A Functional Approach to Environmental-Economic Accounting for units and ecosystem services

DRAFT

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

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1 Introduction

The SEEA EEA has strong accounting foundations but lacks focus on ecological principles. Therefore when attempting to marry the needs of ecology with accounting the compromise currently rests with ecology. The challenge is recognising the work that has been undertaken in ecology and reframing the ideas in context of accounting without compromising ecology, or minimising the compromise. The aim of this paper is to take ecological methods and approaches and apply them in an accounting context based on ideas in both the SEEA CF and EEA.

In order to achieve this aim a number of extensions and additions to SEEA EEA are proposed. The central accounting logic of SEEA EEA remains unchanged including the focus on clearly specifying units for accounting and linking them to the supply of ecosystem services.

One of the key challenges acknowledged in the SEEA EEA and built upon in this paper is the need to bring together ecological principles and accounting methods. Ecological principles require a clear link to the classification and function of ecosystems and methods to report on their condition and ability to provide ecosystem services. Accounting principles require classifications are ontological in nature and they balance their presentation of extent and condition but clearly link to changes in ecosystem services as a result of human interventions. This paper will focus on building from ecosystem function propose the Functional Ecosystem Unit (FEU) and a way to delineate and account for ecosystem assets and ecosystem services. The FEU does not depart from the fundamental logic of SEEA EEA but views that logic through an ecological lens.

There have been a number of other approaches proposed that aim to deal with the question of delineating the ecosystem accounting units problem including Canada's Measuring Ecosystem goods and Services (MEGS) project which builds on the LCEU presented in SEEA EEA; the Government of Victoria ecosystem accounts which focused on the use of BSU for reporting and accounting; Australian Bureau of Statistics Land Accounts which looked at links between land cover and statistical reporting areas and cadastral property valuation data; Sumarga and Hein (2014) used BSU level data to report ecosystem services and delineate the landscape based on topological and hydrographic data and the Secretariat of the Convention on Biological Diversity Quick Start Package (Weber 2014) which worked with the LCEU proposed in SEEA EEA and also proposed an SELU, MCU, RSU and HRSUs.

Key will examine FEUs in the context of: units and aggregation, linking land cover classifications to ecosystem classifications based on ecological concepts and finally linking ecological function to the classification of ecosystem services as discussed briefly in SEEA EEA. Further, to support the demonstration of these concepts examples are provided for each of the main accounts using data from the Avon Richardson region in Victoria which is an area we have a lot of data for and can demonstrate accounts with relative ease. The paper will focus on terrestrial-based FEUs to demonstrate the principles of an FEU whilst acknowledging more work needs to be done for rivers, coastal, inshore and others areas.

2 Background

Ecological systems (ecosystems) are areas containing a dynamic complex of biotic communities (e.g., plants, animals and microorganisms) and their non-living environment interacting as a functional unit to provide environmental structures, processes and functions (SEEA CF 2.21). A key feature of the definition provided in SEEA CF and commonly provided in ecological literature is the recognition of an ***interacting functional unit***. The SEEA CF does not attempt to provide advice on how to account for ecosystems or the services they may provide – this is explored in the SEEA EEA.

The SEEA EEA defines an ecosystem asset as a spatial area containing a combination of biotic and abiotic components and other characteristics that function together (2.31, 4.1) which also recognises the functional characteristics of an ecosystem. The SEEA EEA goes a step further suggesting ecosystem asset accounts can be produced for carbon, water and biodiversity to help understand ecosystem condition.

While ecosystem asset accounts for carbon, water and biodiversity may contribute to the assessment of ecosystem condition they do not link very well with the ecological literature. Clearly understanding the stocks and flows of land, carbon and water across different spatial areas can provide significant insights into changes in ecosystem assets, but for accounting they need to link explicitly to the condition of an ecosystem. Changes in carbon and water stocks and flows are clearly linked but are a result of changes in the condition of an ecosystem as a result of natural or human induced changes.

We proposed starting from ecological principles and moving towards accounting whilst preserving the principles of ecology as an alternative approach to delineating ecosystem units that can be used for accounting. The concept of ecological function is very important and acknowledged in the SEEA however it does not provide guidance no how to incorporate it in an accounting sense. Further the fundamental aim of SEEA is to account for ecosystem services and how they contribute to benefits enjoyed by society both directly and indirectly. Ecosystem services are a direct result of ecosystem function so starting with the concept of function will provide insights into how to classify and account for ecosystem services based on ecological principles.

2.1 Ecosystem accounting units

The statistical units of ecosystem accounting are spatial areas about which information is collected and statistics are compiled. Such information is collected at a variety of scales using a number of different methods. Examples of methods include remote sensing, on-ground assessment, surveys of land owners and administrative data.

To accommodate the different scales and methods used to collect, integrate and analyse data three different, but related, types of units are defined in SEEA Experimental Ecosystem Accounting. They are: basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU).

A basic spatial unit (BSU) is a small spatial area. The BSU should be formed by delineating a "regular grid" (small areas e.g. 100m to 1 km). The grid needs to remain stable (lower left and lower right coordinates do not change) and must be nested so all grid sizes fit within one another. Ideally the grid should be specified at the lowest possible resolution (say 0.5 metre) and this be used as the "master" grid for all other girds to be built from. For instance a 100m BSU is a 200 by 200 version of a 0.5m master grid. Typically the BSU grid is then overlaid on other layers to attribute each BSU grid cell. From a GIS perspective this would involve converting vector data to a grid whilst ensuring the conversion process always uses the mater grid during the conversion to ensure consistency in attribution of cells.

The delineation of an EAU is based on the purpose of analysis or reporting that may be based on administrative boundaries, environmental management areas, large scale natural features (e.g. river basins) and other factors relevant for reporting purposes (e.g. national parks or other protected areas, statistical areas). An EAU can be any size as long as it is linked to the purpose for analysis and reporting and remains relatively stable over time.

The SEEA EEA states the EAU may be considered ecosystem asset. In this paper we consider the EAU to be an aggregation of ecosystem assets based on an area of interest for analytical or reporting purposes.

For most terrestrial areas an LCEU is defined by areas satisfying a pre-determined set of factors relating to the characteristics of an ecosystem. Examples of these factors include land cover type, water resources, climate, altitude, and soil type. A particular feature is that an LCEU should be able to be consistently differentiated from a neighbouring LCEU based on differences in their ecosystem characteristics (SEEA EEA ###).

The Land Cover Ecosystem Functional Unit (LCEU) is an aggregation of contiguous BSUs with homogenous characteristics (such as land cover, elevation, drainage area and soil type). The SEEA EEA suggests an LCEU can be classified into one of the 16 classes in the provisional land cover classification. Many of the tables in the SEEA-EEA are based on aggregating other characteristics (such as extent, condition, service flows) over LCEUs of similar class. Further the SEEA EEA states: "While not strictly delineating an ecosystem, the LCEU can be considered an operational definition for the purposes of ecosystem accounting". As an accounting aggregate an LCEU is operational however from an ecological point of view an LCEU does not necessarily define an ecosystem by its function.

For instance the selection of factors relating the characteristics of ecosystems to create an LCEU is broad ranging and will depend on the users specific needs for reporting. Additional characteristics include: rain fall zones (0-100, 101-300, 301-600, 600 an above), water sheds, soil classes – alone not mixed as suggested above, altitude and slope.

Figure 1 below shows the spatial configuration of LCEUs combining land cover, soil, slope, mean annual rainfall, mean annual temperature, elevation in steps going from left to right. For instance the first image in Figure 1 is a combination of land cover and soil. Working from left to right the number of unique LCEUs is 59, 246, 621, 4145, 4337, 18554. By combing different factors alternative sets of LCEUs can be created and if chosen differently by each country the LCEUs as reporting units would not be comparable.

Whichever set of factors are chosen they do not define a functional ecosystem – the LCEUs can be used as areas for accounting purposes based on factors relating to the characteristics of an ecosystem – they are statistical aggregates similar to establishments, enterprises, government and household entities in the SNA.

Figure 1 LCEU spatial configuration examples

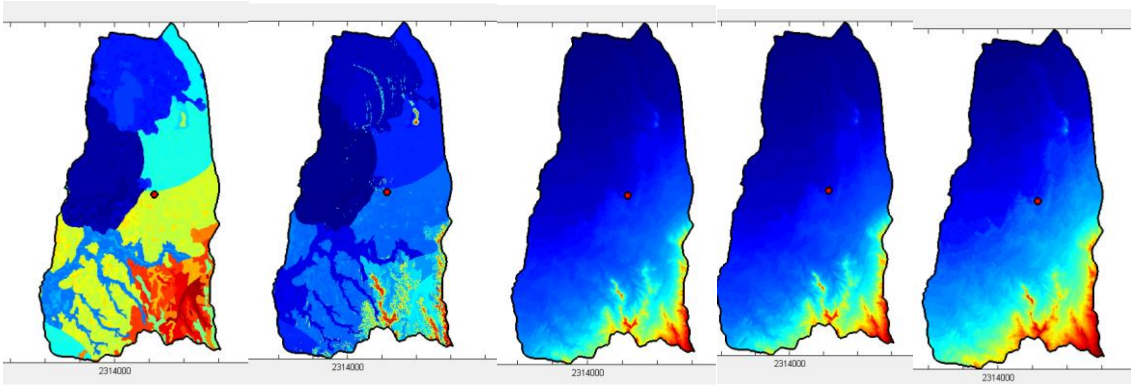


Table 1 below shows the suggested accounting classifications from SEEA EEA for the LCEU. It is not clear how the text in EEA (*Examples of these factors include land cover type, water resources, climate, altitude, and soil type.*) or any other combination could result in the table below. It appears to be an amalgam of use, cover and assets.

Table 1 Provisional Land Cover/Ecosystem Functional Unit Classes (LCEU) – SEEA EEA

Description of classes	
Urban and associated developed areas	Cover / Use
Medium to large fields rain-fed herbaceous cropland	Use
Medium to large fields irrigated herbaceous cropland	Use
Permanent crops, agriculture plantations	Cover or use
Agriculture associations and mosaics	Use or cover
Pastures and natural grassland	Cover
Forest tree cover	Cover
Shrubland, bushland, heathland	Cover
Sparsely vegetated areas	Cover
Natural vegetation associations and mosaics	Cover, Use
Barren land	Cover
Permanent snow and glaciers	Cover
Open wetlands	Asset (not cover – water, or use)
Inland water bodies	Asset(not cover – water, or use)
Coastal water bodies	Asset(not cover – water, or use)
Sea	Asset(not cover – water, or use)

It is conceivable that a specific set of factors may be created to define an LCEU to represent a functional unit. However, it is clearer to maintain the LCEUs as accounting aggregates based on their current definition and look to other avenues to account for ecosystem function and classification.

The ecological equivalent is something far more specific and detailed and relating to concrete ecological functions and consequently services, for example plant communities in a given biotope. The primary focus of ecosystem accounting is to quantify how ecological functions and properties respond to human use (all ecosystem components can be improved or degraded). The main measures of ecosystem accounting should therefore stem from ecological function and enable reporting of area (extent, stock), condition (of the stock), ecosystem services being provided and other properties (for example the number of species).

Building on the SEEA EEA definition of an ecosystem (assets) – the spatial areas containing a combination of biotic and abiotic components that function together – we propose decomposing the components into their elements including biotic – producers, consumers and decomposers; abiotic – inorganic substances (C, N, CO2, Water, air, substrate environment – bedrock); and other linking organic compounds (proteins, humic substances – soil, fossil fuels).

Based on this decomposition of we propose a new unit, the Functional Ecosystem Unit (FEU) is defined as an ecosystem asset and used to estimate the provision of ecosystem services for accounting purposes. It is characterised by using the main structural elements which define plant and animal communities.

Table 2 Ecosystem Accounting Units

Unit	**Use**	**Description**
EAU – Ecosystem accounting unit	Aggregate for reporting and analysis Generally linked to FEUs for analysis of ecosystem assets in bioregions, biomes etc.	**Based on natural features – ecological** An aggregate reporting unit generally based on land characteristics such as such as land cover, elevation, drainage areas and soil types and geographic characteristics. Examples include bioregions, water sheds, biomes etc
AAU – Administrative accounting unit	Aggregate for reporting and analysis Generally linked to FEUs for analysis of ecosystem services and attributed to a group of beneficiaries. ie an region that relies on ecosystem assets for tourism and food production.	**Based on administrative features** An aggregate reporting unit based on land administration such as environmental management areas and statistical areas (SA1, NUTS, NCCI), council areas, suburbs, tenure.
FEU - Functional Ecosystem Unit	Ecosystem Asset for accounting and estimating ecosystem services	Is an ecosystem asset and defined as a homogenous unit using the elements of an ecosystem to define it – with a focus on *producers*. An FEU can be a single BSU or a contiguous group of BSUs that are homogenous
BSU – basic spatial unit	Raster cell or grid for spatial analysis	Is the basic spatial unit that underpins all spatial analysis and is used to create contiguous FEUs and contains groups of BSUs for each LCEU and EAU

Further, an additional unit – the Administrative Accounting Unit (AAU) is proposed and used for aggregation, reporting and analysis of administrative areas which include statistical enumeration areas, regions, councils, suburbs etc. The AAU is different from the EUA which is based on ecological areas for aggregation, reporting and analysis.

The AAU and the EAU complement one another. Both are used to aggregate FEUs for analysis and reporting – the AAU is used to understand the relationship between ecosystem assets (FEUs) and the economic performance of administrative areas and the EAU is used to understand the composition of FEUs and the links to the performance of ecological zones. There are time when the EAU and AAU may be the same area – for instance it is common for larger watersheds to be managed as an administrative unit and also as an ecological (watershed) unit. The BSU remains as the fundamental cell, grid or raster that is used for all spatial analysis and aggregation.

For the remainder of the paper the ecosystem accounting units will follow those listed in Table 2 above.

2.2 Linking FEUs to national and international EAUs

Land cover will often be the only feasible data set to start ecosystem accounting experimentation activities. For such purposes, the SEEA-CF land accounting categories offer a suitable classification framework to develop preliminary (proxy) accounts and analyse areas of intensive changes, hotspots etc. When such focal areas are identified for advanced pilot accounting, then more data-intensive activities will be undertaken, to define and map functional ecosystem units (FEUs).

FEUs are defined on the basis of main structural ecosystem characteristics e.g. plant community associations on land, given that these characteristics drive the main ecosystem functions, such as productivity, species diversity, energy flows, nutrient cycles etc (See Functional Ecosystem Units (FEU) below for further detail).

In Victoria, Australia FEUs is built by combining information of Ecosystem Vegetation Classes (EVCs[2]) and sub bio-regions. In this way a vegetation type, like dry woodland, can be differentiated into areas of varying productivity and species composition. See an example of EVC (55) "Plains grassy woodland" in Appendix V – EVC 55 Plains Grassy Woodland – Composition (with 21 grass species in Wimmera and 14 – in Goldfields). The tag 'land cover', labelled as 'Tree-cover areas' is retained and allows for higher level aggregations and comparability across different EAUs, for example catchments or administrative areas. Land cover is also linked with economic sectors, e.g. agriculture, forestry etc.

On the right hand side in Figure 2 below shows the FEUs are nested within a hierarchy of ecological or bio-region classifications. The Australian IBRA bioregions are developed from WWF global ecoregions (which include 16 classes, 14 terrestrial and 2 aquatic). For Australia this has been broken down at two levels, including 89 bioregions, and 419 sub-regions. The above mentioned *"Plains grassy woodland"* in Goldfields (code Gold0803, dominated by the association *Eucalyptus spp. + Allocasuarina luehmannii*) fits within VIM01 Sub-region "*Goldfields*" (which groups Box Ironbark Forest, Heathy Dry Forest and Grassy Dry Forest); VIM01 is part of the "*Victorian Midlands*" bioregion, and it is part of the WWF's "*Temperate broadleaf and mixed forest"* biome**.**

On the left had side in Figure 2 shows the AAU aggregation of economic data. The principles are the same for both – they are nested in an ontological manner and can be disaggregated into basic data – the economic unit or the FEU. Both the AAU and the EAU remain relatively stable through time supporting temporal comparisons of data. Further, there is a clear link between the economic performance of and AAU and changes in the composition and condition of ecosystem assets (FEUs).

[2] Department of Sustainability and Environment (2007). *Ecological Vegetation Classes (EVC)*. State of Victoria. Retrieved February 2015, from http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/evc-benchmarks

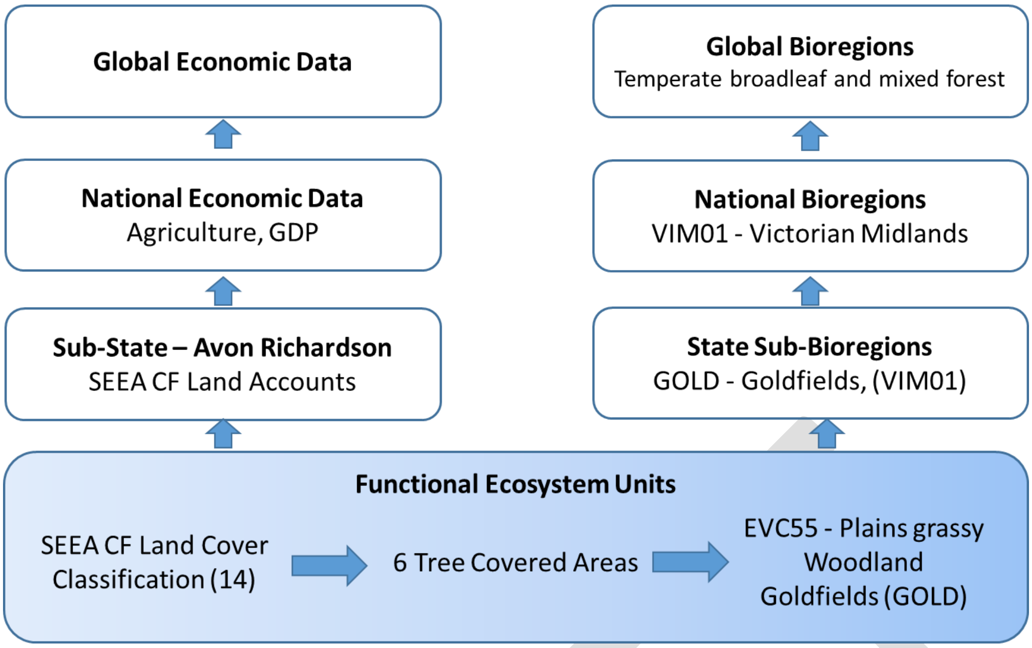


Figure 2 Hierarchy of SEEA CF and SEEA EEA FEU accounting units

Hierarchy of ecological units for ecosystem accounting

1. Ecosphere
2. Global bioregions or Biomes (within continental divisions)
3. National bioregions (within country divisions following the biomes)
4. Broad ecosystems (State sub-bioregions, more detailed within ecoregions or landscapes, e.g. woodland or grassland)
5. Plant community associations (within ecosystem, e.g. birch-spruce association)

Highest level unit is the **global ecosystem** of the planet itself, this level is termed 'ecosphere'.

Global bioregions or Global biomes are terrestrial freshwater and marine ecosystems and are defined on the basis of macro-factors including climate, geography, soil, potential vegetation. The temperate deciduous forest of East USA is an example of such a biome. Common references to global biomes include WWF's Major Biomes3.

A National bioregion (eco-region) is defined as a unit on the basis of topography (mountain, lowlands, coast), human modifications (metropolitan, agricultural-rural, natural, semi-natural) and geographic reference (e.g. New England or Quebec etc). Reference examples include: Classification and mapping of the ecoregions of Italy[4] (Blasi et al. 2014); United States NatureServe's ecological divisions[5] (Comer and others, 2003); and Australia's Bioregions (IBRA)[6]

[3] http://wwf.panda.org/about_our_earth/teacher_resources/webfieldtrips/major_biomes/

[4] C. Blasi, G. Capotorti, R. Copiz, D. Guida, B. Mollo, D. Smiraglia & L. Zavattero (2014) Classification and mapping of the ecoregions of Italy, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana, 148:6, 1255-1345, DOI: 10.1080/11263504.2014.985756

5 Comer, Patrick, Faber-Langendoen, Don, Evans, Rob, Gawler, Sue, Josse, Carmen, Kittel, Gwen, Menard, Shannon, Pyne, Milo, Reid, Marion, Schulz, Keith, Snow, Kristin, and Teague, Judy, 2003, Ecological systems of the United States, A working classification of U.S. terrestrial systems: Arlington, Va., NatureServe, 75 p. (Also available online at http://www.natureserve.org/publications/usEcologicalsystems.jsp.)

The highest spatial detail can be distinguished at the level of an FEU, an ecological community (biotope or habitat). Such community is defined by a specific combination of canopy trees, understory (shrubs, grass, mosses) and also specific animal communities, for example birds, mammals (See Functional Ecosystem Units (FEU) below for detail).

3 Functional Ecosystem Units (FEU)

The classical view of an ecosystem structure (Odum & Odum, 1971; Odum & Barret 2005) includes six components as shown in Table 3 below, which interact with one another and define a functional ecosystem unit. Column one contains the high level ecosystem characteristics, column two the components contained in each characteristic and finally the last column lists the high level functions of an FEU.

Table 3 FUE characteristics and components

Ecosystem characteristics	***Ecosystem Components***	***Ecosystem Functions***
Biotic		
Producers	***(1) Autotrophs****: Plants (trees, shrubs, herbs, grasses), that convert the energy [from photosynthesis (the transfer of sunlight, water, and carbon dioxide into energy), or other sources such as hydrothermal vents] into food.*	Energetic Cycles – regulation
Consumers	***(2) Heterotrophs****: e.g. animals, they depend upon producers (occasionally other consumers) for food.*	Biogeochemical Cycles– regulation
Decomposers	***(3) Saprotrophs*** *: e.g. fungi and bacteria, they break down chemicals from producers and consumers (usually dead) into simpler form which can be reused*	
Abiotic	***(4) Inorganic Substances*** *(C, N, CO2, Water), air, water,*	Evolution – Information, development, behavior, integration, diversity
	(5) Environment: *substrate (bedrock), climate regime, hydrological regime*	
Other linking compounds	***(6) Organic Compounds*** *– proteins, humic substances (soil), fossil fuels*	

In order to delineate each FEU uniquely the set of components needs to be described. A very common approach is to describe the autotrophs more commonly known and plant community associations for each FEU.

The taxonomy and physiognomy of autotrophs (component 1 above), or plant communities, (or vegetation cover) is what forms the main structural elements of terrestrial ecosystems, often organized in several floristic layers e.g. forest-trees, understory-shrubs, grasses and herbs, mosses and lichens.

[6] http://www.environment.gov.au/land/nrs/science/ibra

Phytosociology is the branch of science which deals with plant communities, their composition and development, and the relationships between the species within them. A phytosociological system is a system for classifying these communities. The aim of phytosociology is to achieve a sufficient empirical model of vegetation using plant taxa combinations that characterize vegetation units uniquely. Subtle differences in species composition and structure may point to differing abiotic conditions such as soil moisture, light availability, temperature, exposure to prevailing wind, etc. When tracked over time, species and individual dynamics can reveal patterns of response to disturbance and how the plant community changes over time.

Originally, such vegetation inventories, classification and mapping were carried out using transect methods, where species occurrence were recorded along with their abundance, edaphic (soil), hydrological and other environmental factors (slope, aspect etc). However with the increased availability of satellite and aerial data in the 70s and 80s there was a substantial reduction in on-ground work classifying vegetation. Instead it was thought that satellite and aerial data could be a substitute for on ground work. In the 90s and onwards more work has been looking at linking on-ground observations to validate or calibrate satellite and aerial data.

Brown-Blanquet (xxxxx) developed a classical, widely applied model for identifying and naming plant associations to describe vegetation complexes. This method has been very were widely applied over the past several decades (insert references)

More recent examples included: Plant communities of Italy[7] (Biondi et al. 2014), contains 75 classes, 2 subclasses, 175 orders, 6 suborders and 393 alliances; Plant communities of the Carson Desert, Nevada (Peinado et al. 2014)[8]; List some more – SA, Chile, Mexico.

Studies and inventories of plant community associations are widely applied for habitat (biotope) mapping of protected areas. Detailed association inventories and consequent mapping on national or regional level are rather labour intensive and various ways for mapping such wider areas and countries exist. For example: Vegetation belts of Chile[9] (Luebert and Pliscoff, 2006) is the most detailed vegetation classification system covering mainland Chile (1: 100 000 scale). This system describes 127 vegetation types, defined by the authors using the 'vegetation belts' concept (van der Maarel 2005), within 17 vegetation formations; Ecological Vegetation Classes (EVC) of Victoria (Australia)[10]; and EU's Habitat directive inventories by countries[11] (e.g. Greek Biotope Project; …)

The following sections provide detail on each of the accounts and examples to demonstrate their use.

[7] E. Biondi, C. BLASI, M. Allegrezza, I. Anzellotti, M. M. Azzella, E. Carli, S. Casavecchia, R. Copiz, E. Del Vico, L. Facioni, D. Galdenzi, R. Gasparri, C. Lasen, S. Pesaresi, L. Poldini, G. Sburlino, F. Taffetani, I. Vagge, S. Zitti & L. Zivkovic (2014) Plant communities of Italy: The Vegetation Prodrome, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana, 148:4, 728-814, DOI: 10.1080/11263504.2014.948527

8 M. Peinado, J. Delgadillo, A. Aparicio, J. L. Aguirre & M. Á. Macías (2014) Major plant communities of the Carson Desert (Nevada), North America's coldest and driest desert, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana, 148:5, 945-955, DOI: 10.1080/11263504.2013.845267

[9] Luebert, F. & Pliscoff, P. (2006) Sinopsis bioclimática y vegetacional de Chile. Santiago, Chile: Editorial Universitaria.

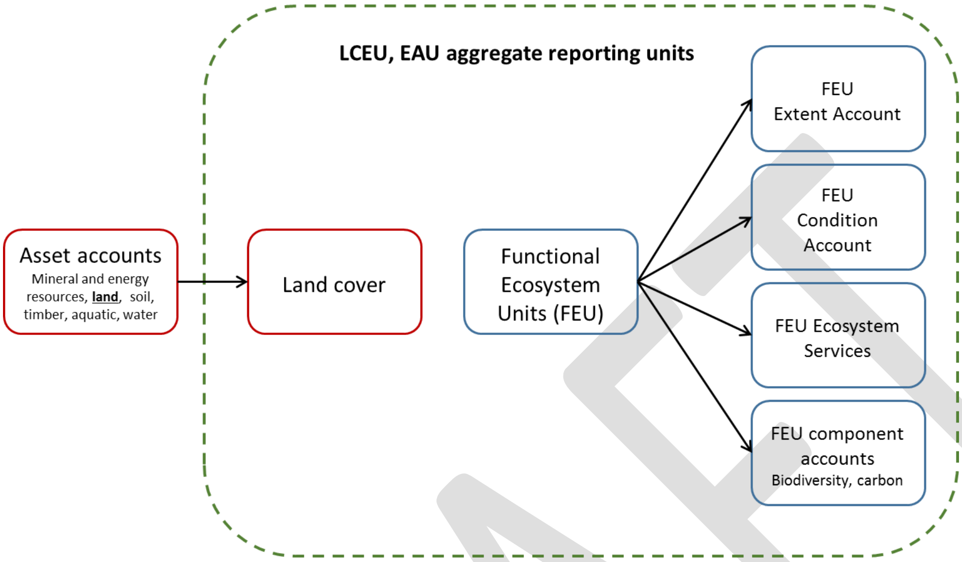
[10] Department of Sustainability and Environment (2007). *Ecological Vegetation Classes (EVC)*. State of Victoria. Retrieved February 2015, from http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/evc-benchmarks

[11] http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

4 Linking Land Cover to FEUs

Figure 3 below shows the links between the SEEA CF asset account, land cover and the FEU. The SEEA CF Land cover is a proxy for an FEU. For each FEU a series of accounts can be created from data at the BSU level which include an extent account, condition account, ecosystem services account and finally a number of component accounts.

Figure 3 Linking FEU to SEEA CF and SEEA EEA



At the highest level land cover is an FEU. Landover is based on compositional characteristics (see Appendix IV – Land Cover Classes SEEA CF). Adopting an ontological approach to the classification of FEUs relies upon building from the land cover classes.

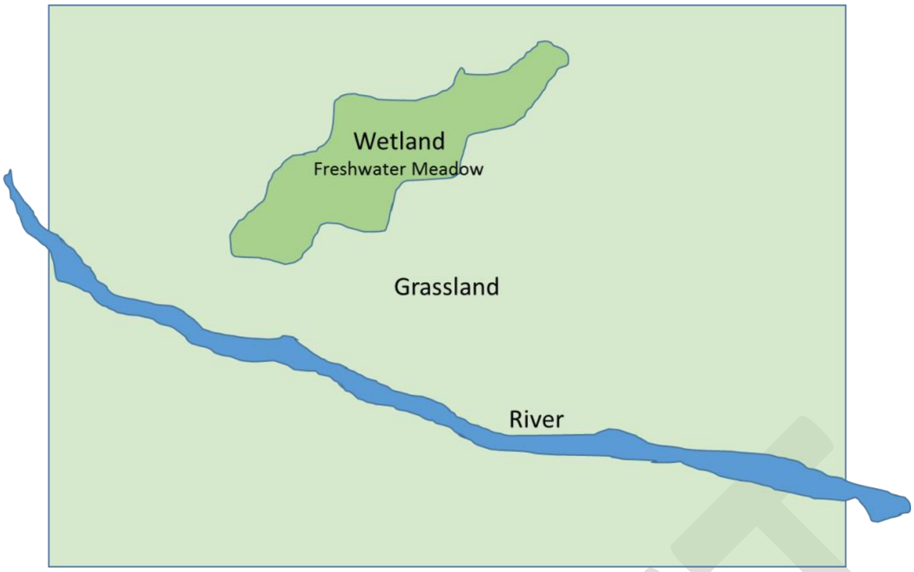
The degree and detail in which FEUs are described should be linked to the purpose or use of the FEUs. Conceivably one could embark of specifying every FEU down to a very fine scale – say a small pond that exists for short periods during the wet season. However, achieving such levels of detail is both very costly and does not necessarily improve decision making (even if it is attractive from a pond ecologists point of view).

The following example is provided to examine the delineation of the FEUs and link it to purpose. In this example there is interest in understanding the role of wetlands in the landscape to provide water purification services for runoff from local grazing lands. It is generally understood that this particular type of wetland is often had hydrological alterations done to reduce flooding and then it is used for grazing.

In Figure 4 below the large light green square is grassland based on SEEA CF land classes. The grassland can also be further disaggregated into FUEs based on the type and composition of grasses which differ in their ability to retain and utilise nutrients.

Generally standard land cover mapping approaches will not recognise a grass-based wetland - in this case Freshwater Meadow. The Freshwater Meadow Wetland has a unique set of autotrophic features with define it as an FEU. In this example the wetland is being used for grazing the same as the neighbouring grassland. The wetlands condition is poor and extent is reduced because it is being used for grazing rather than as a wetland.

Figure 4 Linking Land Cover to FEUs



For the purpose of ecosystem accounting in this example the SEEA CF grasslands will be delineated into to FEUs of specific grass compositions and freshwater meadow wetlands. This disaggregation into FEUs allows for the recognition that the wetland is providing economic benefits to the landholder but could be managed differently to provide water filtration and retention services. From an FEU accounting point of view the wetland has an extant, condition and capacity which the land cover approach alone would not recognise.

The disaggregation and accounting from an FEU point of view provides information to inform the trade-off between using a wetland to provide water filtration and retention services or grazing purposes both of which can be viewed in economic terms.

Alternatively the example could be viewed from an ecological point of view. The wetlands are needed to provide habitat for a rare migrating species. Then the disaggregation and accounting from an FEU point of view would provide information on the trade-off between economic returns from using the wetland for grazing and the wetlands ability to habitat services.

In order to ensure there is a clear link between land cover in the SEEA CF and the FEUs an ontological approach is suggested that provides a nested linkage between the classifications of land cover and FEUs. If Figure 5 below the land cover is presented as the highest (coarsest representation) level of aggregation for an FEU. It can be used to generalise ecosystem services at a very aggregate level but if specific species and or functions need to be understood in more detail it is necessary to define finer classes of land cover in the form FEUs.

Figure 5 Ontological approach linking Land Cover to FEUs

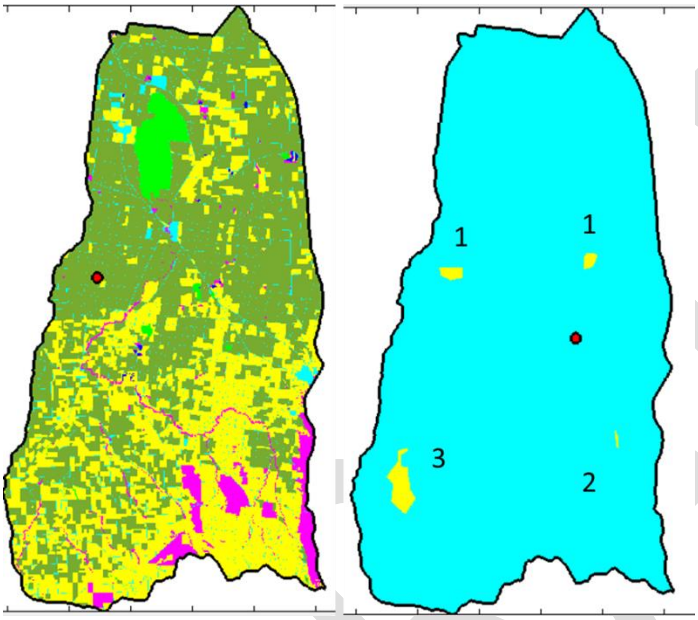
The decision the expand land cover into FEUs should be informed by policy need, relative interest in FEU ecosystem services and cost. However, the systems and methods employed should be consistent so they can be used in the future and provide an integrated approach.

4.1 Land cover accounts

The following land accounts are developed based on a 100 metre BSU for the Avon Richardson area in Victoria Australia to demonstrate links between land cover and FUEs. All data layers have been converted to 100 m BSUs and snapped to a master grid to ensure consistency of attribution to each grid cell.

In Figure 1 below the LHS shows the base case land cover (SEEA CF classes[12]) and on the RHS are areas that have undergone change. On the RHS Area 1-3 are Herbaceous Crops, Inland Water Bodies, Tree Covered Areas and Grasslands have changed to Tree Covered Areas (further detail is provided below at the FEU level to demonstrate greater disaggregation).

Figure 6 AR Landuse (LHS) and Areas of Change (RHS)



The full land cover change table in presented in Table 4 SEEA CF Land below. There is an increase of 3,458 ha in Tree Covered Areas.

Table 4 SEEA CF Land Cover change matrix

[12] The land cover and FEU data for the Avon Richardson has been reclassified to the land cover classifications of the SEEA CF

Sum of Area (ha)	AR_LU_ANCA_new_SEEA_CF														
AR_LU_BASE_SEEA_CF	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 intertidal areas	Grand Total
1 Artificial surfaces (including urban and associated areas)	14747					112									14859
2 Herbaceous crops		190790				2229									193019
3 Woody crops			0												0
4 Multiple or layered crops				14											14
5 Grassland					134593	1179									135772
6 Tree-covered areas						16830									16830
7 Mangroves							0								0
8 Shrub-covered areas								11							11
9 Shrubs and/or herbaceous vegetation, aquatic or regularly flooded									504						504
10 Sparsely natural vegetated areas										0					0
11 Terrestrial barren land											0				0
12 Permanent snow and glaciers												0			0
13 Inland water bodies						8							9851		9859
14 Coastal water bodies and intertidal areas														0	0
Grand Total	14747	190790	0	14	134593	20358	0	11	504	0	0	0	9851	0	370868

Table 5 SEEA CF Land Extent Account (ha)

	1 Artificial surfaces (including urban and	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,	10 Sparsely natural vegetated areas	11 Terrestrial barren land	12 Permanent snow and glaciers	13 Inland water bodies	14 Coastal water bodies and intertidal areas	TOTALS
Opening Stock of Resources	14859	193019	0	14	135772	16830	0	11	504	0	0	0	9859	0	370868
Additions to stock															
Managed expansion						3408									3408
Natural Expansion															0
Upward reappraisals						120									120
Total additions to stock															0
Reductions in stock															
Managed regression		3408													3408
Natural Regression															0
Downward reappraisals	112												8		120
Total reductions in stock															0
Clossing stock	14747	189611	0	14	135772	20358	0	11	504	0	0	0	9851	0	370868

Both in Table 4 and Table 5 the base case opening stock of *6 Tree Covered Areas* is 16,830 ha. Table 6 below shows this area expanded into the 19 FEUs covering both natural and production areas (the rows preceded with a numerical code or used for economic purposes ie 2.2.0 Production Forestry, 9,328 ha). Table 7 has also been expanded to FEUs for 5 Grassland totalling 134,593 ha.

Table 6 FEU for SEEA CF 6 Tree Covered Areas

Sum of Area (ha)	AR_LU_SEEA_CF	
AR_LU_FEU	6 Tree-covered areas	Grand Total
2.2.0 Production forestry	9328	9328
3.1.3 Other forest production	6	6
Box Ironbark Forest	2227	2227
Creekline Grassy Woodland	658	658
Drainage-line Woodland	690	690
Floodplain Riparian Woodland	853	853
Grassy Woodland/Riverine Grassy Woodland Mosaic	27	27
Heathy Dry Forest	250	250
Heathy Woodland	8	8
Hillcrest Herb-rich Woodland	731	731
Low Rises Woodland	2	2
Metamorphic Slopes Shrubby Woodland	90	90
Plains Savannah	69	69
Plains Woodland	1394	1394
Red Gum Swamp	47	47
Riverine Chenopod Woodland	321	321
Riverine Chenopod Woodland/Lignum Swamp Mosaic	121	121
Riverine Chenopod Woodland/Plains Grassland Mosaic	1	1
Semi-arid Woodland	7	7
Grand Total	16830	16830

Table 7 FEU for SEEA CF 5 Grassland

Sum of Area (ha)	AR_LU_NEW_SEEA_CF	
AR_LU_NEW	5 Grassland	Grand Total
1.3.3 Remnant native cover	1	1
2.1.0 Grazing natural vegetation	2103	2103
3.2.0 Grazing modified pastures	130013	130013
3.2.4 Pasture legume/grass mixtures	498	498
Grassy Dry Forest	112	112
Grassy Woodland	1075	1075
Grassy Woodland/Alluvial Terraces Herb-rich Woodland N	666	666
Plains Grassland	118	118
Valley Grassy Forest	7	7
Grand Total	134593	134593

Using this disaggregation in Table 6 and Table 7 above is it possible using the BSU approach to produce an FEU land account shown in Table 8 below.

The CF Land Cover classes contain the following FEUs:

- 2 Herbaceous crops – 3.3.0 Cropping, 3.3.1 Cereals, 3.3.4 Oil seeds, 3.3.8 Legumes
- Tree-covered areas – Creek line Grassy Woodland, Plains Woodland
- 13 Inland water bodies – Water

Table 8 Functional Ecosystem Units Land Extent Account (ha)

	2.1.0 Grazing natural vegetation	3.2.0 Grazing modified pastures	3.3.0 Cropping	3.3.1 Cereals	3.3.8 Legumes	5.7.2 Roads	6.0.0 Water	Creekline Grassy Woodland	Grassy Woodland/Alluvial Terraces Herb-	Plains Woodland	Other FEU	TOTALS
Opening Stock of Resources	2111	131182	155958	28804	5150	11793	218	658	668	1394	32932	370868
Additions to stock												
Managed expansion									70	3458		3528
Natural Expansion												0
Upward reappraisals												0
Total additions to stock												0
Reductions in stock												
Managed regression	8	1169	2089	4	136							3406
Natural Regression												0
Downward reappraisals						112	8		2			122
Total reductions in stock												0
Clossing stock	2103	130013	153869	28800	5014	11681	210	658	736	4852	32932	370868

4.2 FEU accounts by EAU – Bioregion

There are 28 bioregions in Victoria that can be aggregated to the national bioregions. Table 9 below provides an example of the coding structures used in Victoria to link FEUs (Ecological Vegetation Classes, EVC) to bioregions for state and national reporting.

Table 9 Linking FUEs to bioregions for state, national and international reporting

BIOREG_CODE	BIOEVC_CODE	EVCNAME (FUE)
Gold	Gold_0003	(Gold_0003) Damp Sands Herb-rich Woodland
Gold	Gold_0055	(Gold_0055) Plains Grassy Woodland
Gold	Gold_0803	(Gold_0803) Plains Woodland
MuM	MuM_0132	(MuM_0132) Plains Grassland
MuM	MuM_0803	(MuM_0803) Plains Woodland
MuM	MuM_0981	(MuM_0981) Parilla Mallee
Wim	Wim_0055	(Wim_0055) Plains Grassy Woodland
Wim	Wim_0132	(Wim_0132) Plains Grassland

Column 3 in the table lists the combined bioregion and FEU name. Some FUEs may exist in more than one bioregion. For each FEU there is a there is a phytosociology model of the vegetation using plant taxa combinations that characterize vegetation units uniquely. Subtle differences in species composition and structure may occur for each bioregion to account for differing abiotic conditions such as soil moisture, light availability, temperature, exposure to prevailing wind, etc. These phytosociology models are used as an input data for parameterise biophysical models to estimate ecosystems services including water filtration, water flow regulation, biomass accumulation, etc.

Ecologists and environmental managers generally are interested in the rate of change in land cover and FEUs in specific bioregions to inform decision making. The study area presented here has three bioregions – Goldfields, Murray Mallee and the Wimmera. Table 10 below show the changes in FEUs for each bioregion providing an EAU view of Table 8 above.

Table 10 FEU changes by EAU – Bioregions

Sum of Area (ha)	Bioregion Landuse Change			
Landuse	Gold Goldfields	MuM Murray Mallee	Wim Wimmera	Grand Total
2.1.0 Grazing natural vegetation			-8	**-8**
3.2.0 Grazing modified pastures	-21		-1148	**-1169**
3.3.0 Cropping	-34		-2055	**-2089**
3.3.1 Cereals			-4	**-4**
3.3.8 Legumes			-136	**-136**
5.7.2 Roads			-112	**-112**
6.0.0 Water			-8	**-8**
Creekline Grassy Woodland	70			**70**
Grassy Woodland/Alluvial Terraces Herb-rich Woodland Mosaic	-2			**-2**
Plains Woodland	-13		3471	**3458**
Grand Total	**60362**	**1165**	**309341**	**370868**

Table 10 below show the changes in FEUs for each watershed providing an EAU view of Table 8 above.

Table 11 FEU changes by EAU – Watershed

Sum of Area (ha)	River Reach											
AR_LU_ANCA_new	4080017	4080101	4080102	4080103	4150501	4150502	4150503	4150504	4150505	4150506	4150507	Grand Total
2.1.0 Grazing natural vegetation											-8	**-8**
3.2.0 Grazing modified pastures								-21			-1148	**-1169**
3.3.0 Cropping								-34			-2055	**-2089**
3.3.1 Cereals											-4	**-4**
3.3.8 Legumes											-136	**-136**
5.7.2 Roads											-112	**-112**
6.0.0 Water											-8	**-8**
Creekline Grassy Woodland								70				**70**
Grassy Woodland/Alluvial Terraces Herb-rich Woodland Mosaic								-2				**-2**
Plains Woodland								-13			3471	**3458**
Grand Total	**32**	**146**	**386**	**2**	**9022**	**13778**	**1925**	**12237**	**34753**	**12570**	**286017**	**370868**

5 Linking FEUs to Ecosystem Services

A key element for linking FEUs to ecosystem services is the use of phytosociology to achieve a sufficient empirical model of vegetation using plant taxa combinations that characterize vegetation units uniquely (Examples are provided in Appendix III – FEU Plant Composition Examples). The compositional characterisations can be used for both biophysical modelling of ecosystem services, qualitatively estimating ecosystem services and for condition assessments.

5.1 Modelling ecosystem Services

There is a number of biophysical plant growth modelling options to choose from including (non-exhaustive)[13]:

- Fixed cover Crop factor model (Nathan, Littleboy et al. ,1992)
- Heat unit Generic crop model (Williams et al. ,1982, Neitsch et al., 2001; Ritchie, 1985)
- Phenological Dynamic crop model – (wheat Jones and Kiniry (1986), Littleboy et al.,1992), (sunflower Ritchie, 1985), (pasture growth model Moore et al. 1997)
- Native pasture model Southwell (PhD, 2007)
- Composite Basic pasture growth model (Johnson et al., 2003)
- NSW pasture growth model (Jones et al., 2002)
- 3PG forest growth model (Landsberg and Waring, 1997)

[13] Beverly et al 2007

The choice of model is based on user needs, access to modelling capability and availability of parameter sets for a given model in the location it is to be applied, among other things. Further it should be noted that some models have been designed to model specific processes better than others for example water partitioning versus biomass accumulation (carbon). However in most instances information on the plant compositional characterisations is needed in order to choose an appropriate model. EnSym has the above modelling approaches incorporated so the user can specify which model they wish to employ. Based on plant compositional characterisations a series of models have been selected and use to demonstrate the modelling of ecosystem services below.

The biophysical modelling can be used to report on surface water runoff, recharge, carbon sequestration and evapotranspiration etc. For any given point in the landscape the biophysical models contained in EnSym can be run on a daily basis[14] to simulate cropping, grazing, forests and wetlands etc. Figure 7 below shows the annual time series results for surface water runoff (mm per annum) for cropping (blue), grazing (green) and wetland (red).

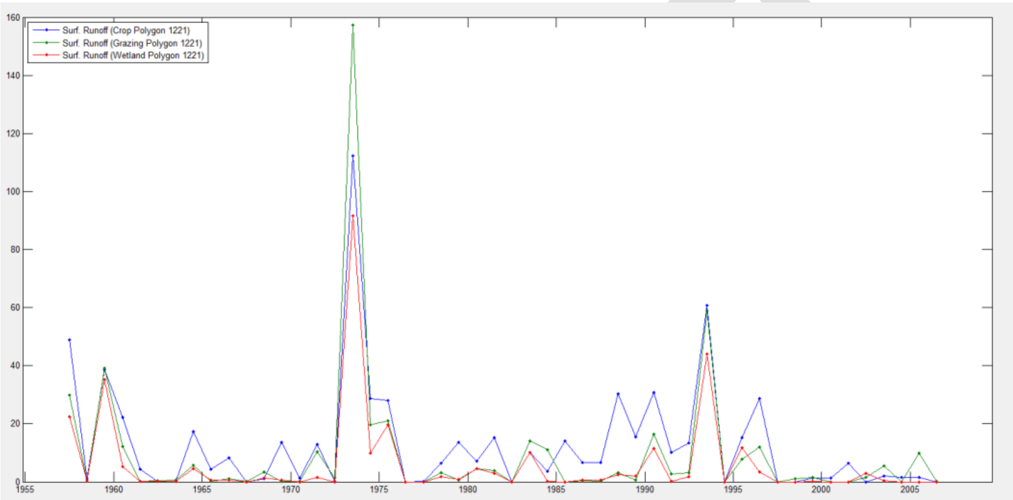


Figure 7 Surface water runoff

Figure 7 above illustrates that there are considerable differences between the three FEU types, with croplands having higher run-off, except during extreme events when run-off on grazed lands peaks highest. The measurement of ecosystem services related to run-off retention (or water flows regulation) is demonstrated on figure 3 below.

In order to see the difference in the results more clearly Figure 8 shows the cumulative change in surface water run-off over the same period, where the lower the cumulative line lays, the higher the ecosystem service (flow regulation).

[14] Daily inputs of rainfall, temperature, etc

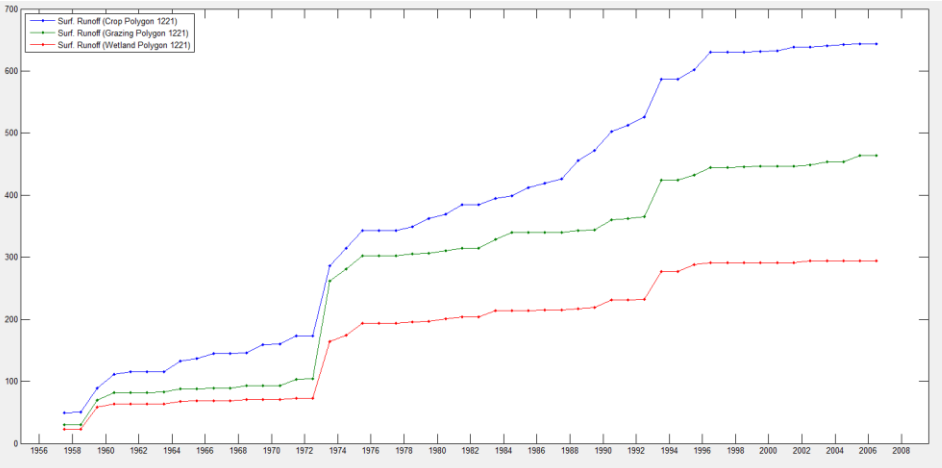


Figure 8 Cumulative surface water runoff – flow regulation

The figure illustrates that croplands exhibit more than twice the rates of run-off, or more than half lower the value of flow regulation services. This has important links to land cover and FEU classification. If BSUs or areas of land are incorrectly classified (say omission of wetlands) and service classes (50% higher for wetlands run-off retention) would incorrectly estimate both the quantity of the service and its location (due to aggregation issues in the SEEA CF land cover).

Similar results can be presented for carbon, evapotranspiration, erosion etc. which are needed for the estimation of other ecosystem services (filtration) and benefits (water for consumption or stream flow).

Table 12 Ecosystem service – flow regulation – runoff (mm/annum)

AR_LU_NEW	Landuse	Sum of Surf. Runoff New	Sum of Surf. Runoff Base	Change in runoff	% change in runoff
Creekline Grassy Woodland	3.2.0 Grazing modified pastures	19	77	(57)	-75%
	3.3.0 Cropping	53	176	(123)	-70%
Creekline Grassy Woodland Total		72	253	(180)	-71%
Plains Woodland	2.1.0 Grazing natural vegetation	16	49	(33)	-67%
	3.2.0 Grazing modified pastures	3,396	8,370	(4,974)	-59%
	3.3.0 Cropping	10,733	23,874	(13,141)	-55%
	3.3.1 Cereals	5	17	(13)	-73%
	3.3.8 Legumes	313	1,062	(750)	-71%
	5.7.2 Roads	402	7,489	(7,088)	-95%
Plains Woodland Total		14,864	40,863	(25,999)	-64%
Grand Total		14,936	41,115	(26,179)	-64%

Table 13 Ecosystem service – water filtration (t/ha/annum)

AR_LU_ANCA_new	Landuse	ANCA Sum of Erosion New	Sum of Erosion Base	Change in erosion	% change in erosion
Creekline Grassy Woodland	3.2.0 Grazing modified pastures	0.01	1	(1)	-98%
	3.3.0 Cropping	0.03	29	(29)	-100%
Creekline Grassy Woodland Total		0.04	29	(29)	-100%
Plains Woodland	2.1.0 Grazing natural vegetation	0.00	0	(0)	-99%
	3.2.0 Grazing modified pastures	0.22	18	(18)	-99%
	3.3.0 Cropping	0.43	1,194	(1,194)	-100%
	3.3.1 Cereals	0.00	1	(1)	-100%
	3.3.8 Legumes	0.02	54	(54)	-100%
	5.7.2 Roads	0.02	0	(0)	-94%
Plains Woodland Total		0.70	1,267	(1,267)	-100%
Grand Total		1	1,297	(1,296)	-100%

Table 14 Ecosystem service – flow regulation – recharge (mm/annum)

AR_LU_NEW	Landuse	Sum of Recharge New	Sum of Recharge Base	Change in recharge	% change in recharge
Creekline Grassy Woodland	3.2.0 Grazing modified pastures	105	449	(344)	-77%
	3.3.0 Cropping	291	2,013	(1,722)	-86%
Creekline Grassy Woodland Total		396	2,463	(2,066)	-84%
Plains Woodland	2.1.0 Grazing natural vegetation	54	163	(109)	-67%
	3.2.0 Grazing modified pastures	8,730	25,968	(17,239)	-66%
	3.3.0 Cropping	10,841	100,933	(90,093)	-89%
	3.3.1 Cereals	17	132	(115)	-87%
	3.3.8 Legumes	928	7,605	(6,677)	-88%
	5.7.2 Roads	772	3,962	(3,191)	-81%
Plains Woodland Total		21,341	138,764	(117,423)	-85%
Grand Total		21,737	141,226	(119,489)	-85%

5.2 FEU - qualitatively estimating ecosystem services

In some instances models are not available or have not been developed sufficiently. However there is sufficient data to infer casual relationships between plant compositional characterisations and ecosystem services. For instance it is clear that an FEU which a high composition of tall trees will provide wind flow regulation services and habitat services. However models may not exist to quantify this in an empirical manner.

Whether a model is developed or not relies upon the need to quantify the ecosystem service. For instance many people and institutes need to understand water partitioning and biomass accumulation so there are many of those models available.

5.3 FEU Condition assessments

Based on the plant compositional characterisations it is possible to use this information to develop methods to estimate the condition of FEUs. There are many cases where benchmarks have been developed that describe the ideal the plant compositional characterisations. These bench marks are then used to develop a condition metric. This is done by comparing a given locations plant composition with that of the bench mark and producing a relative estimate of condition (generally this is normalised to 100). The benchmarks do not need to be based on natural of pre-settlement, they can be based on an ideal given the current context and objectives.

5.4 FEU Ecosystem Services

Based on the compositional approach discussed above we now consider biotic, abiotic and other linking compounds. When these characteristics are combined there are several high level functions (other functions can be listed) that can be described including energetic cycles, biogeochemical cycles and evolution that result in ecosystem services (see Figure 9 below).

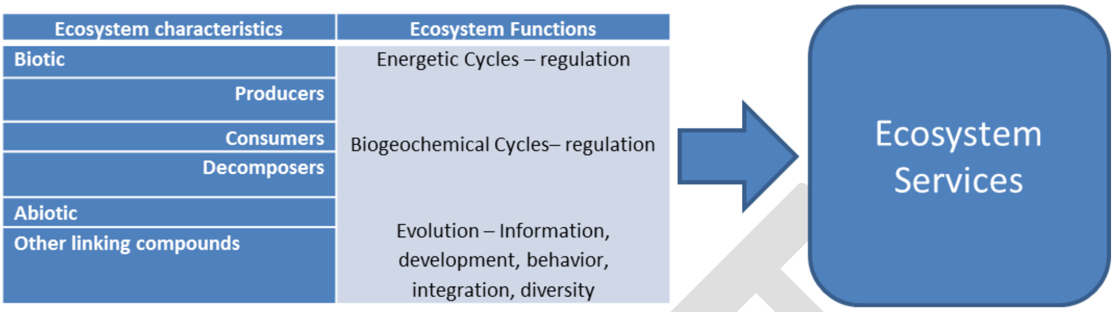


Figure 9 Linking ecosystem function to ecosystem services

All FEUs have the potential to provide both direct and indirect ecosystem services and benefits. In order to assess the service each FEU can provide a number of conditions need to be taken into account. These include (draft list)

- For what purpose is the FEU being managed?
- To what degree is the FEU reliant upon humanities inputs?

Table 1 below provides a list of the ecosystem services based on an ecosystem function approach. This table has been built from concepts and ideas in CICES[15] and FEGS[16] and the table has been qualitatively cross checked with services discussed in both the approaches (See Appendix VII – FEGS and CICES Overview for further detail). Both the CICES and FEGS provide a comprehensive assessment of ecosystem services but neither approaches link to an accounting unit.

By linking ecosystem services explicitly to the FEU accounting unit it is possible understand with greater clarity the composition of ecosystem services. Further since the FEU is based on plant communities it is also possible to developed benchmarks for each FEU and estimate the condition of the FEU against the benchmark.

The CICES classification (See Appendix VII – FEGS and CICES Overview for further detail) of ecosystem services includes functions, assets and benefits whereas the FEU approach starts with plant composition and then links to function and then ecosystem services. Much of the descriptive text in Table 15 below is adapted from CICES and modified were needed to match the approach proposed in this paper.

The following sections provide examples on how to read the information contained in the Table 15 below. Column 1 of the table lists the basic service of an FEU and column 2 is the specific service that results in an outcome that provides benefits, column 4 and 5. Column 3 describes whether the service is intermediate or final, and columns 6 and 7 provide a description and a method to measure the service, respectively.

[15] Insert reference

[16] Insert reference

Plant growth biomass - Grass

Composition – The FEU can be described by the composition of grasses and the type of grasses – say annual versus perennial, species C1-C4. The farmer deliberately manages the composition so there is a relatively stable supply of grass throughout the year and a flush of grass at a time when it is required to finish the animals ready for market. The farmer constantly monitors nutrient availability and soil acidity to ensure grass growth is maximised.

Purpose – plant growth for the production of grass

Inputs – very high and required for the FEU to function and produce grass

ES 1 – plant growth biomass

ES 2 – Grass

Plant growth biomass - Nuts, berries and fungi

Composition – The FEU can be described the composition of trees, shrubs, grasses etc.

Purpose – provide habitat for fauna and allow flora to exist and flourish naturally.

Inputs – very little – some management of invasive species (flora and fauna) and protection from fire.

ES 1 – Plant growth biomass

ES 2 – Nuts, berries and fungi

Final ES – berries or other food taken for consumption

Intermediate ES – berries and food taken by animals from other areas outside of the FEU

Section 2 start

Table 15 FEU – Ecosystem Services Classification

1	**2**	**3**	**4**	**5**	**6**	**7**
ES - Level 1	**ES - Level 2**	**Intermediate or Final ES**	**Direct benefits**	**Indirect/Other Benefits**	**Description**	**Measure**
Plant growth – biomass	Grass	Final	Animals - Input Animals - Asset (Gross Fixed Capital)	Meat, dairy products (milk, cheese, yoghurt), honey etc. Dung, fat, oils, cadavers from land, water and marine animals for burning and energy production	Reared animals and their outputs	tonnes /ha Total head
Plant growth – biomass	Wheat	Final	Wheat	Fodder / animal food	Cultivated crops - Cereals (e.g. wheat, rye, barely), potatoes, vegetables, fruits etc.	tonnes /ha
Plant growth – biomass	Nuts, berries, fungi, etc	Final	Wild berries, fruits, mushrooms, water cress, salicornia (saltwort or samphire); seaweed (e.g. Palmaria palmata = dulse, dillisk) for food		Wild plants, algae and their outputs	tonnes /ha
		Intermediate	Food source for animals outside of the FEU		Wild animals	

ES - Level 1	ES - Level 2	Intermediate or Final ES	Direct benefits	Indirect/Other Benefits	Description	Measure
Plant growth - biomass **Plant growth – structural**	Fruit Trees and vines	Final Final	Fruit - Input Trees - Asset (Gross Fixed Capital)		Orchards and other permanent plantings	tonnes /ha stems /ha
Animal growth - biomass	Meat	Final	Wild animals to eat or capture for other purposes		Game, freshwater fish (trout, eel etc.), marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs) as well as equinoderms or honey harvested from wild populations; Includes commercial and subsistence fishing and hunting for food	tonnes
Animal growth - structure	Animals	Final	Tourism, sport, safari, etc	Existence	Wild animals and their outputs. Lions, tigers, elephants, giraffes, kangaroos, horses for viewing or using for entertainment/sport	animals / ha
Plant growth - biomass/structural	Habitat	Final Intermediate	Habitat for in situ species Habitat for species not in the FEU permanently Landscape connectivity			Nesting, nursery, sites in grass and trees / ha (hollow logs)

ES - Level 1	ES - Level 2	Intermediate or Final ES	Direct benefits	Indirect/Other Benefits	Description	Measure
Plant growth - structural/biomass **Animal growth - structure/biomass**	Genetic Material	Final	Genetic material (DNA) from plants, algae for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc.		Genetic materials from all flora and fauna	Diversity (taxa)
		Intermediate	Resilience, adaptability			
Animal growth - structure		Final	Honey			
		Intermediate	Pollination, seed dispersal, pest control	Pollination and seed dispersal		
Plant growth - structural	Water Flow stabilisation	Final	flood protection/prevention			floods / yr
Plant growth - structural	Air Flow stabilisation	Final	Protection from storms (houses)			
		Intermediate	Shelter for animals			

ES - Level 1	ES - Level 2	Intermediate or Final ES	Direct benefits	Indirect/Other Benefits	Description	Measure
Plant growth - structural	Material	Final	Wood fuel, straw, crops and algae for burning and energy production Wood for secondary processing - furniture		Biomass-based energy sources Furniture and other construction	timber - tonnes / ha
Plant growth - structural and biomass accumulation	**Water Filtration** Nitrogen, Phosphorus fixing & Particle stabilisation	Final	Water authority		Clean water for direct use	Nitrogen ppm Phosphorus - ppm Soil Particulate - g/litre
		Intermediate	Healthy aquatic habitat		healthy water for aquatic habitat	
Plant growth - structural and biomass accumulation	Air Filtration	Final Intermediate	Clean air	Health		Carbon - ppm Particulates ppm NO2 - ppm
Plant growth - structural and biomass accumulation	Carbon fixing / sequestration	Final Intermediate	Atmospheric stabilisation			
Material Cycling		Intermediate	Soil structure, fertility, health		Decomposition and mineralization	Soil organic carbon

ES - Level 1	ES - Level 2	Intermediate or Final ES	Direct benefits	Indirect/Other Benefits	Description	Measure
Plant growth - structural/biomass **Animal growth - structure/biomass**	Plant and animal diversity (richness, endemism)	Final	Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings]		In-situ whale and bird watching, snorkelling, diving etc. Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting Subject matter for research both on location and via other media Ex-situ viewing/experience of natural world through different media Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes	Events (trips) Events (trips) Publications Events (screenings)
Plant growth - structural/biomass **Animal growth - structure/biomass**	Plant and animal diversity (richness, endemism)	Final	Spiritual, symbolic and other interactions with ecosystems and land-/seascapes [environmental settings]		Subject matter of education both on location and via other media Historic records, cultural heritage e.g. preserved in water bodies and soils Sense of place, artistic representations of nature Emblematic plants and animals e.g. National symbols such as American eagle, British rose, Welsh daffodil Spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and	Publications (articles, books) Datasets, Publications Entities

					their parts Willingness to preserve plants, animals, ecosystems, land-/seascapes for future generations; moral/ethical perspective or belief	

Section 2 end

6 Conclusion

The aim of this paper was to propose an approach to ecosystem accounting that built on ecological principles whilst adhering to accounting principles. The FEU is proposed as the ecosystem accounting unit which we believe can be sufficiently delineated to provide a unique and comprehensive classification system. Further the FEU is amenable to aggregation based on recognised national and international approaches currently in use (ie bioregions).

Land cover accounts also link well with the FEUs providing a high level course classification of FEUs. Examples of both SEEA CF land accounts and FEU account were provided to demonstrate the linkages and provide guidance for other to implement ecosystem accounts. The FEU provides a natural link to the SEEA CF for accounting purposes thus making the link with the SNA simpler.

By maintaining a clear distinction between economic accounting based on administrative boundaries (AAU) and ecological accounting using the EAU it is possible to integrate data based on either an economic or ecological focus meeting the needs of both accountants and ecologists alike.

The functional approach of the FEU also provides a clear unit for classifying ecosystem services. The adoption of the phytosociological approach with a focus on autotrophs can be used to assess the condition of an FEU and also infer the ability of an FEU to provide a full suite of ecosystem services.

Further work is required to clarify the full suite of ecosystem services and design methods to estimate there supply. Also further work is required to link and demonstrate how FEUs can be used to build component accounts including biodiversity accounts.

7 Appendix I - Land Classifications SEEA

Table 2.1 Provisional Land Cover/Ecosystem Functional Unit Classes (LCEU)--SEEA EEA	**Table 5.12 Land cover classification---SEEA CF**	**Table 5.11 Land use classification ---SEEA CF**
Description of classes	**Land Cover Categories**	**Land use classification**
Urban and associated developed areas	1 Artificial surfaces (including urban and associated areas)	1 Land
Medium to large fields rainfed herbaceous cropland	2 Herbaceous crops	1.1 Agriculture
Medium to large fields irrigated herbaceous cropland	3 Woody crops	1.2 Forestry
Permanent crops, agriculture plantations	4 Multiple or layered crops	1.3 Land used for aquaculture
Agriculture associations and mosaics	5 Grassland	1.4 Use of built-up and related areas
Pastures and natural grassland	6 Tree-covered areas	1.5 Land used for maintenance and restoration of environmental functions
Forest tree cover	7 Mangroves	1.6 Other uses of land n.e.c.
Shrubland, bushland, heathland	8 Shrub-covered areas	1.7 Land not in use
Sparsely vegetated areas	9 Shrubs and/or herbaceous vegetation, aquatic or regularly flooded	2 Inland waters
Natural vegetation associations and mosaics	10 Sparsely natural vegetated areas	2.1 Inland waters used for aquaculture or holding facilities
Barren land	11 Terrestrial barren land	2.2 Inland waters used for maintenance and restoration of environmental functions
Permanent snow and glaciers	12 Permanent snow and glaciers	2.3 Other uses of inland waters n.e.c.
Open wetlands		2.4 Inland waters not in use
Inland water bodies	13 Inland water bodies	
Coastal water bodies	14 Coastal water bodies and intertidal areas	
Sea		

8 Appendix II – Soil parameters

Soil Parameter	Units	Descriptions
ndeps	-	Number of soil layers
Depth1	mm	Depth from surface to bottom of layer
Airdry1	%	Soil moisture content at air-dry (-1000 KPa)
LowLmt1	%	Soil moisture content at wilting point
UpLmt1	%	Soil moisture content at field capacity
Sat1	%	Soil moisture content at saturation
Ksat1	mm/hr	Saturated soil conductivity
SoiCon1	-	Soil constant based on texture
SoiPow1	-	Soil power value based on soil texture
Init1	%	Initial soil moisture content at simulation start
Na1	EC	Initial soil salinity
B1	mg/l	Initial soil boron concentration
Al1	mg/l	Initial soil aluminium concentration
Stg1Cona	-	Stage 2 soil evaporation shape parameter
Stg2U	mm	Upper limit of Stage 1 drying
CN2	-	Bare soil curve number
CN@100%	-	Reduction in curve number at 100% cover
CNredTill	-	Maximum reduction in curve number due to tillage
CumRain-R	mm	Cumulative rainfall to remove CN roughness effect
MUSLE-K	t/ha/EI30	Soil erodibility factor based on soil texture
MUSLE-P	-	Soil erodibility practice factor based on soil texture
Slope	%	Paddock slope
SlopeLgth	m	Length of slope or contour bank spacing
Ril/InRil	-	Rill/Interrill ratio for RUSLE slope length factor
BulkDen	gm/m3	Bulk density of 0-10cm surface soil
MaxCrackI	mm	Maximum infiltration into cracks
ImpDepth	mm	Root impedance depth (say due to hardpan etc)
Cracking	y/n	If cracking soil then y, else n

9 Appendix III – FEU Plant Composition Examples

9.1 EVC 22: Grassy Dry Forest

Description:

Occurs on a variety of gradients and altitudes and on a range of geologies. The overstorey is dominated by a low to medium height forest of eucalypts to 20 m tall, sometimes resembling an open woodland with a secondary, smaller tree layer including a number of Acacia species. The understorey usually consists of a sparse shrub layer of medium height. Grassy Dry Forest is characterised by a ground layer dominated by a high diversity of drought-tolerant grasses and herbs, often including a suite of fern species.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus spp.	60 cm	20 / ha

Tree Canopy Cover:

%cover	Character Species	Common Name
30%	Eucalyptus melliodora	Yellow Box
	Eucalyptus macrorhyncha	Red Stringybark
	Eucalyptus polyanthemos	Red Box

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Understorey Tree or Large Shrub	2	10%	T
Medium Shrub	9	20%	MS
Small Shrub	4	5%	SS
Prostrate Shrub	2	1%	PS
Large Herb	2	5%	LH
Medium Herb	8	15%	MH
Small or Prostrate Herb	2	5%	SH
Large Tufted Graminoid	3	5%	LTG
Medium to Small Tufted Graminoid	11	30%	MTG
Medium to Tiny Non-tufted Graminoid	2	10%	MNG
Scrambler or Climber	3	5%	SC
Bryophytes/Lichens	na	10%	BL
Soil Crust	na	10%	S/C

9.2 Example of Compositional characteristics - Plains Woodland

Type	Species	Target Density
Overstorey	Buloke (Allocasuarina luehmannii)	50 plants per ha
	River Red-gum (Eucalyptus camaldulensis)	
	Yellow Gum (Eucalyptus leucoxylon)	
	Yellow Box (Eucalyptus melliodora)	
	Grey Box (Eucalyptus microcarpa)	
	Waxy Yellow-gum (Eucalyptus leucoxylon subsp. pruinosa)	
Understorey Tree or Large Shrub > 5m tall	Lightwood (Acacia implexa)	Present
	Silver Needlewood (Hakea leucoptera subsp. leucoptera)	
	Sugarwood (Myoporum platycarpum subsp. platycarpum)	
Medium Shrub 1-5m tall	Gold-dust Wattle (Acacia acinacea s.l.)	200 plants per ha
	Mallee Wattle (Acacia montana)	
	Hedge Wattle (Acacia paradoxa)	
	Golden Wattle (Acacia pycnantha)	
	Varnish Wattle (Acacia verniciflua)	
	Sweet Bursaria (Bursaria spinosa subsp. spinosa)	
	Drooping Cassinia (Cassinia arcuata)	
	Pale-fruit Ballart (Exocarpos strictus)	
	Turkey Bush (Eremophila deserti)	
	Weeping Pittosporum (Pittosporum angustifolium)	
	Gold-dust Wattle (Acacia acinacea s.s.)	
Small Shrub < 1m tall	Common Eutaxia (Eutaxia microphylla)	500 plants per ha
	Rohrlach's Bluebush (Maireana rohrlachii)	
	Spiny Lignum (Muehlenbeckia horrida subsp. horrida)	
	Black Roly-poly (Sclerolaena muricata)	
	Common Eutaxia (Eutaxia microphylla var. microphylla)	
Large Tufted Graminoid (grasses and grass-like tussocks > 1m tall)	Poong'ort (Carex tereticaulis)	500 plants per ha
	Gold Rush (Juncus flavidus)	
	Common Tussock-grass (Poa labillardierei)	
	Plump Spear-grass (Austrostipa aristiglumis)	
	Kneed Spear-grass (Austrostipa bigeniculata)	
	Supple Spear-grass (Austrostipa mollis)	
	Knotty Spear-grass (Austrostipa nodosa)	
	Quizzical Spear-grass (Austrostipa stuposa)	

10 Appendix IV – Land Cover Classes SEEA CF

11 Appendix V – EVC 55 Plains Grassy Woodland – Composition

EVC 55: Plains Grassy Woodland

Description:
An open, eucalypt woodland to 15 m tall occurring on a number of geologies and soil types. Occupies poorly drained, fertile soils on flat or gently undulating plains at low elevations. The understorey consists of a few sparse shrubs over a species-rich grassy and herbaceous ground layer.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus spp.	70 cm	15 / ha
Allocasuarina luehmannii	40 cm	

Tree Canopy Cover:

%cover	Character Species	Common Name
15%	*Eucalyptus microcarpa*	Grey Box
	Eucalyptus melliodora	Yellow Box
	Eucalyptus camaldulensis	River Red Gum
	Allocasuarina luehmannii	Buloke

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Medium Shrub	1	5%	MS
Small Shrub	1	1%	SS
Large Herb	3	5%	LH
Medium Herb	10	30%	MH
Small or Prostrate Herb	3	10%	SH
Medium to Small Tufted Graminoid	18	40%	MTG
Medium to Tiny Non-tufted Graminoid	2	5%	MNG
Bryophytes/Lichens	na	10%	BL
Soil Crust	na	10%	S/C

LF Code	Species typical of at least part of EVC range	Common Name
MS	*Acacia acinacea s.l.*	Gold-dust Wattle
MS	*Acacia pycnantha*	Golden Wattle
SS	*Lissanthe strigosa ssp. subulata*	Peach Heath
LH	*Wahlenbergia luteola*	Bronze Bluebell
LH	*Wahlenbergia communis s.l.*	Tufted Bluebell
MH	*Brachyscome lineariloba*	Hard-head Daisy
SH	*Drosera whittakeri ssp. aberrans*	Scented Sundew
SH	*Ptilotus spathulatus f. spathulatus*	Pussy Tails
SH	*Drosera glanduligera*	Scarlet Sundew
SH	*Siloxerus multiflorus*	Small Wrinklewort
MTG	*Austrostipa scabra ssp. falcata*	Rough Spear-grass
MTG	*Elymus scaber var. scaber*	Common Wheat-grass
MTG	*Lomandra filiformis*	Wattle Mat-rush
MTG	*Austrodanthonia setacea*	Bristly Wallaby-grass

Wimmera bioregion

EVC 55: Plains Grassy Woodland

Description:
An open, eucalypt woodland to 15 m tall occurring on a number of geologies and soil types. Occupies poorly drained, fertile soils on flat or gently undulating plains at low elevations usually in areas with >600 mm annual rainfall. The understorey consists of a few sparse shrubs over a species-rich grassy and herbaceous ground layer.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus spp.	80 cm	15 / ha

Tree Canopy Cover:

%cover	Character Species	Common Name
15%	*Eucalyptus camaldulensis*	River Red Gum

Understorey:

Life form	#Spp	%Cover	LF code
Immature Tree		5%	IT
Medium Shrub	1	5%	MS
Small Shrub	2	5%	SS
Prostrate Shrub	1	1%	PS
Large Herb	1	1%	LH
Medium Herb	18	25%	MH
Small or Prostrate Herb	4	10%	SH
Large Tufted Graminoid	1	1%	LTG
Medium to Small Tufted Graminoid	15	40%	MTG
Medium to Tiny Non-tufted Graminoid	4	5%	MNG
Bryophytes/Lichens	na	10%	BL

LF Code	Species typical of at least part of EVC range	Common Name
SS	*Pimelea humilis*	Common Rice-flower
SS	*Pimelea curviflora s.l.*	Curved Rice-flower
PS	*Astroloma humifusum*	Cranberry Heath
PS	*Bossiaea prostrata*	Creeping Bossiaea
MH	*Hypericum gramineum*	Small St John's Wort
MH	*Drosera peltata ssp. peltata*	Pale Sundew
MH	*Acaena echinata*	Sheep's Burr
MH	*Leptorhynchos squamatus*	Scaly Buttons
SH	*Drosera whittakeri ssp. aberrans*	Scented Sundew
SH	*Hydrocotyle laxiflora*	Stinking Pennywort
SH	*Solenogyne dominii*	Smooth Solenogyne
LTG	*Austrostipa pubinodis*	Tall Spear-grass
MTG	*Schoenus apogon*	Common Bog-sedge
MTG	*Themeda triandra*	Kangaroo Grass
MTG	*Tricoryne elatior*	Yellow Rush-lily
MTG	*Caesia calliantha*	Blue Grass-lily
MNG	*Microtis unifolia*	Common Onion-orchid
MNG	*Microlaena stipoides var. stipoides*	Weeping Grass
TTG	*Centrolepis aristata*	Pointed Centrolepis
SC	*Thysanotus patersonii*	Twining Fringe-lily
SC	*Convolvulus erubescens spp. agg.*	Pink Bindweed

12 Appendix VI - Stream/River Classifications[17]

The river continuum concept assigns different sections of a river into three rough classifications. These classifications apply to all river waters, from small streams to medium-sized and large rivers.

12.1 Headwaters (Stream order 1 to 3)

The creek area in the upper reaches or headwaters of a water system is usually very narrow and lined by thick shore vegetation. This prevents the penetration of sunlight, in turn decreasing the production of organic material through photosynthesis in the water. The majority of the organic matter that does make its way into the system is in the form allochthonous plant material that falls into the river, such as leaves and sticks. In this section, respiration (consumption) out paces production (P/R<1). Here shredders play a major role in breaking down coarse plant material. In this area, the largest diversity of organic material can be expected.

12.2 Mid-reaches (Stream order 4-6)

In the mid-reaches of a river, river structures such as rocks and trees play an important role as a supplier of organic material such as periphyton and other autochthonous (see limnology section of link) organic materials. The photosynthesis to respiration ratio is larger in this section and amounts to P: R> 1. The percentage of shredders in this area is less than that of the headwaters, due to a lack of coarse plant particulates. Collectors and grazers make up a majority of the macro invertebrate structure in this area, with the predator's share remaining unchanged.

12.3 Lower reaches (Stream order >6)

In the lower reaches, there is a large flux in particulate material and also a decrease in production through photosynthesis, due to an increase in water cloudiness (turbidity) and surface film from suspended FPOM. Here, like the headwaters, respiration outpaces photosynthesis, making the ratio again less than 1 (P: R <1). The living community in these areas are made up of almost exclusively collectors, as well as a small share of predators.

[17] Adapted Vannote et al 1980

13 Appendix VII – FEGS and CICES Overview

Final Ecosystem Goods and Services (FEGS)

The USA Environmental Protection Agency carried an Ecosystem Services Research Project, part of which was the development of FEGS-CS. This classification system proposes (hypothetical) final goods and services defined by the crossing (intersection) of pre-selected 'environments' in major classes and subclasses, most of which represent terrestrial and aquatic land cover classes, and an exhaustive list of beneficiaries.

'The FEGS-CS is represented as a collection of tables … called the **FEGS Matrices**, which were collectively designed to be a resource and tool for practitioners to use in consistently defining, identifying, quantifying, and valuing FEGS. Within the FEGS Matrices, sets of FEGS pertaining to specific beneficiaries and provided by particular types of environments are explicitly identified as hypotheses.' (FEGS-CS Version 2.8a).

FEGS-CS organization is modelled after the North American Industrial Classification System that has a flexible aggregation structure. The environmental components (classes and subclasses, Table 16) follows Anderson's Land Use and Land Cover Classification System (Anderson et al. 1976).

Table 16 Environmental components in FEGS

1. AQUATIC	**2. TERRESTRIAL**	**3. ATMOSPHERIC**
11. Rivers and Streams	21. Forests	31. Atmosphere
12. Wetlands	22. Agroecosystems	
13. Lakes and Ponds	23. Created Greenspace	
14. Estuaries and Near Coastal and Marine	24. Grasslands	
15. Open Oceans and Seas	25. Scrubland / Shrubland	
16. Groundwater	26. Barren / Rock and Sand	
	27. Tundra	
	28. Ice and Snow	

The following broad categories of beneficiaries are included (detailed subcategories can be consulted in FEGS-CS (V.1.8), p. 43.): Agricultural; Commercial / Industrial; Government, Municipal, and Residential; Commercial / Military Transportation; Subsistence; Recreational; Inspirational; Learning; Non-Use (existence or bequest); Humanity.

The interaction between a beneficiary (for ex. a tourist) and an environmental class (for ex. a forest) is defined through 21 'appreciation' categories (that can be viewed as a look-up table) shown in Table 16

Table 17 FEGS Ecosystem Services

01 Water	11 Soil
02 Flora	12 Pollinators
03 Presence of the environment	13 Depredators and (pest) predators
04 Fauna	14 Timber
05 Fibre	15 Fungi
06 Natural materials	16 Substrate
07 Open space	17 Land
08 View-scapes	18 Air
09 Sounds and scents	19 Weather
10 Fish	20 Wind
	21 Atmospheric phenomena

These categories need to be measured through an 'ecological production function' where a number of factors and effects including negative ones (such as stressors, pressures, impacts) can be introduced through metrics and indicators for the 'correct' estimation of final goods and services.

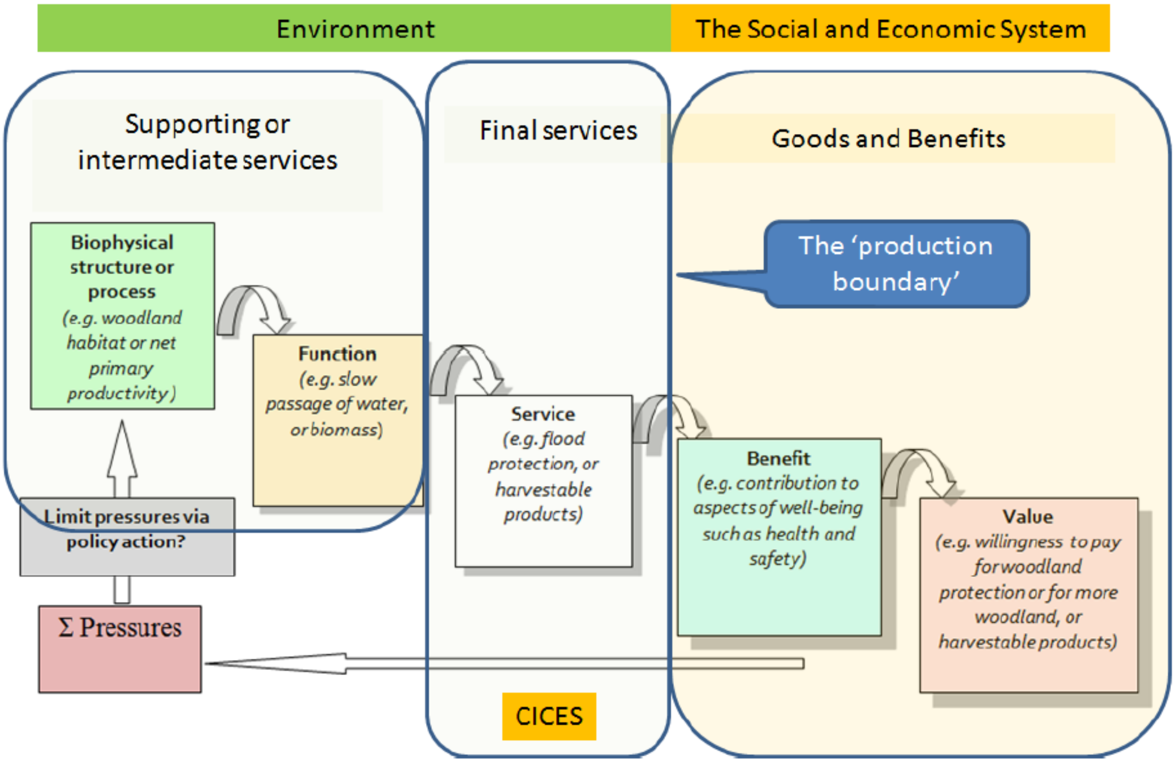
The current initial version of FEGS-CS is proposed for application, experimentation and further development, with additional material (including spreadsheets) available online.

CICES

CICES is a hierarchical classification of ecosystem services. It was designed by the CEM-University of Nottingham and EEA, as part of the SEEA revision process. The current structure was shaped through a wide consultation processes and subsequent updates – following a number of testing applications (modifications were done mostly at the lowest level of the hierarchical classification.

Applications have been tested for mapping purposes, SEEA-accounting and stand-alone assessments of ecosystem services. Currently, two ongoing international European initiatives have adopted CICES: the MAES (Mapping and Assessment of Ecosystems and their Services) process and OPENNESS, a collaborative EU funded (FP7) research project.

CICES development is based on the paradigm called the 'cascade model' (Potschin and Haines-Young 2011) which links ecosystem services, benefits and underlaying biophysical functions



The model facilitates discussions on a number of accounting issues, for example:

- the delimitation of production boundary (goods and benefits),
- differences between 'resource accounting' and ecosystem services accounting, the latter being far more focused on linkages with environmental and biophysical factors,
- the need to develop classifications all along the cascade chain, addressing intermediate functions and final goods and services
- criteria for defining final goods and services and avoiding double-counting (that remains very challenging).

The hierarchical structure of CICES is more comprehensive (than other schemes e.g. Millennium Ecosystem Assessment etc.) and allows for a certain level of translation between different classifications schemes, mostly differences appear at levels 4 and 5 (so levels 1, 2 and 3 are quite stable). Ensuring transferability and comparability is the main purpose of developing a common classification scheme. A web-based tool has been designed to facilitate such translations (http://openness.hugin.com/example/cices).

The hierarchical structure of CICES has been designed so that the categories at each level are non-overlapping and without redundancy. The categories at the lower levels also inherit the properties or characteristics of the levels above. As a result, CICES can be regarded as a classification *sensu stricto*. We recommend the following definitional structure:

a. **Provisioning services:** all nutritional, material and energetic outputs from living systems. In the proposed structure a distinction is made between provisioning outputs arising from biological materials (biomass) and water. The consultation confirmed the classification of water as problematic, because it was regarded by some as primarily an abiotic, mineral output. The majority argued, however, that it should be included; convention and wider usage of the notion of an ecosystem services also suggests that it is appropriate to do so. In addition, water bodies of all scales host communities of species that provide ecosystem services themselves.

b. **Regulating and maintenance:** covers all the ways in which living organisms can mediate or moderate the ambient environment that affects human performance. It therefore covers the degradation of wastes and toxic substances by exploiting living processes; by reconnecting waste streams to living processes it is in this sense the opposite of provision. Regulation and maintenance also covers the mediation of flows in solids, liquids and gases that affect people's performance as well as the ways living organisms can regulate the physico-chemical and biological environment of people.

c. **Cultural Services:** covers all the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people. The consultation suggested that this area was particular problematic in terms of the different terminologies used by the wider community, which often does not make a distinction between services and benefits; the term recreation is, for example, particularly problematic in this respect. We also note that all services, whether they be provisioning or regulating can have a cultural dimension. However, it is valuable to retain the section for Cultural, and to make the category distinct.[18]

[18] Source: Haines-Young, R. and Potschin, M. (2013): Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract No EEA/IEA/09/003

CICES for ecosystem service mapping and assessment					Note: this section is not complete and for illustrative purposes only. Key components could change by region or ecosystem.
CICES for ecosystem accounting				Note this section is open in that many class types can potentially be	
Section	**Division**	**Group**	**Class**	**Class type**	**Examples**
This column lists the three main categories of ecosystem services	***This column divides section categories into main types of output or process.***	***The group level splits division categories by biological, physical or cultural type or process.***	***The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.***	***Class types break the class categories into further individual entities and suggest ways of measuring the associated ecosystem service output.***	
Provisioning	Nutrition	Biomass	Cultivated crops	*Crops by amount, type*	Cereals (e.g. wheat, rye, barely), potatoes, vegetables, fruits etc.
			Reared animals and their outputs	*Animals, products by amount, type*	Meat, dairy products (milk, cheese, yoghurt), honey etc.
			Wild plants, algae and their outputs	*Plants, algae by amount, type*	Wild berries, fruits, mushrooms, water cress, salicornia (saltwort or samphire); seaweed (e.g. Palmaria palmata = dulse, dillisk) for food
			Wild animals and their outputs	*Animals by amount, type*	Game, freshwater fish (trout, eel etc.), marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs) as well as equinoderms or honey harvested from wild populations; Includes commercial and subsistence fishing and hunting for food
			Plants and algae from in-situ aquaculture	*Plants, algae by amount, type*	in situ seaweed farming
			Animals from in-situ aquaculture	*Animals by amount, type*	In-situ farming of freshwater (e.g. trout) and marine fish (e.g. salmon, tuna) also in floating cages; shellfish aquaculture (e.g. oysters or crustaceans) in e.g. poles
		Water	Surface water for drinking	*Amount of freshwater by type, use*	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for drinking
			Ground water for drinking		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for drinking
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*	Fibres, wood, timber, flowers, skin, bones, sponges and other products, which are not further processed; material for production e.g. industrial products such as cellulose for paper, cotton for clothes, packaging material; chemicals extracted or synthesised from algae, plants and animals such as turpentine, rubber, flax, oil, wax, resin, soap (from bones), remedies (e.g. chondritin from sharks), dyes and colours, ambergris (from sperm whales used in perfumes); includes consumptive ornamental uses.
			Materials form plants, algae and animals for agricultural use		Plant, algae and animal material (e.g. grass) for fodder and fertilizer in agriculture and aquaculture;
			Genetic materials from all biota		Genetic material (DNA) from wild plants, algae and animals for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc.
		Water	Surface water for non-drinking purposes	*By amount and use*	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
			Ground water for non-drinking purposes		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
	Energy	Biomass-based energy sources	Plant-based resources	*By amount and source and sector (agriculture, forestry, marine)*	Wood fuel, straw, energy plants, crops and algae for burning and energy production
			Animal-based resources		Dung, fat, oils, cadavers from land, water and marine animals for burning and energy production
		Mechanical energy	Animal-based energy	*By amount and source and sector (agriculture, forestry, marine)*	Physical labour provided by animals (horses, elephants etc.)
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organism, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Bio-chemical detoxification/decomposition/mineralisation in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto)degradation, (rhizo)degradation etc.
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Biological filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine biota, adsorption and binding of heavy metals and organic compounds in biota
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*	Bio-physicochemical accumulation, filtration and storage of pollutants in land/soil, freshwater and marine ecosystems, including sediments; adsorption and binding of heavy metals and organic compounds in ecosystems (combination of biotic and abiotic factors)
			Dilution by atmosphere, freshwater and marine ecosystems		Bio-physicochemical dilution of gases, fluids and solid waste, wastewater in atmosphere, lakes, rivers, sea and sediments
			Mediation of smell/noise/visual impacts		Visual screening of transport corridors e.g. by trees, green infrastructure to reduce noise and smells
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk; area protected*	Erosion / landslide / gravity flow protection; vegetation cover protecting/stabilising terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; vegetation on slopes also preventing avalanches (snow, rock), erosion, protection of coasts and sediments by mangroves, sea grass, macroalgae, etc.
			Buffering and attenuation of mass flows		Transport and storage of sediment by rivers, lakes, sea
		Liquid flows	Hydrological cycle and water flow maintenance	*By depth/volumes*	Capacity of maintaining baseline flows for water supply and discharge; e.g. fostering groundwater; recharge by appropriate land coverage that captures effective rainfall; includes drought and water scarcity aspects.
			Flood protection	*By reduction in risk; area protected*	Flood protection by appropriate land coverage; flood prevention by mangroves, sea grass, macroalgae, etc. (supplementary to coastal protection by wetlands, dunes)
		Gaseous / air flows	Storm protection	*By reduction in risk; area protected*	Natural or planted vegetation that serves as shelter belts
			Ventilation and transpiration	*By change in temperature/humidity*	Natural or planted vegetation that enables air ventilation
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*By amount and source*	Pollination by bees and other insects; seed dispersal by insects, birds and other animals
			Maintaining nursery populations and habitats	*By amount and source*	Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc.
		Pest and disease control	Pest control	*By reduction in incidence, risk; area protected*	Pest and disease control including invasive alien species
			Disease control		In cultivated and natural ecosystems and human populations
		Soil formation and composition	Weathering processes	*By amount/concentration and source*	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure; includes biological, chemical, physical weathering and pedogenesis
			Decomposition and fixing processes		Maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes;
		Water conditions	Chemical condition of freshwaters	*By amount/concentration and source*	Maintenance / buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
			Chemical condition of salt waters		Maintenance / buffering of chemical composition of seawater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic parameter*	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) etc.
			Micro and regional climate regulation		Modifying temperature, humidity, wind fields; maintenance of rural and urban climate and air quality and regional precipitation/temperature patterns
Cultural	Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data by plant, animal, ecosystem type*	In-situ whale and bird watching, snorkelling, diving etc.
			Physical use of land-/seascapes in different environmental settings		Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting
		Intellectual and representative interactions	Scientific	*By use/citation, by plant, animal, ecosystem type*	Subject matter for research both on location and via other media
			Educational		Subject matter of education both on location and via other media
			Heritage, cultural		Historic records, cultural heritage e.g. preserved in water bodies and soils
			Entertainment		Ex-situ viewing/experience of natural world through different media
			Aesthetic		Sense of place, artistic representations of nature
	Spiritual, symbolic and other interactions with ecosystems and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*By use by ecosystem type*	emblematic plants and animals e.g. National symbols such as American eagle, British rose, Welsh daffodil
			Sacred and/or religious		spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and their parts
		Other cultural outputs	Existence	*By biota, feature/ecosystem type or component*	Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes
			Bequest		Willingness to preserve plants, animals, ecosystems, land-/seascapes for future generations; moral/ethical perspective or belief