this issue, general comments aimed at not losing carbon asset accounting comprehensiveness are presented in this paper.

   The paper concludes with a list of questions for Workshop discussion.

B. Ecological underpinning of carbon accounts

5. The core attributes of an ecologically grounded carbon accounting system are:

   a) completeness and consistency,
   b) separate reporting of geocarbon (geosphere stocks and flows of carbon, eg coal and oil) and biocarbon (biosphere stocks and flows of carbon, eg in plants), and

c) operational criteria for disaggregating biocarbon based on the degree of naturalness of the ecosystem.

B 1. Completeness and consistency

6. The principles of completeness and consistency in the SNA are highly valued by a multitude of users with varying objectives, many of whom are engaged in time series analysis. For the same reasons, the carbon accounting system should be comprehensive with the accounts aiming to eventually cover, and separately report, all anthropogenic and non anthropogenic stocks and flows in the biosphere, geosphere, atmosphere and oceans. Carbon inventories prepared under UNFCCC and IPCC guidelines report net annual flows resulting from covered (selected) human activities.

7. In contrast to biocarbon, accounting for geocarbon is relatively easy because fossil fuel inventories already exist in many countries; fossil fuel use is largely human-driven; and it effectively generates one way carbon flows (emissions). In addition, there are a relatively small number of entities owning the asset and generating stock change.

8. Accounting for biocarbon is more challenging with carbon reservoirs (where stocks of GHG precursors are stored (IPCC 2001)) covering the entire landscape (including marine ecosystems); the temporal and spatial variation in stocks calls for skilful 'fit for purpose' assessments within funding constraints; distinguishing anthropogenic from non-anthropogenic stock changes is complicated; and the number of entities is large both for stocks in situ and for anthropogenic stocks. Accounting for the stock of carbon in the atmosphere and oceans is also relatively straightforward and there are already estimates of this.

9. These challenges, particularly with biocarbon, should not discourage adopting completeness and consistency as fundamental principles for carbon stock accounts, and here we need look no further than the 80-year experience in national economic accounting. Completeness and consistency equates to systems understanding; improved information for research, analysis and policy where establishing rigor in the base aggregates is highly valued because it enables perspective to be ascertained for the individual components; information users understand that data gaps will be filled over time which encourages researchers to fill the gaps using consistent definitions and classifications; reduced risk of systemic errors in the accounts; information users understanding that constant improvement (revisions) is crucial for time series data; and a long term investment with public funds used to steadily improve and populate a comprehensive accounting framework that endures. Notwithstanding the substantial attractions, completeness and consistency are demanding in research time and financially.

B2. Separate reporting of geocarbon and biocarbon

10. UNFCCC inventories report flows (not stocks) and are structured around human activities that cause greenhouse gas emissions (energy, industrial processes, solvent and other product use, agriculture, land use change and forestry, waste, other). They do not directly provide for disaggregation of geocarbon and biocarbon flows, although this can be readily achieved. This first level disaggregation is critical for stock accounts. Reporting to this level, as a minimum, is important for researchers investigating changes in the global carbon cycle and informing the policy debate on engaging the land sector to contribute to reducing atmospheric CO_2 levels through reduced emissions and increased removals of CO_2 from the atmosphere.

11. Classification criteria at this level are relatively undemanding, although peat requires attention. Peat is sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material. Peatland is an area with a naturally accumulated peat layer at the surface (Joosten 2010). Peatland vegetation ranges from forests to grasslands and mossbeds; it also includes mangroves, saltmarshes, paddies and a variety of other ecosystems. Emissions from peat combustion are covered in the UNFCCC energy sector as a solid fuel. Emissions from peatland destruction are partially covered in the LULUCF inventory, depending on the overlying vegetation type and land use (for example, marine ecosystems are excluded from UNFCCC inventories). Peat stocks and flows align with the biocarbon sector. Wetland drainage and peat used for energy can generate significant carbon emissions (see for example, Hooijer et al. 2010).

B 3. Criteria for disaggregating biocarbon

12. Ecosystems vary in their stability and therefore longevity and hence their capacity to accumulate high carbon stocks. Understanding the underlying causes of these fundamental ecosystem quality differences should inform the carbon account structure.

13. Ecosystems with high biodiversity at the genetic, taxonomic and ecosystem levels have vast webs of ecological and coevolving interactions that build persistence capacity and longevity (Odum and Barret 2004; Thompson 2005). Greater genetic diversity within a species enhances micro-evolutionary capacity with populations better able to adapt to local conditions (Bradshaw and Holzapfel 2006). High taxonomic diversity means the species pool contains plants and animals with varying life histories and niche tolerances with natural selection revealing those best suited to new conditions (Hooper et al. 2005). Natural selection acting on biodiverse ecosystems can also optimise a plant's physiological processes (Cowen and Farquhar 1977) and trophic interactions (Brown et al. 2004) in response to environmental change. Genetic, taxonomic and functional biodiversity underpins resilience to climate change and other disturbance. Some of the resilience may be climate change related such as regeneration after fire, resistance to and recovery from pests and diseases and adaptation to changes in radiation, temperature and water availability (Mackey et al. 2008; Secretariat of the Convention on Biological Diversity 2009).

14. These biodiversity-based resilience processes mean natural ecosystems, as distinct from human-made or modified ecosystems, are more likely to persist and hence accumulate large carbon stocks in soils and plants, particularly big and old trees. The carbon stock framework presented in Table 1 accommodates the highest level of ecosystem-type aggregation without losing the biodiversity-longevity quality attribute. This being, Ecosystems natural, Ecosystems semi-natural, Ecosystems agricultural and Ecosystems other. This classification allows for a 'grey area', whereas the SEEA Central Framework (Figure 5.3.1) recommends that asset accounts for timber and aquatic resources be disaggregated into either Natural or Cultivated. A Semi-natural category recognises the difficulty in applying a natural-agricultural classification for some areas, particularly forests as the FAO has experienced. A semi-natural category also allows for transparency in the improvement in ecosystem allocation.

15. In contrast to the SEEA Central Framework's asset account treatment of Timber and Aquatic resources, its land cover classification (Table 5.6.2) does not distinguish ecosystems by their naturalness. Weber (2011) presents a socio-ecological landscape unit classification that moves towards incorporating naturalness by disaggregates landscapes into five ecosystems (Mountain, Highland, Lowland (inland), Coastal, and River) with a second level disaggregation comprising:

    1) Urban and associated developed areas

2) Broad pattern agriculture
3) Agriculture associations and mosaics
4) Pastures and natural grassland
5) Forest tree cover
6) Other dominant natural land cover
7) Composite land cover (no dominant land cover)

This classification may not be meaningful for the substantial area, globally, of non-riverine landscapes e.g. steppes, savannas, deserts, tundras, islands and marine vegetated ecosystems.

16. From a carbon accounts perspective, disaggregating in particular Forest tree cover and Pastures and natural grasslands by naturalness criteria would enhance significantly the usefulness of the classification. For example, a fast-growing wood plantation (which is an agricultural production system and should be recorded as such) generates large volumes of wood used to make wood products which store carbon for varying periods. It also provides a high annual rate of CO_2 removal . However, the average amount of carbon stored in a given area of plantations that is periodically cut and regrown is much less than the carbon stored in an old-growth forest or a secondary forest that is allowed to regrow undisturbed (Thornley and Cannell, 2000, Mackey et al. 2008).

17. Natural ecosystems with their biodiversity-based resilience processes hold relatively large stocks of carbon in relatively stable ecosystems for relatively long periods of time. Agricultural cropping regimes, including plantations, are efficient food and fibre production systems but less efficient in carbon storage. Land use allocation and climate change policy making will be better informed with statistical information systems that incorporate ecosystem naturalness in their classification system.

18. Implementing such a land and marine ecosystem classification will require new science-based criteria for land classification and changed data collection and reporting practices across multiple jurisdictions.

C. Carbon stock accounts - core information and policy needs

C1. Balancing the global carbon budget

19. Climate change is caused by increases in the total stock of greenhouse gases in the atmosphere. In 2009, the six greenhouse gases included in the Kyoto Protocol reached 439 parts per million (ppm) CO_2 equivalent[1], an increase of 160 ppm compared to pre-industrial levels. Carbon dioxide, the most important anthropogenic greenhouse gas (IPCC 2007), reached a level of 386 ppm CO_2 equivalent by 2009 and increased to 389 ppm in 2010 (European Environment Agency 2012; Global Carbon Project n.d. b). The IPCC considers that avoiding dangerous climate change requires limiting greenhouse gas concentrations in the atmosphere to between 445 and 650 ppm CO_2 equivalent.

20. Large amounts of carbon flow naturally and continuously between the geosphere, biosphere, and the atmosphere. This is commonly called the global carbon cycle, and it includes many complex interactions. Physical and biological processes in the oceans play a crucial role in

[1] Greenhouse gases have different effects on the climate system. A greenhouse gas equivalent measure (CO_2 equivalent) is used to enable aggregation. This is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas.

regulating the exchange of carbon dioxide (CO_2) with the atmosphere. Through photosynthesis, terrestrial and marine plants capture CO_2 from the atmosphere and return it to the atmosphere through plant, soil and animal respiration (including decomposition of dead biomass).

21. UNFCCC carbon accounts report flow information (Muukkonen 2011; Ajani 2011) which combined with knowledge of underlying bio-physical processes builds our understanding of climate change. More recently, scientists have turned their attention to comprehensive carbon stock estimation. This is partly motivated by the difficulty balancing global carbon flow data and identifying the source(s) of the problem: possible errors in the ocean models, errors in anthropogenic biocarbon flow estimates or unidentified non-anthropogenic terrestrial carbon flows (Houghton 2007). In 2011, the Global Carbon Project (n.d. a) commenced the Earth Carbon Pools Size and Certainty project which aims to present a comprehensive account of all carbon stocks on earth. The Global Carbon Project is a non government environmental research organisation formed to assist the international science community establish a common, mutually agreed knowledge base supporting climate change policy debate. It is an initiative of the Earth System Science Partnership (ESSP), which consists of the International Geosphere-Biosphere Programme, International Human Dimensions Programme on Global Environmental Change, World Climate Research Programme, and Diversitas, an International Programme of Biodiversity Science. The growing science community interest in quantifying carbon stocks opens potential fruitful collaboration between SEEA, the Global Carbon Project and IPCC.

22. Carbon stock accounts are a missing but crucial information set with climate change caused by increases in the stock of greenhouse gases in the atmosphere and the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to limit this stock and achieve '*… stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*' (United Nations 1992, Article 2). The Article 3 states that policies and measures to deal with climate change should be '*comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors*'.

C2. Policy in a world of limits

23. Climate change policy is about limits: 1) atmospheric concentrations of greenhouse gases to avoid dangerous climate change; 2) land and water with competing uses including biocarbon storage; 3) rates of carbon uptake by different ecosystems and carbon stocks within ecosystems; and 4) time.

24. Distinguishing geocarbon from biocarbon reflects the fundamental property difference that geocarbon emissions are irrecoverable in any relevant time frame, while biocarbon emissions are theoretically recoverable but in practice limited by the time available, the rate at which they can be recovered, and the land area available.

25. Houghton (2007) estimates that human induced changes in land use released 156 Gt C over 1850 to 2000. The Global Carbon Project reports human activity caused 10.0 +/- 0.9 Gt C carbon stocks to be lost to the atmosphere in 2010: 0.9 +/- 0.7 Gt C from the land sector and the balance from fossil fuels and cement (Global Carbon Project, n.d. b). At this rate, a theoretical world-wide return of all land to pre-industrial revolution carbon stock levels would offset less than two decades of fossil fuel emissions (but in practice take decades to centuries to accomplish). The land sector, however, cannot return to its full carbon carrying capacity. It is limited by competing food, housing and infrastructure claims and because, in some areas, soils and forests have been permanently degraded. In such a situation, policy is about optimisation in

a world of limits. Carbon accounts with an ecosystem biodiversity-stability quality classification will help inform the land-use public policy debate. For example, for a given 'target' for land-based carbon storage, maintaining and rebuilding natural ecosystems with their higher carbon densities means more agricultural land remaining for food production.

D. Carbon asset account in physical units

26. Table 1 presents a framework for a carbon stock account. It transposes the comprehensive and ecologically-grounded stock and flow framework presented at the London Technical Expert Meeting on Ecosystem Accounts (Ajani 2011) into the SEEA Central Framework format. The table provides comprehensiveness in the recording of the opening and closing stock of carbon 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.

27. The first level disaggregation of carbon reservoirs enables reporting of stocks and stock changes for geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils); accumulated in products; and capital assets in the economy (e.g. buildings).

28. Geocarbon is disaggregated into Rocks (eg carbonate rocks like limestone), Oil, Gas, Coal and Other. This classification aligns with extraction for human use, however the classification will need advice from the geologists given the multiple reservoirs of carbon in the one location which gives rise to the method of accounting for conventional and unconventional oil and gas.

29. Biocarbon stocks are tagged to ecosystem type (Ecosystems natural, Ecosystems semi-natural, Ecosystems Agricultural, and Ecosystems other) for both 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. Ecosystem type definitions are as follows:

Ecosystems natural: 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 ecosystems include terrestrial and marine ecosystems.

Ecosystems semi natural: 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.

Ecosystems agricultural: are human designed, engineered and maintained systems that grow animals and crops mainly for food, wood and fibre and as feedstocks for biofuels and other materials on agricultural lands. Plantations of trees (commonly defined as woody perennial plants greater than two metres tall at maturity) are a type of agricultural ecosystem.

Agricultural lands incorporate some natural ecosystem processes to varying degrees (e.g. pollination, mineralization).

Ecosystems other: include settlements and land with infrastructure.

30. 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 is physical supply and use tables, since they are not under the control of a particular owner. Ocean water can be conveniently split into shallow and deep ocean reservoirs. The stock of carbon in the atmosphere is usually expressed as ppm but this can be converted to a mass (1 ppm by volume of atmospheric CO_2 = 2.13 Gt C). 'Accumulations in economy' are the stocks of carbon in anthropogenic products such as oil in storage, concrete, wood products, steel, bitumen and landfill. Consistent with the SEEA Central Framework, Accumulations of carbon in the economy are disaggregated into Inventories (eg oil in storage) and Fixed assets (eg wood and concrete in buildings). Geosequestration is the depletion of highly stable and dense fossil carbon stocks stored in geological formations and accumulation of carbon in less stable and less dense reservoirs.

31. The row entries in the carbon stock account align with those outlined in the SEEA Central Framework: opening stock, additions, reductions and closing stock. In this, Additions to and Reductions in stock have been split between managed and natural expansion, while additional rows for imports and exports have been included.

There are six types of additions to the stock in carbon asset accounts.

i. **Natural expansion**: These additions reflect increases in the stock of carbon over an accounting period due to natural growth. This will be for mainly, perhaps exclusively, biocarbon.

ii. **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 inventories but will also be applicable to geocarbon with the injection of greenhouse gases into the earth.

iii. **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.

iv. **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.

v. **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 Ecosystems semi-natural by the establishment of a national park on an area used for agriculture would be equalized by an equivalent decrease in Ecosystems agricultural. Here, it is only the land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon.

vi. **Imports**: A line for imports is shown to enable accounting for imports of produced goods (e.g. petroleum products). It may be that the trade in carbon credits and potentially trade leading to changes in ownership of carbon assets may also need to be considered.

There are five types of reductions in the stock of carbon assets.

i. **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 Ecosystems natural) or biocarbon losses that might reasonably be expected to occur based on past experience. Natural contraction includes losses from episodic events including drought and some fires and pest and disease attacks. Natural contraction also includes losses due to volcanic eruptions, tidal waves and hurricanes.

ii. **Managed contraction**: These are reductions in stock due to human activities and include the removal or harvest of carbon assets through a process of production. This includes mining of fossil fuels and felling of timber. Extraction includes both those quantities that continue to flow through the economy as 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.

iii. **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.

iv. **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 offset by an equivalent increase in Ecosystems semi-natural. Here it is only the land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon.

v. **Exports**: A line for exports is shown to enable accounting for imports of produced goods (e.g. petroleum products). It may be that the trade in carbon credits and potentially trade leading to changes in ownership of carbon assets may also need to be considered.

Catastrophic losses, as defined in the SNA, are split between Managed contraction and Natural contraction.

32. Because of its comprehensiveness, the framework accommodates the approaches presented at the London meeting by Gundimeda (2011), Ivanov (2011) and Ajani (2011); however, being a physical account, it does not accommodate the monetary component of Gundimeda (2011). Populating the account for Australia is feasible for geocarbon using existing data sets. Populating the biocarbon segment was not possible because whilst single year carbon stock estimates have been prepared for large land areas [Australia (770 million ha); outback Australia (15 million ha); south east Australian eucalypt natural forests (15 million ha) and the Great Western Woodlands (16 million ha)] these studies have been one-off projects. They establish, however, the

groundwork for advancing the information base and here SEEA, in consultation with scientists, could provide crucial guidance with the aim of progressively populating the account with consistent data. Muukkonen (2011) identifies that whilst carbon flow accounts can draw heavily on data prepared for UNFCCC and Kyoto accounting, carbon stock accounts data for the land sector is another matter.

E. Data

33. There are strong arguments for comprehensive carbon asset accounts linked with UNFCCC flow inventories and incorporating a biodiversity-stability ecosystem classification. Linking will require a collaborative effort by experts in global carbon cycle science and ecosystems, the UN Statistics Division and the IPCC to develop common approaches to:

    a. Place where activity is recorded/stocks are held.
    b. Geographic coverage (i.e. comprehensive (including marine ecosystems) with consistent treatment of, for e.g., emissions from international transport fuel, stocks in international waters).
    c. Activity coverage (i.e. all anthropogenic and non anthropogenic).
    d. Geocarbon classifications including treatment of unconventional oil and gas sourced from same reservoir as conventional oil and gas.
    e. Classification criteria for Ecosystems natural, Ecosystems semi-natural, Ecosystems agriculture and Ecosystems other.
    f. Distinguishing anthropogenic from non anthropogenic stocks and flows.
    g. Netting (disentangling uptake from removals in the land sector).

34. Like the SNA's evolution, full data population cannot be immediate. Ad hoc projects estimating terrestrial carbon stocks will continue. Their value for researchers and policy could be significantly enhanced with SEEA providing guidance to build consistency in terminology, classifications and spatial and temporal decisions. The linking of carbon accounting to the core SNA and in particular to the transactions related to minimising the emissions of carbon (e.g. via taxes and emission trading schemes) would further enhance the usefulness of the carbon accounts. Preparing these guidelines requires collaboration with ecosystem scientists, global carbon cycle scientists and the IPCC.

F. Carbon and ecosystem accounting

35. The December Technical Expert Meeting on Ecosystem Accounts agreed that calculation of the balance of carbon remaining in an ecosystem after each period (sometimes referred to as 'net carbon balance') should be included as a key output of the accounting tables. Cosier (2011) considers it may be necessary for indicators of ecosystem condition to vary regionally because of varying environmental characteristics and the differing pressures on these landscapes. What constitutes a scientifically rigorous approach to measuring and reporting ecosystem condition falls within SEEA Experimental Ecosystem Accounts Issue 7 (Ecosystem Health/Total ecological potential).

36. Leaving this determination to one side, the following points are made regarding the potential for using the carbon accounts to derive estimates of carbon remaining after human appropriation as an indicator of ecosystem condition:

    a. The word 'balance' has been widely adopted such that its special meaning for closed systems is being lost. Such systems include international monetary transactions and the global carbon cycle where the flow of exchanges must balance. This is a simple but important understanding about system dynamics that informs researchers and statistical reporting. Two confusions are created if the word 'balance' is used to name a measure applying to ecosystems which are open systems. First, the use of the word 'balance' may create the misunderstanding that 'balance' exists and second, it may diminish understanding of systems where balance is a particular characteristic. An internet search suggests the practice is common with one of the more interesting examples: 'Seasonal carbon balance of sangiovese grapes grown in two different central Italy environments'.

b. The carbon asset accounting framework presented in Table 1 can provide change in carbon stock data disaggregated by ecosystem type with anthropogenic stock changes accounted for.

c. Meaningful indicators require the table uses an ecosystem biodiversity-stability quality classification and be populated with data that separates anthropogenic from non anthropogenic so that the influences of climate variability are distinguished from changes due to degradation or land use change.

G. Matters for discussion

37. Conceptually carbon asset accounting fits comfortably with the SEEA Central Framework approach. The generation of such an account combined with UNFCCC carbon flow accounts would significantly enhance the information available for public discussion, research and policy on matters concerning the global carbon cycle and land use in a world of limits. Preliminary work indicates that populating the account for geocarbon is largely feasible; this is not currently the case for biocarbon. This raises the following matters for discussion:

a) Following the SEEA Central Framework asset account framework to prepare the carbon asset account as presented in Table 1, what comments can be made about its structure and row and column classifications?

b) How can the SEEA process build the essential collaboration with the IPCC and other climate change and ecosystem scientists and the World Bank's WAVES project?

Table 1 Carbon asset account (physical units)

Tonnes of carbon	**Geocarbon**					**Biocarbon**				**Atmosphere**	**Water in Oceans**	**Accumulation in economy**		**Australian TOTAL**
	Rocks	Oil	Gas	Coal	Other	Ecosystems natural	Ecosystems semi-natural	Ecosystems agriculture	Ecosystems other			Inventories	Fixed assets	
Opening stock														
Additions to stock														
Natural expansion														
Managed expansion														
Discoveries														
Upwards reappraisals														
Reclassifications														
Imports														
Total additions to stock														
Reductions in stock														
Natural contraction														
Managed contraction														
Downwards reappraisals														
Reclassifications														
Exports														
Total reductions in stock														
Closing stock														

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