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SEEA Technical Note: Land Accounting

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SEEA Technical Notes

This note is a part of a series of Technical Notes prepared to support the development of data based on the System of Environmental Economic Accounts (SEEA) Central Framework, the first international standard in environmental economic accounting. Since SEEA is not a single account but a series of modules, the accounts in each of the various modules can be developed separately in accordance with the priorities and the resource availability in each country.

The series of Technical Notes is comprised of a) a note addressing general issues that cut across domains focusing on institutional arrangements and institutional processes that encourage efficient implementation of the standard and associated data compilation exercises (see *Institutional Arrangements and Statistical Production Processes for the Implementation of the SEEA-Central Framework*) and b) a number of notes on specific modules. It is recommended that those wishing to develop data related to any of these specific modules should read the cross cutting note in conjunction with the note on the specific modules to be developed.

The notes on modules summarize the data requirements and other operational considerations in 10-15 pages designed to provide sufficient guidance to initiate the development of the accounts. The notes also provide reference information for additional publications that will support the full development of the accounts and provide information on extensions and linkages that can be exploited once the accounts and tables are in place.

I. Introduction to land accounting

1. Land is a unique asset that delineates the space in which human activities and environmental processes take place, and within which environmental assets and economic assets are located. Land is central to economic and environmental accounting. Beyond an assessment of the ownership and use of land as part of economic production, some of the issues that can be considered in the context of land accounts include the impacts of urbanisation, the sustainability of agriculture and forestry, the use of inland freshwater resources, and biodiversity conservation.

2. This technical note provides an overview of land accounting according to the System of Environmental Economic Accounting 2012 Central Framework (SEEA CF) which was adopted by the United Nations Statistical Commission in 2012 as the international statistical standard for environmental economic accounts. The general purpose of SEEA Technical Notes is to summarise the key features for a given topic to support countries in the implementation of the SEEA.

3. Land area is analysed in many different ways and as such accounts can be prepared from several points of view. From a spatial point of view, accounts can be compiled for the country as a whole or for regions within countries. For example, accounts can be compiled for administrative regions (e.g. state, provincial or local government boundaries) or bio-physical regions. That is, regions based on the physical characteristics, such as flora and fauna or topography (e.g. mountains, plains). From an economic view point, accounting can be done by the area of land owned by different institutional sectors, land used by different industries and land zoned for different activities (e.g. residential, industrial, conservation).

4. Land also constitutes an important component in the assessment of national and institutional sector wealth. Land is bought and sold in combination with physical attributes of the land (e.g. soil) and the produced assets that may be located on the land (e.g. buildings) and, thus, the composite value will incorporate these values as well as a value of the space itself (the location).

5. In addition, land accounts also help unlock the power of Geographic Information Systems (GIS) to locate areas of change and map a wide range of social, economic and environmental information. While the focus initially is to build environmental-economic information at the national level, local environmental conditions can vary widely across a country resulting in the need for analysis and policy action that differ by local area. GIS can be very important in integrating data sets organized by administrative regions and others organized by bio-physical or topographic regions.

6. National assessments of the changing shares of different categories of land use and land cover within a country can provide useful indicators of change. For example, how changing shares of land cover and land use relate to income generation over time. Such information can be used to assess how factors interact in particular regions and help to target policy action appropriately.

7. The land accounts can be used to produce a range of indicators identified in international initiatives. For example, the Commission for Sustainable Development[1] has

[1] See https://sustainabledevelopment.un.org/csd.html for more information on the Commission's work.

indicators for land use change, land degradation, arable area, and forest area. Furthermore, land accounts are the central to ecosystem accounting. Land areas may be used to provide a measurement basis for ecosystem accounting in a similar way to which statistical units, such as establishments, provide a basis for measurement in economic statistics. SEEA Experimental Ecosystem Accounting develops these ideas in more detail.

8. Section II has brief discussion of SEEA-CF accounts and classifications for land coverage and land use. Section III describes the Core tables for land that will ultimately be important in developing international data sets. Section IV deals with the data sets required to produce the core tables including the main concepts, data sources and compilation methods. Section V describes how the core tables and related datasets may be extended to address broader issues and linked to other data sets. Section VI provides references and links to supporting material.

II. SEEA-CF accounts - land

9. Land accounts can be prepared in both physical (e.g. hectares) and monetary ($, €, ¥, etc.) terms. The SEEA-CF accounts that are most fundamental for land are the Asset accounts for land, first with land classified by land cover and secondly, classified by land use.

10. At its most basic level, land cover comprises all of the individual features that cover the area within a country. For the purposes of land cover statistics the relevant country area includes land and inland waters. The area of coastal waters is generally excluded from land accounts but provision is made to extend the coverage to include coastal waters and the Exclusive Economic Zone (EEZ) if there is a need (e.g. because fish or other marine resources are harvested).

11. The SEEA definition of land cover and the full classification are presented below:

Land cover *refers to the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces*[2].

12. Current land cover is a function of natural changes in the environment and of previous and current land use, particularly in agricultural and forestry areas. Thus, a clear and systematic description of classes of land cover allows the land cover classification to be compared with that for types of land use, while maintaining pure land cover criteria.

13. The 14 classes in Table 1 constitute a set of land cover types with clear boundaries based on definitions from the Land Cover Classification System (LCCS) of the FAO. This land cover classification can be used at all scales, independently of the method of observation, thus allowing cross-referencing of local and regional maps with continental and global maps without loss of information. Extended descriptions of the classes are provided in Annex I.[3]

[2] Definition from the SEEA Central Framework, paragraph 5.257

[3] As part of the SEEA Central Framework research agenda (see annex II), the interim land cover classification presented in table 5.12 will be further tested to ensure its suitability for the standardization of statistical data sets at the international level. Note that wetlands may be part of multiple classes. Work is underway to identify secondary classes to address this issue. In the meantime, if wetlands are a subject of interest, it may be desirable to separately identify them within each class.

Table 1 Land cover classification (interim)

	Category
1	Artificial surfaces (including urban and associated areas)
2	Herbaceous crops
3	Woody crops
4	Multiple or layered crops
5	Grassland
6	Tree covered areas
7	Mangroves
8	Shrub covered areas
9	Shrubs and/or herbaceous vegetation, aquatic or regularly flooded
10	Sparsely natural vegetated areas
11	Terrestrial barren land
12	Permanent snow and glaciers
13	Inland water bodies
14	Coastal water bodies and inter-tidal areas

14. In effect, an area that is "used" implies the existence of some human intervention, including active management. Land in use therefore includes protected areas which are under the active management of institutional units of a country for the purpose of excluding most economic or human activity from that area. Land use is defined as follows:

Land use *reflects both (i) the activities undertaken and (ii) the institutional arrangements put in place; for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions*[4].

15. Not all land in a country is used following the definition above. Some areas are "not in use", although they may have a use in supporting ecosystems and biodiversity. In order to provide a complete accounting for land use within a country, both land in use and land not in use must be included.

16. The complete classification for land use comprises 46 basic classes and is presented in full in Annex I of SEEA-CF, with a summary presented in Annex II of this note. The higher level classes for land and the classes for inland water are presented below. Classes for coastal water and the EEZ are parallel to those for inland water.

[4] Definition from the SEEA Central Framework, paragraph 5.246

Table 2 Land use classification

1	**Land**
1.1	Agriculture
1.2	Forestry
1.3	Land used for aquaculture
1.4	Use of built up and related areas
1.5	Land used for maintenance and restoration of environmental functions
1.6	Other uses of land n.e.c.
1.7	Land not in use
2	**Inland waters**
2.1	Inland waters used for aquaculture or holding facilities
2.2	Inland waters used for maintenance and restoration of environmental
2.3	Other uses of inland waters n.e.c.
2.4	Inland waters not in use

17. Data from remote sensing (either aerial photography or satellite images) are increasingly available for the entire area of a country and can form the basis of preliminary land cover accounts. Remote sensing images can provide some indication of land use but these data can also be difficult to interpret in some cases. Additional precision can often be found in a range of administrative datasets (e.g. those of local governments) associated with the regulation of land use. Constructing preliminary datasets based on remote sensing data can identify where additional administrative data are most needed. Ultimately, classification in the most challenging cases may require on site verification.

18. Account 1 shows the Physical asset account for land cover from the SEEA Central Framework. It shows the opening and closing areas for different land cover types and various additions and reductions in those areas over the accounting period. The different additions and reductions are explained in the following paragraphs.

Account 1: Physical asset account for land cover (hectares)

	Artificial surfaces	Crops	Grassland	Tree covered area	Mangroves	Shrub covered area	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow, glaciers and inland water	Coastal water and inter-tidal areas
Opening stock of	12 292.5	445 431.0	106 180.5	338 514.0	214.5	66 475.5	73.5	1 966.5		12 949.5	19 351.5
Additions to stock											
Managed expansion	184.5	9 355.5									
Natural expansion			64.5								1.5
Upwards reappraisals			4.5	181.5							
Total additions to stock	184.5	9 355.5	69.0	181.5							1.5
Reductions in stock											
Managed regression			4 704.0	3 118.5	9.0	1 560.0	1.5				
Natural regression					1.5	64.5					
Downwards reappraisals						4.5					
Total reductions in stock			4 704.0	3 118.5	10.5	1 629.0	1.5				
Closing stock	12 477.0	454 786.5	101 545.5	335 577.0	204.0	64 846.5	72.0	1 966.5		12 949.5	19 353.0

19. Managed expansion represents an increase in the area of a land cover type due to human activity. For example, crop areas may be converted to tree covered areas as a result of silvicultural measures such as planting and seeding, or tree covered areas may be converted

to crop or grassland following tree clearing. Generally, the managed expansion of one land cover type will also lead to the recording of a matching entry for managed regression of another land cover type or types. In the rare case where there is a managed expansion in the total area of land within scope of the account (e.g. in the case of land reclamation) a matching entry is not recorded.

20. Natural expansion is an increase in area resulting from natural processes including seeding, sprouting, suckering or layering. In the case of sparse natural vegetation and terrestrial barren land, the natural loss of vegetation from other vegetation types would lead to increases in these areas. Changes in the extent of permanent snow, glaciers and inland water bodies can also be due to natural variation in, for example, rainfall. Generally, the natural expansion of one land cover type will also lead to the recording of a matching entry for natural regression of another land cover type or types. Again a matching entry is not recorded in rare cases where there is a natural expansion in the total area of land within scope of the account (e.g. in the case when land is created through volcanic activity or landslide).

21. Managed regression represents a decrease in the area of a land cover type due to human activity. As for managed expansion, a matching entry is recorded in all cases of managed regression, except in cases where there is a managed regression in the total land area.

22. Natural regression should be recorded when the area of a land cover type reduces for natural reasons. As for natural expansion, a matching entry is recorded in all cases of natural regression, except in cases where there is a natural regression in the total land area (e.g. the loss of land due to erosion by the sea).

23. Reappraisals can be upward or downward and reflect changes due to the use of updated information that permits a reassessment of the size of the area of different land covers. For example, new satellite imagery or updated interpretation of satellite imagery or new administrative data sources. The use of updated information may require the revision of previous estimates to ensure a continuity of time series.

24. Account 2 is the Physical asset account for land use and has the same rows as the physical asset account for land cover as described above. With columns based on the Land use classification.

Account 2: Physical asset account for land use

Example to be added.

25. Land cover and land use are interrelated. For example, land uses associated with agricultural production are closely aligned to crop area. However, while land use and land cover can be closely related, this is not always the case. For example, tree covered areas can be used for forestry, for the maintenance and restoration of environmental functions, or may not be used at all (i.e. land not in use). Another common example is grazing land which is agricultural land use but would show up as grasslands or sparse trees as land cover.

26. With data structured in an accounting format based on common statistical units, it is possible to link land cover to land use. This allows the preparation of accounts showing land cover by land use as well as matrices showing the changes in both land cover and land use over an accounting period. In assessing land cover and land use change, it may be useful to

determine the proportion of the opening stock of land whose cover or use has remained unchanged. To undertake this type of analysis the data must be based on spatially referenced data sources.

27. The basic land accounts are very important for establishing the long run potential to describe and analyse data in varying geo-spatial configurations. This foundational aspect of these accounts and associated datasets needs to be a primary consideration from the outset of developing the SEEA based information for land. Before developing a GIS system (or modifying an existing one) for environmental-economic accounts, one should consider the full breadth of potential bio-physical and economic datasets that one might want to eventually integrate. Also it has to be kept in mind that land accounts are at the core of ecosystem accounting. Where ecosystem accounting is a priority in a country, that link needs to be kept in mind when designing the land accounts.

28. Account 3, the monetary account for land requires the separation of the value of land from other attributes that contribute to the market value of the combined asset – land plus, for example, produced assets that may be located on the land (e.g., buildings). As monetary valuation of land is required for the national accounts, it is not specifically addressed in this note. However, it should be pointed out that the information on land use contained in the SEEA accounts may be useful in improving the estimates of the value of land for the national accounts balance sheet.

Account 3: Monetary asset account for and use

	Type of land use								Total
	Agriculture	Forestry	Land used for aquaculture	Use of built up and related areas	Land used for maintenance & restoration of environmental functions	Other uses of land n.e.c.	Land not in use	Inland water	
Opening value of stock of land	420 000	187 500		386 000	2 000				995 500
Additions to stock									
Acquisitions of land	3 500								3 500
Reclassifications		200		2 500					2 700
Total additions to stock	3 500	200		2 500					6 200
Reductions in stock									
Disposals of land		3 500							3 500
Reclassifications		1 250			200				1 450
Total reductions in stock		4 750			200				4 950
Revaluations	18 250	15 350		65 000					98 600
Closing value of stock of land	441 750	198 300		453 500	1 800				1 095 350

29. Another important characteristic of land, is that of ownership, which is generally requires access to administrative records. Ownership information can allow the creation of datasets by economic activity or economic sector which may be very useful in some policy applications.

30. Land may in some cases support more than one use. While the basic classification should reflect the dominant use, capturing information on secondary uses may be important in some environmental context, for example land primarily used for agriculture may also support animal habitats in peripheral areas such as wind breaks and hedge rows.

III. Core Tables and Aggregates / Indicators for land

31. There are two core tables for land – the land cover change matrix and the land use change matrix.

32. Generally the total area of land for a country will remain unchanged from one period to the next and so the total opening and closing stock of land in physical terms (hectares) will be unchanged. However, there are situations where the area of land for a country may change. It may increase, for example due to reclamation of land through the construction of dykes and other barriers. It may also decrease, for example due to land subsidence or higher water levels.

33. Changes in the total area of land may also occur due to political factors. For example, the total area may increase or decrease due to war and associated events and or possibly resolution of areas of disputed territory[5].

34. The starting point for land cover tables is the classification of opening and closing stocks of all land in the country by land cover. These data form the foundation of the Physical Asset Account for land cover and the land cover change matrix as described in SEEA-CF.

35. The Land cover change matrix (see Table 4) shows the area of different land cover types at the beginning of the reference period (opening stock), the net increases and net decreases according to the land cover type it was converted from (in the case of increases), or what it was converted to (in the case of decreases), and finally, the area covered by different land cover types at the end of the reference period (closing stock). The table shows, for example, that between opening and closing stocks the area of crops grew from 7,756 to 8,454 thousand hectares, comprising additions to crop area from grassland (643,000 ha), tree covered area (12,000 ha) and regularly flooded areas (43,000 ha). The table also shows the corresponding reductions (as negative numbers) to the areas of grasslands, tree covered area and regularly flooded areas.

[5] If total land area changes due to any of these rare circumstances, all data outputs and the associated metadata should clearly indicate the size and reason for the change.

Table 4 Net land cover change matrix (hectares)

Land cover		Net increases (positive numbers) and decreases (negative numbers) from other land covers												
(1,000 ha)	Opening stock	Artificial surfaces (including urban and associated areas)	Crops (herbaceous, woody and multiple/layered)	Grassland	Tree covered area	Mangroves	Shrub covered area	Shrubs and/or herbaceous vegetation, aquatic or regularly flooded	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow, glaciers and inland water bodies	Coastal water and inter-tidal areas	Net change	Closing stock
Artificial surfaces (including urban and associated areas)	987	*	-	29	-	-	-	-	-	-	-	-	29	1016
Crops (herbaceous, woody and multiple/layered)	7756	-	*	643	12	-	-	43	-	-	-	-	698	8454
Grassland	14345	-29	-643	*	-	-	-	-	-	-	-	-	-672	13673
Tree covered area	23345		-12	-	*	-	-	-	-	-	-	-	-12	23333
Mangroves	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Shrub covered area	16342	-	-	-	-	-	*	-	-	-	-	-		16342
Shrubs and/or herbaceous vegetation, aquatic or regularly flooded	567	-	-43	-	-	-	-	*	-	-	-	-	-43	524
Sparse natural vegetated areas	112	-	-	-	-	-	-		*	2	-	-	2	114
Terrestrial barren land	45	-	-	-	-	-	-		-2	*	-	-	-2	43
Permanent snow, glaciers and inland water bodies	-	-	-	-	-	-	-	-	-	-	*	-	-	-
Coastal water and inter-tidal areas	-	-	-	-	-	-	-	-	-	-	-	*	-	-
* Diagonal cells are empty by definition.	63499	-29	-698	672	12	0	0	43	-2	2	0	0	0	63499

36. It is important to understand that the matrix shows net changes, which may mask information. For example, if natural forest is lost in one place but an equal amount of plantation forest is added elsewhere, then no net change of tree covered area would be shown. Similarly, when agricultural land is converted into built-up land, but, at the same time, agricultural land is created through deforestation, total crop or grassland (used for agriculture) may not change. Where these phenomena are relevant, the format of Table 1 can be extended to show increases and decreases in separate tables and thus allow more detailed analysis[6].

37. The core table for land use is the land use change matrix structured the same as the land cover change matrix (above) Rows and columns showing land cover classification in Table 4 would be replaced with the land use classification presented above in Table 2.

38. Countries should look at the full classification structure in determining to what level it will classify land use in its own systems. It should consider the extent and degree of variation of specific land covers and uses, along with the analytical and policy requirements. Given there are only a total of 34 basic classes for land and four each for inland water, coastal water and EEZ, it is recommended that countries consider coding at the lowest level of the classification.

39. The level of classification of land use will determine the extent of indicators that can be prepared based on the land asset account information. The more detailed the initial

[6] Presenting the data in maps can be very useful in setting out gross changes in land uses.

classification the more detailed the indicators that will be potentially available to address policy needs.

40. The land accounts information is important in informing at least four of the proposed indicators for the Sustainable Development Goals currently under discussion for the post 2015 agenda. The four currently identified as potential indicators are:

i. Proposed Indicator for Target 15.1: Forest area as a percentage of total land area
ii. Proposed Indicator for Target 6.6: Change in wetlands extent over time (% change over time)
iii. Proposed Indicator for Target 2.4: Emissions of greenhouse gases in agriculture (per hectare of land and per unit of output, separately for crop and livestock sectors).
iv. Proposed Indicator for Target 15.1: Coverage of protected areas broken down by ecosystem type, including total area of forests in protected areas (thousands of hectares)

41. While the first indicator comes directly from the Land Cover accounts, the other three require information from other SEEA accounts or extensions to the accounts.

42. For example, the second indicator requires the separate identification of wetlands which can be found in more than one of the basic classes of the interim Land Cover Classification. If this indicator is required, then separate identification of wetlands within these classes should be undertaken in the initial preparation of the data.

43. The third indicator requires additional information from the Air Emissions Accounts identified by ISIC classes[7]. It would also require the identification of land use by industry. Linked land use to industry would be an extension to the core table information that should be considered for the development of these sort of indicators.

44. The fourth indicator requires information on ecosystem accounts. Land accounts are the fundamental link between the accounts in SEEA-CF and the Ecosystem Accounts. In building the land accounts, it will be important to assure that the foundation for this important linkage are put in place.

45. The land accounts are also specifically linked to two of the OECDs proposed Green Growth Indictors (numbers 7, and 10) and would be useful in delineating areas for a third (number 11) :

- Indicator 7. Forest resources (area and volume of forests; stock changes over time);
- Indicator 10. Land resources (land cover types, conversions and cover changes; land use state and changes);
- Indicator 11. Soil resources (erosion of topsoil, particularly on agricultural land)

46. The generation of indicators of various types for regions within a country will depend on the level and quality of special coding available within the systems used to produce SEEA

[7] See the separate Technical Note being prepared on the Air Emissions Account for additional guidance on this subject.

accounts. As noted earlier, the Land accounts form the foundation for such efforts and consideration of the full range of desired indicators should be undertaken at an early stage.

IV. Compilation

47. The initial compilation of a land account will require several steps that may not need to be undertaken for each data cycle but should be revisited periodically in conjunction with periodic budget and planning cycles:

i. Define the accounts of interest, the desired geographical scope, the frequency of reporting (e.g. 3 yearly, annual, quarterly), the temporal basis (e.g. financial year, calendar year, hydrological year) and the desired level of geographic coding and considering other data to be linked (e.g. economic statistics, social statistics, population).

48. Setting out the specific accounts and the dimensions of each account that would best respond to the information needs of the country should be done at this stage. This will provide a basis to examine the adequacy of the existing data and assess where additional information may be required.

49. Particular attention should be made to how these land accounts will be linked to the ecosystem accounts and the national accounts.

50. Land accounts will be important in constructing a number of the indicators being proposed to support the SDGs. These indicators may require additional detail beyond that in the core tables such as the separate identification of wetlands within classes 6 and 9 of Land Cover.

ii. Identify potential data sources and assess their suitability for accounts (considering, spatial and temporal coverage, classifications used, frequency of production, accuracy and ease of access of data). In this step the metadata associated with the data sources should be closely examined to assess coherence between data sources and consider where methodologies for differences in concepts, coverage (including units of observation), timing and classification will be required.

51. As mentioned earlier, there is often national or international information available on land cover, typically derived from remote sensing. As well as information on agriculture — a major use of land — available from Agricultural Surveys or Censuses. Since land use is often regulated at the local government level, accessing administrative information which can be important in refining the land cover and land use estimates may require working with a large number of administrative entities or agencies and thus require considerable initial effort.

52. Cadastral data sets that bring together administratively based information on all or significant portion of a countries land are available for many countries. These may provide sufficient information for the initial classification of various land uses with the reference to a single dataset.

53. The integration and arrangement of this information requires skills and knowledge of GIS in addition to statistical skills and knowledge of accounts and information about land. A prerequisite to the successful ongoing production of land accounts is GIS information technology.

54. At this point if sufficient basic data are not available to produce one or more of the accounts, it may be necessary to initiate a project to generate the missing data. This may well

mean that account development splits into two paths one for the accounts that can be initiated with existing data and one where development will have to await the availability of basic data.

55. In some cases where partial data exist but there are some important data gaps it may be a good idea to construct a preliminary account filling in missing data with the best available estimates. While such an exercise may not produce a viable account, it may well reveal more about the extent and importance of data gaps thus providing a better foundation for the development of these missing basic data.

56. In the case where basic data must be developed, it is recommended that a separate project be initiated to develop the necessary data. This project should follow the GSBPM steps and generic principle as set out in the first note in this Technical Note series. Depending on the organization of responsibilities within the statistical infrastructure of the country this step may involve additional agencies or sectors of the NSO.

57. In cases where the existing data is in another agency the establishment of institutional and operational arrangements governing the shared use of these data may need to be put in place before the data can be secured. Again this may require that development of different accounts proceed along different time paths.

iii. Secure access to data, associated metadata and the rights to disseminate the accounts that are derived from that data. Where needed obtain access to expertise in organizations from which data is being sought to assist with analysis and/or training.

58. SEEA compilers will at an early stage need to assure access to these data if it doesn't already exist. A key consideration is the terms of access under current institutional arrangements. These should support cooperative working arrangements and the release of the land accounts with sufficient detail to address the policy issues important for the country.

59. In cases where institutional arrangements are not yet established, it should be noted that this step can take considerable effort and time as it will be important for all agencies involved to clearly appreciate the mandate of the other agencies and associated constraints.

60. Establishing and maintaining good working relations with the agencies that are the source for basic data can pay dividends later in the production process when estimation challenges can benefit from expertise in all concerned agencies.

iv. Set out a plan for the progressive implementation of SEEA based on the availability of resources and basic data.

61. While data sources for particular countries will vary, data are typically available from government agencies concerned with: agriculture; forestry; fishing; environment; geological survey; urban planning and land administration. Statistical offices may also have data on agricultural, and/or natural resource management practices more generally, based on surveys. The operators of satellites, such as the European Space Agency (ESA) and National Aeronautics Space Administration (NASA), international agencies such as the Food and Agricultural Organisation (FAO) as well as conservation organisations (such as Artificial Intelligence for Ecosystem Services ARIES) also provide information on land cover, land use and other data related to land.

62. Broadly, three sources are used – satellite images, administrative data and field surveys. Satellite images are important as they enable a broader assessment of all areas in a country, and as higher resolution images become available permit more detailed analyses. Administrative sources can provide more precise information for some land areas. Field surveys are important as they can provide a high level of specificity regarding the land cover and, in particular, the land use in a given area. Increasingly, data based on combinations of satellite images, administrative data and field surveys are being compiled.

63. While sources such as satellite imagery can provide data on the entire country, it should be pointed out that challenges in classification will need to be carefully considered. As with many classification processes one must consider dominance in coverage of a particularly area and that may be difficult to ascertain depending on the resolution of images available. Also, in some instances images may hide coverage aspects, for example a tree covered wetland will often from a satellite image simply look like any tree covered area.

64. In developing land accounts a particular need is to understand the means by which the underlying data on land cover and land use are collected and the original purpose of the collection when using administrative data.

65. The original purpose of administrative data can influence what is recorded in a particular dataset. For example, continuing the tree covered wetland example, given the responsibilities of a forestry agency, it would likely record this as forest and not as wetland. Whereas another agency responsible for policies or regulations affecting water might record it as a wetland. Working closely with the originating agencies and fully considering the associated metadata will be important to insure the appropriate integration of such alternate data sets.

66. In some cases, the data may be collected and compiled so that the location of the data is known. For example, data may be attributed to a particular point (e.g. via coordinates of latitude and longitude) or in reference to small areas, such as grid cells (e.g. 100m x 100m), land parcels (e.g. the areas of land defined by land ownership as identified in land title registers) or small areas defined by particular administrative or data collection requirements (e.g. census collection districts).

67. Data on land values and land ownership are often to be found in administrative data sets. These characteristics often require particular attention to confidentiality constraints. Also, as mentioned earlier, separating the value of land from other attributes such as structures is a complex task. Attention should be paid to what attribute information is available from any datasets that are to be used. The most up to date guidance on estimating land value can be found in a land Compilation Guide published by Eurostat and the OECD[8].

68. When considering the key data to be used for land accounting, scale, resolution and accuracy are important. However it is essential that data sets that are well established and likely to be produced and updated on an ongoing basis are used. This will enable repeated reporting of change over time. In some instances it may be necessary to consider trading-off quality and continuity.

[8] Eurostat-OECD manual: http://unstats.un.org/unsd/nationalaccount/consultationDocs/LandCompiGuide.pdf

69. A challenge in geospatial analysis is combining information from various sources according to a common geographical classification.[9] For this purpose it is necessary to delineate (or mark out) a set of relatively small spatial areas (essentially building blocks). Information can then be attributed to these spatial areas, different types of data may not be easily attributed to the same spatial scale so different methods/techniques may need to be employed in attributing the data to these areas such as area weighting. Each technique will have to be considered relative to increases in uncertainty that it may introduce.

70. When multiple sets of information are attributed to particular places, geospatial analysis can be leveraged for significant increases in analysis. Also, where information can be organised to the same spatial areas in a time series, geospatial analysis allows the change over time to be examined in a way that is not possible through analysis of standard accounts and tables.

v. Import data and process data including applying concordances that may be required between the classifications used in the imported data and the classifications to be used in the SEEA based accounts and estimate adjustments for difference in concepts, coverage (including units of observation), and timing.

vi. Prepare, edit and balance accounts, including the estimation of data for any data gaps and develop aggregates and associated tables and indicators.

vii. Analyse accounts tables and graphic representations including undertaking an analysis of time series where possible and recognising the likely need for multiple iterations of this and the previous step. Data quality should be assessed and documented at this stage.

71. These three steps are the core activities in building the accounts and will be repeated in cycle during each production period. This allows the strength of the accounting approach to be used to confront the various data sources and check for consistency and reasonableness in comparison to other datasets.

72. The first time accounts are estimated for a new program, particular attention needs to be made with regard to adjustments required to the source data to ensure the methods used are appropriate and sound.

73. It is recommended that in cases where significant basic data come from other agencies that staff of those agencies be asked to participate in the analysis of the estimates.[10] These experts often have in depth knowledge that can allow the identification and resolution of inconstancies.

viii. Disseminate accounts, including material to assist interpretation such as indicators, methodological notes and statements of data quality.

62. The dissemination of data should always be accompanied by sufficient documentation and metadata to allow users to fully understand the information being disseminated. This is particularly important for the initial dissemination of a new program of

[9] A specific geographic classification is not described in the SEEA Central Framework. However, related classifications on land use and land cover are discussed in Chapter 5 and SEEA Experimental Ecosystem Accounting discusses the measurement issues in more detail.

[10] In particular, it may be important to assure that confidentiality masks are consistent across agencies such that residual disclosure does not occur.

data where one might want to identify the initial data as 'experimental' or 'preliminary' and make it clear that user input is being sought in order to improve future releases.

ix. Archive data and related methodological and other documentation.

x. Review accounts, data sources, methods and systems, including actively seeking user feedback.

63. These last two steps are very important for all statistical programs but when initiating a new program of data, seeking user feedback is crucial. This in turn depends on the existence of good documentation on the methods and systems so as to properly inform users and assess their feedback.

V. Extensions and links

64. Extensions to land accounts can relate to the spatial disaggregation of data contained in other accounts of the SEEA Central Framework and the national accounts, as well as to the SEEA Experimental Ecosystem Accounting.

65. While the core tables for land cover and land use do not call for information on the reasons for land cover or land use change, the standard format for the asset accounts do and basic information on the reasons for change should be sought from the sources used to classify the opening and closing positions. Satellite images will not provide such information but it might be possible to infer it in some cases, although confirmation from alternate sources would be encouraged. Administrative or survey sources are more likely to provide such information but again the original purposes of the datasets will need to be considered in interpreting these sources.

66. A starting point for the general approach is the land cover change matrix, Table 3 above. For example, managed expansion can be derived from the changes in land cover related to urban growth and development of infrastructure (through conversion of crops or tree covered area), intensification and industrialisation of agriculture (through conversion of family farming and mosaic landscapes), extension of agriculture in general (through conversion of tree covered land), drainage of regularly flooded areas (wetlands) for crops or artificial surfaces (urban land), and deforestation (of tree covered areas for timber production or agriculture development). Relating land cover and land use is particularly important. The relationship of land cover to land use can be highlighted by preparing accounts showing land cover by land use. If this is done for several points in time, then changes between two points in time can be highlighted. Such change accounts would, for example, show the extent to which forest areas (a land cover) is changing from say maintenance and restoration of environmental functions (a land use) to say forestry (another use.).

67. The accounts described in the SEEA-CF generally relate to specific stocks and flows recorded for a country as a whole. However, all materials, substances and resources are found in particular locations and, from a policy perspective, knowledge of the location of various stocks and flows may be of particular relevance. Indeed, national averages usually hide important local variations and spatially disaggregating data can help to better identify environmental spatial patterns.

68. The quality of spatial coding must be assessed carefully as additional datasets are linked and integrated with the land accounts. The original purpose and sources may not provide precise locational information in all cases. For example, data for many economic data

programs are gathered by enterprise, usually though the head office, head offices are often not located where the majority of material flows occur, particularly in large scale manufacturing or mining operations. It may be necessary to pursue more precise locations for some economic activities to fully exploit such data integration.

69. Both land use and land cover accounts can also be presented in monetary terms. That is, while the table structure remains the same, the units of measurement are in monetary units ($, €, ¥, etc.). Data sources for valuation are generally more aligned with land use and therefore monetary accounts by land use are easier to construct. As well land use accounts generally relate more directly to the existing monetary information on land as an asset in the national accounts.

70. Many sources of information on the value of properties have the value for the combined characteristics of the property. This will include the characteristics of the land such as soil, the value of structures such as production plants or buildings and the location. Estimating the value of only the land is a complex and challenging task.

71. A joint Eurostat/OECD Task Force, is developing a compilation manual that provides guidance on this complex issue and it recommended that countries use this as a basic source for undertaking this task[11].

72. The potential of combining geospatial analysis with the data contained in SEEA style accounts is demonstrated by the following example. This example works within the general framework provided and shows measures of land use. The accounts may also be structured to consider land in terms of ownership by economic units, for example by industry or institutional sector. It should be recognised that the completion of geospatial analysis requires strong underlying information systems. A description of the systems, methodologies and best practices in GIS is beyond the scope of the SEEA Central Framework and this note, but this type of information can be found elsewhere[12].

73. A relatively simple example of spatially attributed information is presented in Figure 1. A focus on the use of specific spatial areas enables a stronger, joint consideration of social, economic and environmental implications of various policy choices and options. The expansion in the use of land for housing, for example, requires in turn infrastructure such as roads, sewers, and water supply lines and at the same time can lead to encroachment into high quality agricultural land. Potential environmental impacts include loss of wildlife habitat, increased air pollution and greenhouse gas emissions, and the contamination of rivers, lakes and aquifers. The type or form of expansion may also be significant. For example, is the expansion relatively high or low density in terms of changes in human population?

74. Figure 1 shows a simple presentation of human settlements and agricultural land (Statistics Canada 2010). In this, settlements were defined as tracts of land where humans have altered the physical environment, while dependable agricultural land is land free of severe constraints to crop production. The methodology used to create this map also provides a more detailed, harmonised and comparable suite of data that enables a more complete

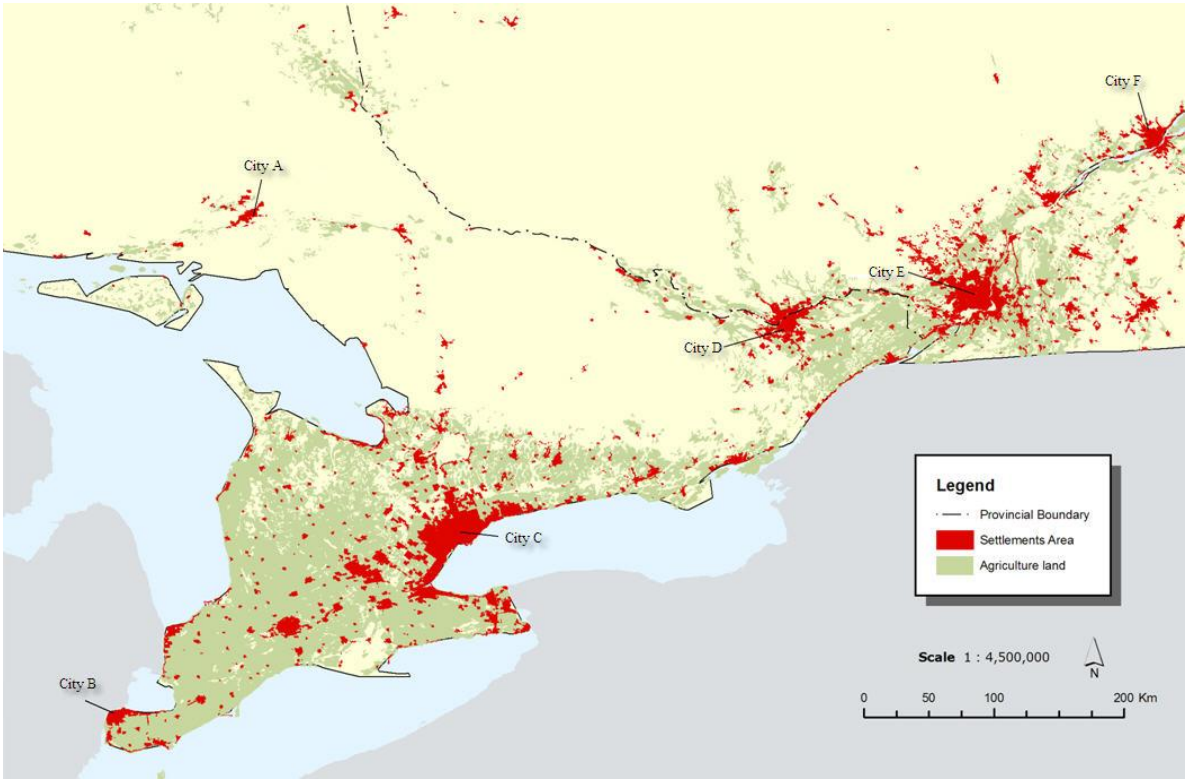
[11] Specific reference for Eurostat-OECD Task Force document.

[12] For example, see the text books of de Smith et al (2013) or Tomlinson (2005) and a range of on-line information. For example the websites of ESRI, ESA, Geoscience Australia, NASA, and USGS

analysis of settlements and formed the basis for the development of indicators that can be used to track land cover and land use change (Filoso 2011).

75. Another example from Australia can be found at Experimental Land Account for the Great Barrier Reef, 2014.

Figure 1. Map of settlements and dependable agricultural land



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Annex I Description of land cover classes

The following descriptions of different land cover types are based on the FAO Land Cover Classification System (LCCS).

01 Artificial surfaces (including urban and associated areas)

The class is composed of any type of areas with a predominant artificial surface. Any urban or related feature is included in this class, for example, urban parks (parks, parkland and laws). The class also includes industrial areas, and waste dump deposit and extraction sites.

02 Herbaceous crops

The class is composed of a main layer of cultivated herbaceous plants (graminoids or forbs). It includes herbaceous crops used for hay. All the non-perennial crops that do not last for more than two growing seasons and crops like sugar cane, where the upper part of the plant is regularly harvested while the root system can remain for more than one year in the field, are included in this class.

03 Woody crops

The class is composed of a main layer of permanent crops (trees or shrub crops) and includes all types of orchards and plantations (fruit trees, coffee and tea plantation, oil palms, rubber plantation, Christmas trees, etc.).

04 Multiple or layered crops

This class combine two different land cover situations:

Two layers of different crops. A common case is the presence of one layer of woody crops (trees or shrubs) and another layer of herbaceous crop, e.g., wheat fields with olive trees in the Mediterranean area and intense horticulture, or oasis or typical coastal agriculture in Africa, where herbaceous fields are covered by palm trees.

Presence of one important layer of natural vegetation (mainly trees) that covers one layer of cultivated crops. Coffee plantations shadowed by natural trees in the equatorial area of Africa are a typical example.

05 Grassland

This class includes any geographical area dominated by natural herbaceous plants (grasslands, prairies, steppes and savannahs) with a cover of 10 per cent or more, irrespective of different human and/or animal activities, such as grazing or selective fire management. Woody plants (trees and/or shrubs) can be present, assuming their cover is less that 10 per cent.

06 Tree-covered areas

This class includes any geographical area dominated by natural tree plants with a cover of 10 per cent or more. Other types of plants (shrubs and/or herbs) can be present, even with a density higher than that of trees. Areas planted with trees for afforestation purposes and forest plantations are included in this class. This class includes areas seasonally or permanently flooded with freshwater. It excludes coastal mangroves (→07).

07 Mangroves

This class includes any geographical area dominated by woody vegetation (trees and/or shrubs) with a cover of 10 per cent or more that is permanently or regularly flooded by salt and/or brackish water located in the coastal areas or in the deltas of rivers.

08 Shrub-covered areas

This class includes any geographical area dominated by natural shrubs having a cover of 10 per cent or more. Trees can be present in scattered form if their cover is less than 10 per cent. Herbaceous plants can also be present at any density. The class includes shrub-covered areas permanently or regularly flooded by inland fresh water. It excludes shrubs flooded by salt or brackish water in coastal areas (→07).

09 Shrubs and/or herbaceous vegetation, aquatic or regularly flooded

This class includes any geographical area dominated by natural herbaceous vegetation (cover of 10 per cent or more) that is permanently or regularly flooded by fresh or brackish water (swamps, marsh areas, etc.). Flooding must persist for at least two months per year to be considered regular. Woody vegetation (trees and/or shrubs) can be present if their cover is less than 10 per cent.

10 Sparsely natural vegetated areas

This class includes any geographical areas were the cover of natural vegetation is between 2 per cent and 10 per cent. This includes permanently or regularly flooded areas.

11 Terrestrial barren land

This class includes any geographical area dominated by natural abiotic surfaces (bare soil, sand, rocks, etc.) where the natural vegetation is absent or almost absent (covers less than 2 per cent). The class includes areas regularly flooded by inland water (lake shores, river banks, salt flats, etc.). It excludes coastal areas affected by the tidal movement of saltwater (→14).

12 Permanent snow and glaciers

This class includes any geographical area covered by snow or glaciers persistently for 10 months or more.

13 Inland water bodies

This class includes any geographical area covered for most of the year by inland water bodies. In some cases, the water can be frozen for part of the year (less than 10 months). Because the geographical extent of water bodies can change, boundaries must be set consistently with those set by class 11, according to the dominant situation during the year and/or across multiple years.

14 Coastal water bodies and intertidal areas The class is defined on the basis of geographical features of the land in relation to the sea (coastal water bodies, i.e., lagoons and estuaries) and abiotic surfaces subject to water persistence (intertidal areas, i.e., coastal flats and coral reefs).

Annex II Land Use Classification

1 Land

1.1 Agriculture

This category includes tilled and fallow land, and naturally grown permanent meadows and pastures used for grazing, animal feeding or agricultural purpose. Scattered land under farm buildings, yards and their annexes, and permanently uncultivated land, such as uncultivated patches, banks, footpaths, ditches, headlands and shoulders are traditionally included.

1.2 Forestry

Land used for forestry. Excludes land that is predominantly under agricultural or urban use.

1.3 Land used for aquaculture

Aquaculture refers to the farming of aquatic organisms: fish, molluscs, crustaceans, aquatic plants, crocodiles, alligators, turtles and amphibians. Farming implying some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc.

1.4 Use of built-up and related areas

Land affected or adapted by man, under buildings, roads, mines and quarries and any other facilities, including their auxiliary spaces, deliberately installed for the pursuit of human activities. Included also are certain types of open land (non built-up land), which are closely related to these activities, such as waste tips, derelict land in built-up areas, junkyards, city parks and gardens. Land under closed villages or similar rural localities are included.

1.5 Land used for maintenance and restoration of environmental functions

This class includes protected areas as defined by IUCN, International Union for Conservation of Nature, i.e., clearly defined geographical spaces, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

1.6 Other uses of land n.e.c.

Land used for uses not elsewhere classified.

1.7 Land not in use

Areas where there are no clearly visible indications of human activities or institutional arrangements put in place for the purpose of economic production or the maintenance and restoration of environmental functions and where ecological processes are not significantly disturbed.

2 Inland waters

Inland waters are areas corresponding to natural or artificial water courses, serving to drain natural or artificial bodies of water, including lakes, reservoirs, rivers, brooks, streams, ponds, inland canals, dams, and other land-locked (usually freshwater) waters. The banks constitute limits whether the water is present or not.

2.1 Inland waters used for aquaculture or holding facilities Inland water areas that are used for aquaculture facilities including supporting facilities. Aquaculture refers to the farming of aquatic organisms: fish, molluscs, crustaceans, aquatic plants, crocodiles, alligators, turtles and amphibians.

2.2 Inland waters used for maintenance and restoration of environmental functions

Protected inland water areas as defined in 1.5. This class includes enhanced areas (areas with enhancement including stocking, fertilization, engineering, predator control, habitat modifications and/or access limits.)

The class excludes protected wetlands (→1.5) and protected coastal waters (→3.2).

2.3 Other uses of inland waters n.e.c.

Inland water areas used for uses not elsewhere classified.

Annex III Examples of data sources

Data on permanent land (accounting unit) features

Data on local and higher level **administrative, statistical** and **territorial divisions** are usually publicly available from national sources. Global sources of harmonized administrative data can be accessed online, for example ESRI's World Administrative Divisions; and for statistical areas, examples can be consulted from sources like EU's NUTS, Australia's Statistical Areas. Such data is needed for statistical area-units delineation (sometimes following the boundaries of communes, municipalities, provinces, counties etc.), which conforms to principles of confidentiality. Other relevant themes of longer-term land management may be: protected areas (global source - http://www.protectedplanet.net/) and other designations (such as water provision, green corridors and belts etc.).

Well accepted **ecological** and **bio-physical classifications** (and datasets) can be accessed from global sources, including WWF's Terrestrial Ecoregions; USGS's Global Ecosystems (mapped for the Americas and Africa); potential vegetation (that can be used to assess 'pre-settlement' reference conditions, see global source: Ramankutty and Foley, 1999) etc. Nationally available source may be available in a form derived or different from the globally accepted ones, usually with higher detail, including local and regional geographic features.

Globally harmonized river catchments can be accessed from FAO's hydrosheds, by continent and global soil types from ORNL DAAC data sets (local or national sources would be preferable if existing).

Data on dynamic (asset) land features

Land use and land cover data will often be the only readily-available source to develop proxy of ecosystem assets over large (complete country coverage) areas and map the places where certain ecosystem services are generated. Despite being subject to error, such data may be

sufficient to perform initial analysis, estimate Tier I accounts, and detect subset areas (hotspots of changes) for more detailed ecosystem accounting pilots, and advance towards national Tier II and III accounts.

Land cover may be derived from the following globally available sources:

a. FAO Global Land Cover-SHARE

The FAO product Global Land Cover-SHARE (year 2014 Beta-Release 1.0) is constructed using the best quality national and international data sources. 11 land cover classes were harmonized and reclassified according to the LCCS nomenclature and included in the SEEA-CF. The individual classes (layers) can be downloaded online in quantitative area coverage form, expressed as area per grid-cell (from 0 – 100 ha) and also a composite map of dominant classes. Validation results indicate overall Producer's accuracy of 80% (variable between 50 and 100% for the individual classes). The available product has to be tested if possible to apply for multi-temporal analysis (e.g. for countries where the original data source contains more than one year maps).

The 1km grid-maps may be too coarse for spatial analysis, yet the available data may be applied to enhance its quality and spatial detail, as well to reproduce annual time-series using remote sensing imagery.

b. MODIS Land Cover

Modis Land Cover is a set of annual products based on NASA's MODIS imagery, and available at 500m x 500m spatial resolution. The product name is 'Land Cover Type Yearly L3' (version 51 is the latest), metadata can be reviewed, and spatial data downloaded from http://reverb.echo.nasa.gov/. The data is distributed as 'granules', which need to be identified by the user (online) prior to downloading. If the study area is large (e.g. a continent) considerable pre-processing will be needed to ensemble ('mosaic') and harmonize the datasets. MODIS land cover products[13] are summarised below. See nomenclatures for the five products in Annex 1.

The MODIS Land Cover Type product contains five classification schemes, which describe land cover properties derived from observations spanning a year's input of Terra- and Aqua-MODIS data. The primary land cover scheme identifies 17 land cover classes defined by the International Geosphere Biosphere Programme (IGBP), which includes 11 natural vegetation classes, 3 developed and mosaicked land classes, and three non-vegetated land classes.

The MODIS Terra + Aqua Land Cover Type Yearly L3 Global 500 m SIN Grid product incorporates five different land cover classification schemes, derived through a supervised decision-tree classification method:

- Land Cover Type 1: IGBP global vegetation classification scheme
- Land Cover Type 2: University of Maryland (UMD) scheme
- Land Cover Type 3: MODIS-derived LAI/fPAR scheme

[13] https://lpdaac.usgs.gov/products/modis_products_table/mcd12q1

- Land Cover Type 4: MODIS-derived Net Primary Production (NPP) scheme
- Land Cover Type 5: Plant Functional Type (PFT) scheme

V051 Land Cover Type products are produced with revised training data and certain algorithm refinements. For further details, please consult the following paper:

Friedl, M. A., Sulla-Menashe, D., Tan, B., Schneider, A., Ramankutty, N., Sibley, A., andHuang, X. (2010). MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. *Remote Sensing of Environment*, 114, 168–182.

Temporal analysis of land cover change may be obstructed by the data quality and course resolution, however it may be feasible to improve the available data for accounts estimation.

c. ESA's GlobCover

The European Space Agency has produced the GlobCover maps at 300 m spatial resolution for year 2005-6 and 2009 using MERIS imagery. The two temporal maps are not compatible for land use change analysis however. GlobCover applies a hierarchical classification scheme. Global and regional nomenclatures can be consulted online (see Annex II in ESA's report "GLOBCOVER Products Description and Validation Report" [14]).

d. GlobeLand30

Very high resolution global land cover maps were produced by China, known as GlobeLand30, for years 2000 and 2010, with 10 classes and 30 m resolution, based on the freely available imagery from NASA's Landsat satellite instruments. The data is available online after registration, and was also donated to the UN.

GlobLand30 classification nomenclature[15]

1. Water bodies
2. Wetland
3. Artificial Surfaces
4. Tundra
5. Permanent snow and ice
6. Grass lands
7. Barren lands
8. Cultivated land
9. Shrub lands
10. Forests

GlobLand30 may be the most appropriate dataset for ecosystem accounting, because of its highest spatial detail and the possibility to analyze land cover change; however its quality needs to be well evaluated, since it is the newest source, among other reasons.

[14] http://due.esrin.esa.int/files/GLOBCOVER_Products_Description_Validation_Report_I2.1.pdf

[15] http://www.globallandcover.com/GLC30Download/index.aspx

Land use data is usually not readily and uniformly available and therefore needs to be assembled from a number of sources, most commonly applicable would be sought from agriculture, forestry, mining, transport, industry and urban planning and administration (including parks and recreation). Protected areas administration and management (including zoning), hunting and fishing areas etc. may provide very relevant land use information too. The subject generally needs much further efforts for developing harmonized inputs (including spatial data) in land and ecosystem accounting. The European CORINE product introduced land use categories in its combine land cover and use nomenclature (see details in Section 3). Examples of mapping ecosystem services with land use include Bateman et al. (2013) and specific tools for the purpose: LUSI, Polyscape (see Jackson et al. 2013) etc.

Administrative data (including maps) on **land ownership** are likely to be available from national sources such as *Official land cadasters* or similar *land administration registers,* for example UK's Ordinance survey. Classification of Land ownerships should be developed, including private and public domains, which may overlap or differ from land use. For example, abandoned cropland may still belong to a farmer, but actually be used for nature restoration.

Land cover, land use and land ownership can change in a very dynamic way independently from each other. Therefore these three properties of land may need to be classified and mapped separately for a complete accounting application at Tier III.

Note that a **number of other themes and sources** of spatial data related to ecosystem functions or components will be very relevant for the accounting purposes (to map condition for example):

- Forest cover and deforestation - University of Maryland product "Global Forest Change
- Vegetation types, physiognomy, productivity, habitats etc.