The building blocks for land and ecosystem accounting

INFORMATION PAPER FOR THE LONDON GROUP MEETING

STOCKHOLM, 12-15 SEPTEMBER 2011

Michael Vardon[1]

Mark Lound[2]

Valdis Juskevics[3]

Andrew Cadogan-Cowper[4]

[1] michael.vardon@abs.gov.au

[2] mark.lound@abs.gov.au

[3] valdis.juskevics@abs.gov.au

[4] andrew.cadogan@abs.gov.au

A. Introduction

1. The purpose of this paper is to identify, describe and classify the statistical building blocks needed for the production of environmental accounts in accordance with the System of Environmental-Economic Accounting (SEEA). In particular, the paper focuses on the building blocks for land and ecosystem accounts.

2. The building blocks of environmental accounts, and most of the data collected by national statistical offices, are called statistical units. A statistical unit is the entity about which information is sought and for which statistics are ultimately compiled[5]. It is the unit at the base of aggregates presented in environmental accounts or other tabulations of data.

3. The identification and description of the statistical units for land and ecosystem accounting is necessary to:

- Define the components of the environment (and, in particular, terrestrial ecosystems about which data are compiled) and the economic units that own or manage these units (from which data may be collected);
- Define the main characteristics of statistical units so that survey frames, related statistical process (e.g. sampling regime) and infrastructure needed for land and ecosystem accounts can be constructed or adapted from existing infrastructure;
- Describe the main classifications of statistical units relevant to land and ecosystem accounts;
- Understand how the characteristics and classifications of statistical units are useful for aggregating and disaggregating data.

4. In order to construct environmental accounts it is important that both the environmental and economic units are clearly articulated and that they are defined in such a way as to facilitate the collection and integration of data from different sources. The statistical units of the economy, including businesses and households, are well documented in the *System of National Accounts* (SNA) and related documents. National statistical offices, like the Australian Bureau of Statistics (ABS), have much experience in the use of economic units for the compilation of national accounts and other economic data.

5. The statistical units of the environment are less well documented. They have been identified for water accounts in the *International Recommendations for Water Statistics*. A range of progress has been made recently on the identification, description and aggregation of units for the production of land and ecosystem accounts.

6. How to treat the atmosphere, which is undoubtedly a key component of every ecosystem that supports living organisms, is an interesting question for statistical units. The atmosphere exists above the land, and it is likely that for some purposes the atmosphere should be a statistical unit in its own right (i.e. it is something we want information about) and that this unit can be subdivided (e.g. in airsheds). However, while the question is interesting it will not be addressed further in this paper.

7. This paper draws mostly on the ABS experience of developing environmental accounts. The ABS has produced of a range of environmental accounts over the past 15 years as well as being involved in a range of experimental work being undertaken by: Victorian and Queensland Government agencies; the Australian National University; Queensland University; catchment management authorities; a range of academics; and the Wentworth Group of Concerned Scientists.

[5] See UNSD October 20007 "Statistical Units" paragraph 14: http://unstats.un.org/unsd/isdts/docs/StatisticalUnits.pdf

B. Statistical units of the economy

8. The following information on the statistical units of the economy is drawn from the 2008 SNA[6] and the *International Recommendations for Industrial Statistics*[7]. For land and ecosystem accounting it is important to understand the statistical units of the economy as it is these units which own and manage the land and are responsible for everything that occurs on the land (e.g. the trees, soil, wildlife, agricultural crops and livestock).

9. The statistical units of the economy are enterprises, establishments and households. From these units information may be sought (e.g. where and how much land is owned by each unit) and from which this information may be collected (e.g. via survey). Importantly, economic units can report information about environment units.

1. Enterprises and establishments

10. An enterprise is an economic unit in its capacity as a producer of goods and services. An enterprise may operate one or more establishments, and may produce a variety of goods and services[8]. For example, a particular enterprise may be involved in retailing and have stores (i.e. establishments) located in different locations. In the course of production enterprises will use natural inputs (e.g. land and water) as well as other goods and services. Enterprises may own or lease land and undertake a variety of activities on the land. The way the land is used and managed by enterprises has significant impacts on the land cover, the condition of the soil and the availability and quality of water. Enterprises are classified to sector based on the legal characteristics of the enterprise.

11. An establishment is an enterprise or part of an enterprise that is situated in a single location and in which only a single productive activity is carried out or in which the principal productive activity accounts for most of the value added[9]. Establishments are also known as type-of-activity units (TAUs) or local kind-of-activity units (local KAUs)[10]. Establishments are classified to an industry (e.g. agriculture, mining, manufacturing, education) using the *International Standard Industry Classification Revision 4* (ISIC Rev. 4) [11] on the basis of their principal productive activity. For example, an establishment that gains most of its income from growing wheat will be classified as agriculture. Establishments also include government operations (i.e. a government office is an establishment) and these are assigned to an industry based on their productive activity. For example, a government operated water supply system would be classified to the water supply industry.

12. As establishments have a single location, economic activities can be linked to specific locations and placed within river basins, administrative areas or other geographic boundaries. It is important to distinguish establishments within enterprises when an enterprise has more than one establishment, especially when establishments are involved in different productive activities, or when they have the same productive activities but are located in different areas (e.g. river basins or administrative areas). For example, if an enterprise engaged in the making of wine consists of three separately located establishments including two vineyards where only grapes are grown and a third where grapes are grown and wine is made. It is important to separate the establishments within the enterprise as they will have different management activities and environmental impacts, while the different locations are likely to have different environmental characteristics. In particular, if the establishments are located in different river basins or

[6] 2008 SNA: http://unstats.un.org/unsd/sna1993/draftingPhase/WC-SNAvolume1.pdf

[7] UNSD February 2008 International Recommendations for Industrial Statistics: http://unstats.un.org/unsd/statcom/doc08/BG-IndustrialStats.pdf

[8] See 2008 SNA paragraph 5.1

[9] See 2008 SNA paragraph 5.3

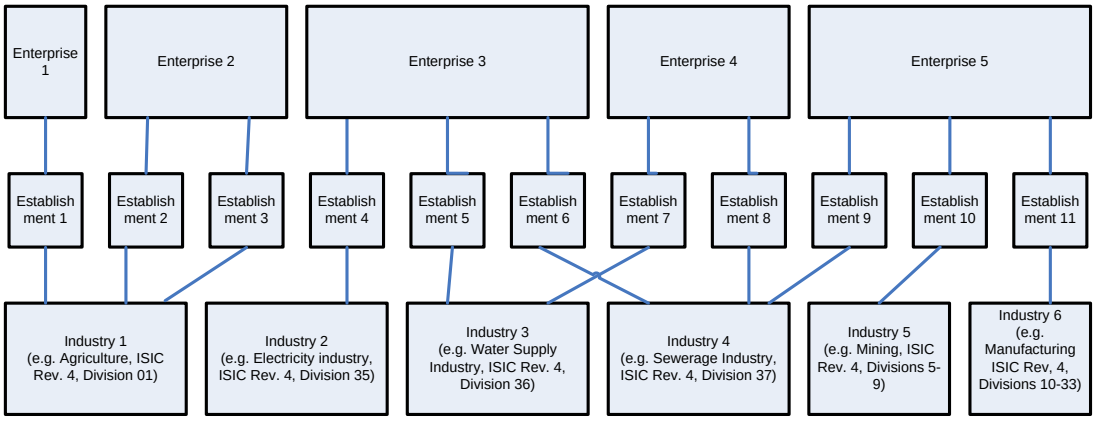
[10] See 2008 SNA paragraph 5.14

[11] See ISIC Rev. 4. http://unstats.un.org/unsd/cr/registry/isic-4.asp

administrative areas, then the environmental impacts may be incorrectly allocated to one river basin or administrative area rather than divided between the two.

13. For the purpose of compiling environmental accounts (and other data presentations) similar establishments are grouped by industry using ISIC Rev. 4. Figure 1 shows the relationships between enterprises, establishments and industry classification. An enterprise may have only one establishment and can be classified to industry on the basis of its principal activity, as is the case for Enterprise 1 and Establishment 1 in Figure 1. Establishment 1 is classified to Industry 1. In this case it could be one farm. An enterprise may have two or more establishments as is the case for Enterprises 2, 3, 4 and 5. In the case of Enterprise 2, the principal activities of both of its establishments are the same and hence are classified to Industry 1 (Agriculture, ISIC Rev. 4, Div. 01). It could be that the establishments are two farms, separated by distance, but owned and operated by one enterprise. Enterprises 3 and 5 each have three establishments, which each have a different principal activity and so are classified to three different industries. Enterprise 4 also has two establishments, and in the example shown (which is common in many countries), Enterprise 4 has establishments engaged in water supply (ISIC Rev. 4, Div. 36) and sewerage (ISIC Rev. 4, Div. 37) industries.

Figure 1: Relationship of enterprises, establishments and industry classification



2. Characteristics of establishments

14. For economic units, which usually equate to reporting units, Table 1 presents the six characteristics that should be recorded according to the *International Recommendations for Industrial Statistics*.

Table 1: Characteristics of establishments

Characteristics of economic units
1. Identification code
2. Location
3. Industry
4. Type of economic organisation
5. Type of legal organisation
6. Size*

**E.g. as measured by value of production or number of employees*

3. Households

15. The definitions of households used in demographic and social statistics and economic statistics are slightly different but very closely approximated[12]. In the SNA a household is defined as a group of persons who share the same living accommodation, who pool some, or all, of their income and wealth and who consume certain types of goods and services collectively, mainly housing and food. In general, each member of a household should have some claim upon the collective resources of the household. At least some decisions affecting consumption or other economic activities (as households can be producers) must be taken for the household as a whole[13]. In demographic and social statistics the concept of a household is based on the arrangements made by persons, individually or in groups, for providing themselves with food and other essentials for living[14].

16. The majority of the population live in households but there are also persons living in institutions that are not members of a household. This group constitutes the institutional households[15]. Persons living permanently in an institution, or who may be expected to reside in an institution for a very long, or indefinite, period of time are treated as belonging to a single institutional household when they have little or no autonomy of action or decision in economic matters[16]. Some examples of persons belonging to institutional households are members of religious orders living in monasteries, convents or similar institutions; long-term patients in hospitals, including mental hospitals; prisoners serving long sentences; persons living permanently in retirement or nursing homes and persons living in military bases.

17. Households can own and use land. The way the land is used (e.g. for building homes) has an impact on land cover and can also affect soil and water quality, among other things. In some cases an establishment and a household can be deeply entwined, as is often the case in farming.

C. Statistical units of the environment

18. The statistical units of the environment are the parts of the environment about which information is collected and accounts are compiled. Conceptually and practically some parts of the environment are difficult to separate. As a result the statistical units of the environment have proved challenging to identify and to date there has been no comprehensive assessment or description of these units for land and ecosystem accounts.

19. A part of this has been the difficulty of distinguishing between the base statistical unit and the aggregation and classification of units for the purposes of producing environmental accounts. A second difficulty has been the need to distinguish between area (the "land") and the biotic and abiotic entities which occur and interact on the land (the "ecosystem"). Also there has been some confusion in separating the unit from the characteristics or attributes of the unit that are to be measured (Annex 1 provides a preliminary list of the attributes of units to be measured). These issues are discussed later.

20. While the units for land and ecosystem accounts are still being developed they have been described for water accounting and it is useful to review these before the discussion on statistical units for land and ecosystem accounting.

Statistical units for water accounting

21. For water accounts the statistical units have been defined in the International Recommendations for Water Statistics as the inland water resources, split by surface water bodies and, with a number of divisions below these levels, aquifers (Table 2). In water accounts, the statistical units of the environment may be observation units or analytical units, but not reporting

[12] See 2008 SNA paragraph 4.150

[13] See 2008 SNA paragraph 4.149

[14] See Principles and Recommendations for Population and Housing Census Revision 2., paragraph 1.448

[15] See Principals and Recommendations for Population and Housing Census Revision 2., paragraph 1.455

[16] See 2008 SNA paragraph 4.152

units. For example, a lake can be a statistical unit but any information about the lake (surface area, volume of water contained, inflow, outflow and evaporation) will have to be reported by a unit of the economy that owns, manages or monitors the lake.

22. Each of the inland waters resources has a range of complex and interrelated characteristics. For example, a river consists of the water flowing through the river, the riverbed, riverbank, the primary channel and maybe a series of secondary channels. The river also provides habitat to living organisms (e.g. plants and animals) in the water or along the riverbed. In addition, the water in the river may also provide goods and services to the economy, such as water for irrigation, serve as a transport route or a sink for emissions. A river, a riverbed or a riverbank may be owned (in part or full) by different economic units. A river may also define administrative boundaries, for example, national borders.

23. It is important to note, that sometimes it is difficult to classify or find the exact boundary between the different water resources, for example where a lake ends and a river begins, where a river ends and an artificial reservoir begins, or a river ends and the sea begins. In practice the units for inland waters need to be classified on the best information available and this may require some subjective judgements. It is important to recognise that the classification of units is exclusive. That is a particular unit must be either a lake or wetland – it cannot be both.

24. The classification of wetlands is a particularly difficult task. The definition of wetlands provided below is after that of the *Ramsar Convention on Wetlands*. However, for the purposes of water statistics it has been modified as the Convention takes a very broad approach in defining wetlands. Article 1.1 of the Convention states:

"*For the purpose of this Convention wetlands* are *areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*".

25. Wetlands are further described in the *Ramsar Convention Manual 2006*[17] as:

"*Areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by shallow water*."

26. As such the *Ramsar Convention* definition of wetlands cuts across other definitions of water resources. That is, under the convention definition, artificial reservoirs, lakes and ponds, rivers and streams could all be defined as wetlands. Also the Ramsar Convention definition includes marine areas not in scope of the International Recommendations for Water Statistics. This is clearly seen in the classification of wetlands developed to support the Convention.

27. In the *International Recommendations for Water Statistics* it is recommended that countries base the categorisation of wetlands on water depth. That is areas of shallow water or permanently or temporarily saturated soils be identified as wetlands, as indicated in the Ramsar Manual. Countries can record the classification of particular water resources under the Ramsar Convention as one of the characteristics of statistical units.

28. Each of the units for water accounts has a range of characteristics. The *International Recommendations for Water Statistics* recommends six characteristics be attached to each unit. These characteristics are shown in Table 3. Additional characteristics may be added for particular water resources (for example, aquifers may be divided into confined and non-confined).

[17] Ramsar Convention Secretariat, 2006. *The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971)*, 4th ed. Ramsar Convention Secretariat, Gland, Switzerland. [Online 19/05/2009 http://www.ramsar.org/lib/lib_manual2006e.htm#cap1]

Table 2. Statistical units for water accounts

INLAND WATER RESOURCES	
Surface water	
Lakes	Depressions in the earth's surface occupied by bodies of standing water. Lakes generally contain large bodies of standing water, but also include small and shallow water bodies such as ponds and lagoons.
Rivers and streams	Consist of channels where water flows continuously or periodically.
Wetlands	Areas of marsh, fen, peatland, swamp or shallow water, permanently, intermittently or seasonally saturated with water.
Glaciers	Accumulation of ice of atmospheric origin, generally moving slowly on land over a long period. These include ice sheets; ice caps; ice fields; mountain glaciers; valley glaciers; and cirque glaciers[18].
Snow and ice	Areas where seasonal or permanent layers of snow and ice form on the ground's surface.
Artificial reservoirs	Man-made reservoirs used for storage, regulation and control of water resources.
Aquifers[19]	
Unconfined aquifer	Also known as a water table aquifer, is bounded below by an aquitard and has no overlying confining layer. Its upper boundary is the water level, which rises and falls freely. The water in a well penetrating an unconfined aquifer, which is at atmospheric pressure, does not rise above the water table.
Confined aquifer	Are bounded above and below by an aquitard. The groundwater pressure is usually higher than the atmospheric pressure and if a well is drilled into the aquifer, the water level may rise above the top of the aquifer.

29. It is usual for lakes, rivers, wetlands, artificial reservoirs, glaciers and groundwater resources to have a name, for example, Lake Baikal (Russia), The Amazon River (Brazil), Lake Kariba (Zambia and Zimbabwe), Malaspina Glacier (USA) and The Great Artesian Basin (Australia), etc. In some cases the name also accurately describes the type of water resource, as is the case with Lake Baikal and the Malaspina Glacier in the examples given above. However this is not always true, as, for example, Lake Kariba is an artificial reservoir. So, in the case of Lake Kariba, the "Type of water body" (Characteristic 4) would be artificial reservoir.

30. An identification code is a unique number assigned to each inland water resource. This may comprise of digits identifying its geographic location, type, management or physical characteristics. Identification codes should not change as long as the water resource (i.e. statistical unit) exists, even if some of the statistical unit's other characteristics change. Common identification codes, shared with hydrological institutions and other water research related agencies, administrative authorities and other government departments greatly facilitate the integration of data, for example ensuring that shared data can be readily attributed to the correct water resource (e.g. river, artificial reservoir, lake, aquifer, etc).

[18] For an extensive list of types of glaciers please see the National Snow and Ice Data Center website [Online 19/05/2009 http://nsidc.org/glaciers/questions/types.html]

[19] For the definition of unconfined and confined aquifers see FAO Aquastat glossary. [Online 23/06/09 http://www.fao.org/nr/water/aquastat/data/glossary/search.html]

Table 3: Characteristics of inland water bodies relevant to water accounts

Characteristics of inland water bodies
1. Name
2. Identification code
3. Location
4. Type of water body
5. Organisation(s) responsible for management
6. Physical characteristics

31. The location of the water resources should be recorded ideally as a standard file format (such as a shape file) readable by a geographic information system (GIS), for example, a line or polygon for a river and polygons for lakes, artificial reservoirs and aquifers. The location can also be recorded as occurring within a particular river basin or administrative area. The geographic centre (or centroid) could be used for lakes and artificial reservoirs but is less meaningful for rivers.

32. The type of water body is allocated according to the classification provided in Table 2. In many countries there may be further sub-division of these units. For example, rivers may be subdivided into stretches or segments, or be classified on the basis of the amount of water flowing through them over a particular period of time, artificial reservoirs by their storage capacity and groundwater by the nature of the aquifer (confined or unconfined). Some of these can be recorded in the physical characteristics of these units.

33. The organisation(s) responsible for managing the water resource is an economic unit (or units) such as, for example, a department of environment or local government agency. The characteristics of these economic units, as outlined above in the section on economic units, should also be recorded. This is important, as it is from these units that information about the water resources may be collected (e.g. via survey or administrative means). In cases where more than one economic unit has responsibility for management of a particular water resource it is useful to identify the organisation with principal responsibility for management and to note the roles of the other economic units.

34. The *physical characteristics* of the inland water bodies include a range of data, for example, the length, width and depth of artificial reservoirs, lakes and rivers. It should be noted that the physical characteristics may vary over time and that it may be useful to record ranges for particular characteristics (e.g. maximum, minimum, average).

D. Statistical units for land and ecosystem accounting

35. Land covers around 29% of the Earth's surface. By convention, the land is divided into seven continents: Africa; Antarctica; Asia; Australia; Europe; North America and South America. The continents of Asia and Europe are sometimes combined and referred to as Eurasia. Land also exists outside the continental land masses as islands. The area beneath the ocean, which comprises 71% of the Earth's surface and the space above the ocean floor is also of interest in environmental accounting (e.g. accounting for marine ecosystems) but are not considered further in this paper. On the land a range of ecosystems exist – often termed terrestrial ecosystems. There are also marine ecosystems, and both marine and terrestrial ecosystems are dependent on the atmosphere

36. The land contained by the continents and islands may be divided in a number of ways. For example, overlaying the continents and islands is a political geography of 196 countries [20], with

[20] In June 2006 the UN recognises 192 countries. Not recognised by the UN are Kosovo, South Sudan, Vatican City and Taiwan. http://www.un.org/en/members/index.shtml

many countries having sub-national political or management boundaries (e.g. states, provinces, counties, shires, etc.). In Australia there are 56 natural resource management regions, each with an agency responsible for managing the land, water and other natural resources within these regions.

37. The land may also be divided by physical boundaries, for example, on the basis of geomorphic or hydrological characteristics, such as the 354 drainage basins of the world or the 245 river basins[21] of Australia. Physical boundaries can also be a combination of geomorphic and biological characteristics, such as the eight bio-geographical provinces of the world[22] or the 85 bioregions of Australia[23].

38. Data outputs are required for both political and physical boundaries for environmental accounts, and often for a range of each type of boundaries. The output of social and economic data for both of these boundaries is derived by aggregating the data on the economic units (i.e. establishments and households) which occur within these boundaries, for example, population counts, number of businesses or amount of value added. The boundaries for geographic outputs are discussed again later in the paper.

39. Like the economic data, the output of environmental data should also represent the aggregation of data from the statistical units of the environment that occur within the geographic boundaries defined. For water accounting, the number of lakes and artificial reservoirs (both identified as specific types of environmental units) occurring within the boundaries are counted and various aggregates of data may be presented. For example, the total volume of water stored in both lakes and artificial reservoirs.

40. For land, the total area of a particular area can be reported (i.e. the number of hectares). However, the environmental units from which this total is aggregated is not clear. Conceptually the area can be built-up (or broken down) in two general ways: an approach based on cadastral parcels (i.e. the boundaries of the areas of land which are owned); and a grid based approach. Each of these approaches is described below.

41. Both approaches have their uses and importantly each approach enables units to be classified and like units grouped and aggregated to produce land accounts and other types of tables. Typical uses of each approach are also mentioned below.

42. To produce land and ecosystem accounts either approach may be used but it is likely that a combination of both methods would be needed to produce accounts of the greatest utility. The aggregation of the basic units into different geographic output areas, for example, river basins or counties, states /provinces is also addressed.

1. Grid based approach

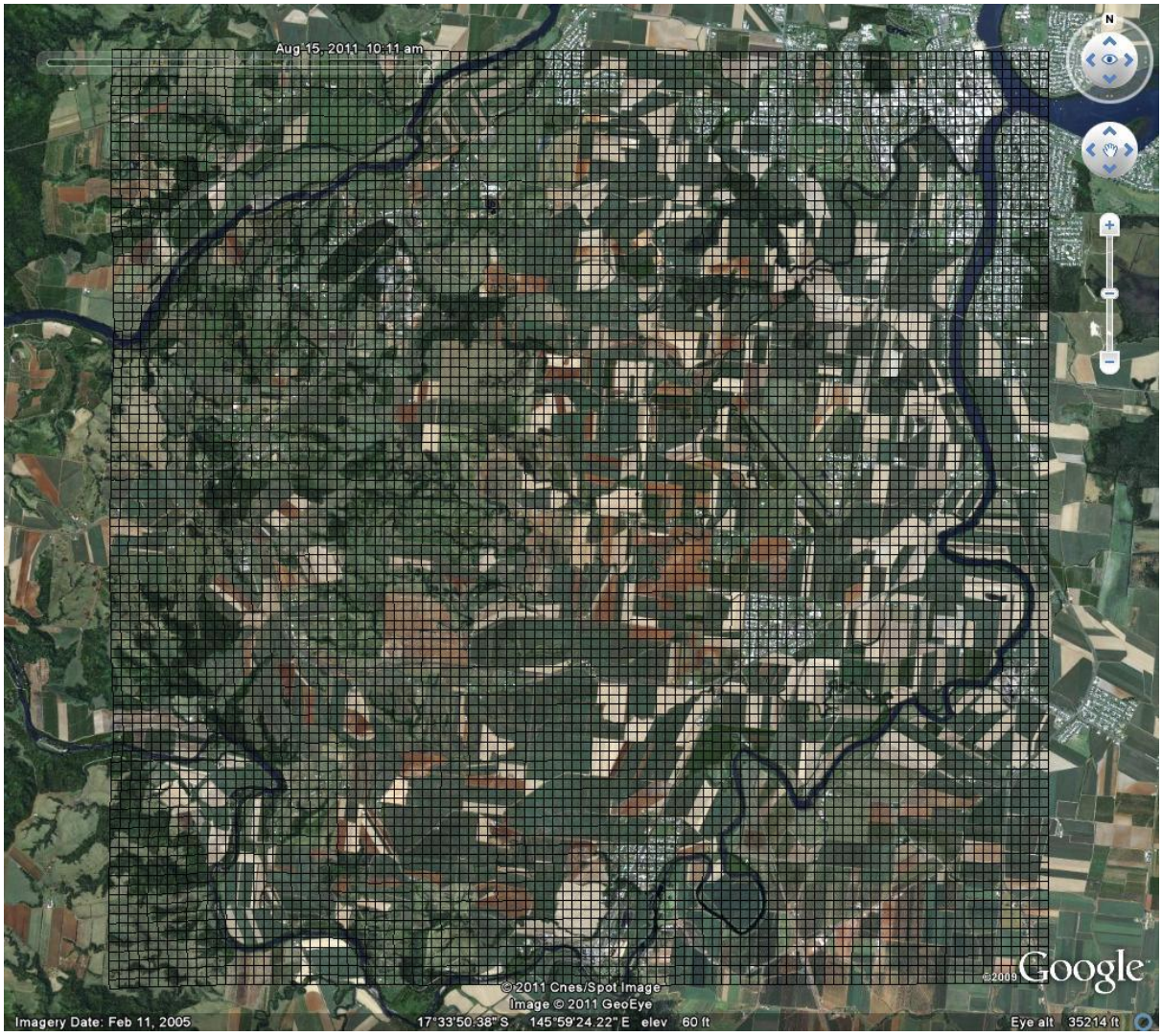
43. The grid approach is based on the division of land by an arbitrary grid to form the statistical unit of observation. The cells of the grid are the statistical units and can be of varying size, from 1 m^2 to 1km^2 or larger. The size of the grid varies with the source of data, and in general the source of the data determines the grid size. For example, a grid of one hectare cells (e.g. 100m x 100m) is overlaid on a satellite image in figure 2.

[21] Geoscience Australia 1997 http://www.ga.gov.au/meta/ANZCW0703005427.html#citeinfo (also see BoM website http://www.bom.gov.au/hydro/wr/basins/

[22] Udvardy 1975. A Classification of the Biogeographical Provinces of the World http://cmsdata.iucn.org/downloads/udvardy.pdf

[23] See Interim Biogreographic Regionalisation of Australia http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html

Figure 2. A grid of one hectare cells (100m x 100m).



44. Grid based approaches are used commonly for remotely sensed data; that is from images and other data gained from both satellites and aerial photography. For example, the Landsat satellite produces data at a range of resolution around 250 m^2, while the MODIS Satellite for 250 m^2 to 1 km^2. SPOT images can be for 25m^2 areas or less. Data mapped to 250m^2 grids from the Landsat and MODIS satellites underpin much of the land cover mapping in Australia and in particular the dynamic land cover dataset.

45. In the grid based approach, the characteristics of each of the grid cells are collected and each cell is coded to a particular type based on the combination of these characteristics. For the purposes of accounts, the number of the cells of the same class (e.g. forest, woodland, grassland, urban land, etc), within a particular boundary are counted and the total area presented in a table. The data from each of the grid cells can be added together to approximate different geographic output areas. For example, in the case of Australia, the grid data may be re-aggregated to provide data for states/territories, river basins or natural resource management areas.

46. In the grid based approach the cells of the grid will almost certainly not exactly match the shape of the desired output area. That is, some cells will be divided by the boundary of the output area. In these cases the cell, which is an observational unit, may be split into an analytical unit, to produce two smaller units the attributes of which can be divided between the two output areas.

2. Cadastral based approach

47. A cadastre is a register of the land covering the entire land area of country or sub-national political boundaries (e.g. states and provinces). The cadastre defines the legal boundaries of the land parcels which are owned and managed by people or organisations. For example, these land parcels may be owned and managed by businesses, not-for-profit organisations, households (individual people or groups of people) or the government. Figure 3 is a snapshot of the cadastre from Australia for the same area shown in figure 2. The land parcels or units of the cadastre shown are those that have the centroid of the parcel within the 10 km x 10 km area contained by the grid in figure 2.

Figure 3. A snapshot of the cadastre of Australia

48. A feature of the cadastre is that it evolves and the current cadastre represents the political, legal and administrative decisions of the past. In general, the size of the land parcels in the cadastre increases with distance from population centres reflecting the use of smaller land parcels for housing and non-agricultural economic activity. One useful attribute of using the cadastre as a statistical unit is that the economic activities of the owner or manager (a separate but related statistical unit) can be directly linked to the land.

49. Like the grid based approach the characteristics of the units of the cadastre can be used to classify them and then like units may be grouped for the purposes of reporting data in accounts. Importantly, the units of the cadastre can be linked and grouped according to the characteristics of

the owner of the land (i.e. the economic unit). This linking enables the cross-classification of the characteristics from both economic and environmental units at the unit record level.

50. Also like the grid approach, the cadastre land parcels will not exactly match the spatial boundaries of the output areas (i.e. some land parcels are bisected). This problem is typically small. For example of the 62,809 land parcels that make up the Burnett River Basin, only 912 or 1.4% of land parcels are bisected by the boundary of the basin.

51. The cadastre approach to units also shows linear features, such as roads, rivers and area for transmission of electricity as essentially one unit, rather than as a series of connected grid cells in the alternative approach.

3. Using the grid and cadastre based approaches

52. The two approaches represent different approaches to the collection, integration and dissemination of data. The grid based approach spatially locates data typically collected from satellites or from areas where particular observations are made (e.g. on-ground vegetation surveys done in plots). This can be described as physical data.

53. The cadastre based approach is perhaps best suited to the collection of data about the economic and other activities occurring on the land which are not easily observed by other means. It can provide information on urban and rural areas. In urban areas there is a high correlation of the characteristics of the owner or management of the land with the land cover and use. In rural areas the cadastre approach needs to be combined with physical data because the unit (i.e. the cadastral parcels) are larger and more likely to have more than one land cover and use.

54. The cadastre approach is particularly useful where the integration of physical and economic data is important. In this the physical data collected from a grid based approach can be combined with the data collected from surveys of households and businesses about the use and management of land as well as the social and economic characteristics of the owners and managers of the land. Some of these characteristics may be available from administrative data (e.g. land registers, tax data). This combination of approaches allows a range of analyses to be undertaken in addition to the construction of SEEA-style accounts.

55. The production of SEEA style accounts requires the delineation of spatial boundaries for the required data outputs. These could be existing physical or political boundaries or a hybrid of the two – like the accounting catchments described in the SEEA-Water[24].

56. Annex 1 lists some the characteristics of land and ecosystems that would be needed to construct environmental accounts and provides an indication of the approaches that could be used to collect and aggregate data.

4. Classification of environmental units

57. Environmental units, whether they be grid or cadastre based, may be classified on the basis of a range of characteristics including: vegetation cover, water cover, land use, soil type, terrain, elevation, rainfall, ownership, and management activities (See Annex 1). Units may also be classified according to a combination of characteristics.

58. In most cases the unit may display more than one type of a particular characteristic. For example, a farm (representing a cadastre based environmental unit) may have grassland and forest. In such cases two options are available. In the first case, the observational unit may be split into two analytical units, so that all of the grassland is in one unit and all of the forest is in the other. In the second case the unit is not split but the unit has a primary characteristic (i.e. what represents the greatest area) and a secondary characteristic (or secondary characteristics if there are more than two land cover classes)

[24] See SEEA-Water, paragraph 2.89 http://unstats.un.org/unsd/envaccounting/seeaw/

59. Several classifications for land use and land cover have been developed internationally and for Australia. These classifications can be applied to environmental units, whether the units are derived from grid or cadastre based approaches.

5. Identification, definition and description of ecosystems

60. The definition of ecosystems has proved elusive. In particular, the recognition that people and their activities are an integral part of the environment and earth's ecosystem[25], means that agricultural and urban areas need to be considered in the identification and classification of ecosystems.

61. Ecosystems are usually defined in terms of a suite of interacting components. However defined, the units that make up the environment are a mix of biological (e.g. plants and animals) and physical (rocks, minerals, water, etc.) and these interact in complex ways among themselves and with the units of the economy.

62. For land and ecosystem accounting a pragmatic way forward is to define ecosystems as all the living and non-living entities that occur in a particular place. In this case, a grid based statistical unit is probably the more appropriate and like statistical units may be grouped. For example, the grid cells containing rainforests, can be grouped to define a specific rainforest (e.g. the Daintree Rainforest). In this example, it is assumed that land cover is a proxy for ecosystems. The ecosystem can be described in more detail, according to species composition, structural components, time since fire disturbance or its condition in comparison to a particular reference state.

E. Conclusion

63. The identification, description and classification of statistical units are fundamental issues for the production of data needed for environmental accounts. Because of the multiple sources of data needed for environmental accounts it is important to understand and define the units at the base of aggregate outputs, whether the outputs are aggregation of units engaged in particular types of economic activity (e.g. the mining and manufacturing industries) or the aggregation of units for a particular spatially defined area (e.g. a river basin, state or province or accounting catchment).

64. The identification of units at the base of statistical aggregates – establishments and households (economic units) or grid or cadastre based spatial units (environmental units) – is needed to ensure sound statistical methods can be employed to collect, process and present data. The adoption of consistent units and the standard classification of units by agencies involved in data collection and processing will greatly enhance the ability of data from different sources to be integrated, analysed and be used for purposes other than that for which they were originally intended.

F. Acknowledgement

65. A great many people have contributed to the development of the ideas contained in this paper as well as provided comment on earlier drafts. I would particularly like to thank Jeremy Webb (UN Economic Commission for Africa); Alessandra Alfieri and Ricardo Martinez (UN Statistical Division); Jean-Louis Webber (European Environment Agency); Gary Stoneham (Victorian Department of Treasury and Finance); Mark Eigenraam (Victorian Department of Sustainability and Environment); Jane McDonald (Wentworth Group of Concerned Scientists); Phil Gibbons (Australian National University); Alistair Nairn, Eden Brinkley, Ben Searle, Brian Harrild, Duncan Cockburn, Tom Walter, Steve Hilly and John Ovington (ABS).

[25] Millennium Ecosystem Assessment 2005. Ecosystems and Human Well-being: A Framework for Assessment. (see page 26) [Online 18 June, 2010: http://www.millenniumassessment.org/documents/document.299.aspx.pdf]

Annex 1. Data items for land and ecosystem accounts

	Data item	Comment	Approach (data source)
Physical			
	Land area	e.g. hectares	Cadastre, business and household surveys
	Land cover	e.g. forest, grassland, 'hard' surfaces	Mostly grid
	Topography	e.g. slope, elevation	Mostly grid
	Species	both plants and animals	Mostly grid
	Soil type		Mostly grid
	Soil depth		Mostly grid
	Soil nutrients		Mostly grid
	Climate	Rainfall, temperature, wind	Mostly grid
	Water resources	e.g. water source (river, lake, artificial reservoir, soil water) by volume	Grid and cadastre
	Subsurface resources	Minerals, oil and gas	Grid and cadastre
	Timber		Mostly grid
	Ecosystem goods and services		Grid, business and household surveys
Socio-economic			
	Ownership	e.g. by sector or industry	Cadastre, business and household surveys
	Operation (leased land)	e.g. by sector or industry	Cadastre, business and household surveys
	Land management activities	e.g. by Classification of environmental and land management activities	Cadastre, business and household surveys
	Land use	e.g. by production of goods and services	Cadastre, business and household surveys
	Land value		Cadastre
	Other natural resource values	e.g. timber, water	Cadastre, business and household surveys
	Income	e.g. household and business	Cadastre, business and household surveys
	Taxes paid	e.g. household and business	Cadastre, business and household surveys
	Zoning	e.g. residential, industrial, commercial, etc	Cadastre
	Fixed assets	e.g. buildings and other produced assets on the land	Cadastre, business and household surveys