Classification and prioritization of ecosystem services

Issue paper

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A. Background

1. At the request of the Australian Bureau of Statistics (ABS), this issues paper was prepared by Simone Maynard and Steve Cork, both of who have extensive experience working on ecosystem services in Australia.

2. Neither author is able to speak on behalf of all ecosystem services researchers in Australia generally, but both have strong links with other researchers and policy makers and both have been involved in recent reviews of the application of the ecosystem services concept in Australia.

3. This paper addresses concepts and questions raised in *Issue 8: Classification of ecosystem services* and *Issue 9: Prioritization of ecosystem services* in *SEEA Experimental Ecosystem Accounts: A Proposed Outline, Road Map and list of issues*.[1] This paper also refers to the report *Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting*.[2]

4. In relation to *Issue 8*, it is noted that: (i) ecosystem services can be defined broadly as the functions of ecosystems that provide benefits to human well-being and arise from the interaction of biotic and abiotic processes; (ii) a Common International Classification for Ecosystem Services (CICES) is needed in order to integrate and compare across potential data sources for ecosystem service flows; and (iii) developments since the CICES report was written have to be reviewed and, where relevant cross-referenced, as part of finalization of CICES.

5. It is recognised that the two tasks emerging from *Issue 8* are: (i) Review recent developments related to the ecosystem services classification (CICES) and propose final version; and (ii) Identify deviations from other typologies in use (e.g. from TEEB) and explain the reasoning for deviations (if any).

6. To contribute to these tasks, this issues paper reviews *Proposal for a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting* in relation to major ecosystem services research and applications in Australia over the past decade; comments on how well the proposed CICES incorporates lessons learned from those projects; and identifies any deviations in the CICES from topologies found to be useful in Australia.

7. In relation to *Issue 9*, it is note that: (i) there has been a general call within the context of the World Bank WAVES global partnership to examine which services should be regarded as priorities for ecosystem accounting; (ii) for the purposes of ecosystem accounts, prioritization can be made considering economic importance, possibility to consistently include the service in SEEA, and availability of data; (iii) there is a need to analyse how available data can be used to construct meaningful national level physical and monetary statistics suitable for incorporation in SEEA; and (iv) it will also be important to provide general clarifications in regards to avoiding overlap or double-counting (or perceptions thereof) in national accounts by including different types of measures.

8. It is recognised that the three tasks emerging from *Issue 9* are: (i) review criteria for prioritizing ecosystem services measurement for ecosystem accounts; (ii) analyze the interrelations between different service flow measures and determine which are most relevant and most feasible for

[1] http://unstats.un.org/unsd/envaccounting/londongroup/meeting17/LG17_9a.pdf

[2] Haines-Young, Roy and Marion Potschin (2010) Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting, Prepared for EEA for the UN Committee of Experts on Environmental-Economic Accounting, 23- 25 June 2010, New York http://unstats.un.org/unsd/envaccounting/ceea/meetings/UNCEEA-5-7-Bk1.pdf

ecosystem accounts; and (iii) investigate availability of measures for capturing ecosystem service flows at different levels either in physical or monetary terms, or both.

9. To contribute to these tasks, this issues paper provides general comments on the role of economic valuation in prioritizing ecosystem services and suggests that consideration of the interactions between ecosystem services and social-ecological resilience might be a useful addition to thinking about which services should be given priority (i.e., those that appear to be closest to points at which their decline or increase might comprise ecological and/or social resilience, adaptive capacity and/or human well-being).

B. Insights on classification of ecosystem services from Australian studies

10. The following comments draw on ecosystem services projects carried out in Australia to address issues raised in the report *Proposal for a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting* (Haines-Young & Potschin 2010).[3]

11. The approach of exploring links between the CICES and other frameworks is a very useful one and give confidence that the CICES will fit comfortably with other accounting and ecosystem service assessment approaches.

12. The authors of this issues paper have not had time to cross-reference the CICES against schemes used for classifying land uses in Australia, but we expect that the same conclusions could be drawn as for the cross-referencing done in the *Towards a Common International Classification …* report. This can be confirmed through subsequent work.

13. There have been many pieces of research on ecosystem services in Australia over the past decade, mostly focussed on establishing the economic and/or other benefits flowing from one or a few services — these projects have usually not needed to develop a classification of ecosystem services. Since 2005 there has been a strong tendency to use the Millennium Ecosystem Assessment (MA) classification as the standard, but more recent studies have used the classification developed by The Economics of Ecosystems and Biodiversity (TEEB) program and/or UK National Ecosystem Assessment[4].

14. Several major projects in Australia have developed classifications of ecosystem services in consultation with stakeholders but with reference to existing classifications[5] [6] [7]. Others have adopted classifications from the literature[8] [9], Some of these classifications are described in Appendix 1.

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[3] Haines-Young, R. and Marion P. (2010) Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting, Prepared for EEA for the UN Committee of Experts on Environmental-Economic Accounting, 23- 25 June 2010, New York http://unstats.un.org/unsd/envaccounting/ceea/meetings/UNCEEA-5-7-Bk1.pdf

[4] N. Crossman, CSIRO, personal communication (2011) in reference to a major CSIRO study of ecosystem services in the Murray Darling Basin currently in progress

[5] Binning, Cork, Parry & Shelton (2001). Natural Assets: An Inventory of Ecosystem Goods and Services in the Goulburn Broken Catchment

[6] Reid N., Karanja F & Thompson D (2006) Ecosystem services and Biodiversity Indicators. Paper presented to the 13th Australian Cotton Conference, Gold Coast, 8-10 August 2006

[7] Maynard S., James D. & Davidson A. (2010) The Development of an Ecosystem Services Framework for South East Queensland. *Environmental Management* **45**, 881-95, <http://www.springerlink.com/index/10.1007/s00267-010-9428-z>

[8] Bennett L. T., Mele P. M., Annett S. & Kasel S. (2010) Examining links between soil management, soil health, and public benefits in agricultural landscapes: An Australian perspective. *Agriculture, Ecosystems & Environment* **139**, 1-12, <http://linkinghub.elsevier.com/retrieve/pii/S0167880910001714>

15. In order to understand the structure of the Australian classification systems as described in Appendix 1, it is important to understand the decision contexts of the assessments for which they were developed. The classifications addressed in this paper are (in alphabetical order):
    - Bennett[10] - Uses a service-based approach to examine links between soil management, soil health, and public benefits in Australian agricultural landscapes.
    - Goulburn Broken[11] – Aims to provide an insight into the full range of ecosystem services currently provided in a catchment (highly dominated by agricultural land use), and provide the basis for a more detailed assessment of what might happen to those services under a set of scenarios for the future.
    - Gwydir[12] - Aimed to gauge the most important ecosystem services to the Gwydir community (in terms of their input to cotton growing); to assess the vulnerability and ease of management of the various ecosystem services; to develop analytical approaches and tools to assess ecosystem services; and to assess the ecological, economic and social impact of changes in delivery of priority ecosystem services.
    - South East Queensland (SEQ)[13] - Stakeholders across a region collaborated to develop an 'agreed' ecosystem services framework to allow for consistent approaches to assessing ecosystem services; and incorporating ecosystem services into policy and planning in SEQ. Over 160 professionals have been involved in its development from business, industry, government, non-government, academia and community.
    - Wallace[14] - Wallace proposed an alternative classification. Wallace's main concern was that previous classifications did not express ecosystem services in terms of the contribution they made to human wellbeing – thus his approach was a variation on approaches that link processes with services and services with benefits.

16. The conceptual framework proposed in Figure 2 of Haines-Young & Potschin (2010), representing a cascade of processes and functions leading to the services that give rise to benefits and values, is consistent with the most recent major studies conducted in Australia,[15] which have themselves drawn on the same literature drawn on by Haines-Young & Potschin (2010). Although these studies have different classification systems to each other, these studies have also reached the same conclusions as Haines-Young & Potschin (2010): (i) that it is important to distinguish between ecosystem structure, process, and function; (ii) that it is important to distinguish between ecosystem functions and services; and (iii) that it is useful to distinguish between services and benefits.
17. Maynard et al.[16] concluded that, although the capacity of an ecosystem (ecosystem function) to provide a service only becomes a service once a benefit and beneficiary can be clearly identified, there is still some merit in estimating the relative potential of different ecosystems to provide ecosystem services when dealing with stakeholder groups and social-environmental planning. A national or international accounting system is constrained by having to work with demand for ecosystem services as it is expressed by public opinion, markets and need, but projects that work interactively with stakeholders can often turn capacity into actual services by creating awareness and new land management that generates a "market" for the services. Presumably this could be dealt with in SEEA Volume 2 by regularly updating assessments of beneficiaries and it is a question for those developing the SEEA Volume 2 as to how beneficiary-demand will be assessed and how frequently.

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[9] N. Crossman (2011), as above
[10] Bennet et al (2010, as above
[11] Binning et al (2001), as above
[12] Reid et al (2006), as above
[13] Maynard et al. (2010), as above
[14] Wallace K. (2007) Classification of ecosystem services. *Biological conservation* **139**, 235 – 246.
[15] Maynard et al. (2010), as above
[16] Maynard et al. (2010), as above

18. It is noted that Haines-Young & Potschin (2010) refer to the need to consider the scale at which ecosystem services are generated and used. It is also noted that the reference in a previous draft to Costanza's (2008)[17] thoughts about scale-based classifications has been removed from the text (although the citation still appears in the reference list). The current draft suggests (pages 17 and 19) that some way of coding ecosystem services based on their scale could facilitate alignment of ecosystem services classifications with classifications of markets (which often are based on scale from local to global). Based on experience in Australia, this idea has merit and should be developed further. For example, in the study of ecosystem services in SEQ, Maynard et al [18] found it necessary to consider the relative magnitude of each service that was generated within the study region providing a robust basis for regional planning, but also providing an opportunity to identify the community's dependency on services generated from outside of the region.

19. Little mention of the temporal scale of ecosystem service provision is provided in any of the AU classifications, CICES or SEEA. The time scales that ecosystem services are generated over are important when considering the sustainable management of the functions that provide ecosystem services, the value of specific ecosystem services over time and identifying beneficiaries. We note that the SEEA Central Framework discusses this in paragraphs 2.138- 2.141 (time of recording of flows). Generally flows will be recorded per year, but more or less frequently may be required for ecosystem accounts (as opposed to the already established environmental (water, energy, timber, etc) and national (economic) accounts.

20. Haines-Young & Potschin (2010) argue that a CICES should move away from 'flat', 'one-dimensional' structures that are essentially lists of services that require updating when new services are identified or existing ones are reconceived. They propose that the CICES 'should use categories that are both as generic as possible, and linked in a nested hierarchy to accommodate different scales of concern or thematic content'. We agree that this is a sensible approach for environmental accounting. Maynard et al[19] have also adopted generic ecosystem service descriptors recognizing it has the benefit of use by all groups assessing ecosystem services in the region at different scales and for different purposes. It appears that the draft classification (CICES Table 6) could accommodate all studies so far done in Australia and likely most future ones.

21. Perhaps the point has not been made strongly enough in developing the CICES, that it would be highly desirable if the classification could be used as an overarching framework for all assessment frameworks of ecosystem services, both to guide convergence of thinking in the development of ecosystem service frameworks without discouraging diversity and to enable information collected to feed into national and international environmental accounts – recognising that ecosystem service assessments can extend well beyond just accounting for services.

C. Similarities and differences between Australian ecosystem services classifications and the proposed CICES Framework

22. Haines-Young & Potschin (2010), in Section 8 (page 20), identify four major issues to be considered if a final CICES is to be produced. The following paragraphs provide comment on these from an Australian perspective.

[17] Costanza R. (2008) Ecosystem services: multiple classification systems are needed. *Biological Conservation* **141**, 350-2

[18] Maynard et al. (2010), as above

[19] Maynard et al. (2010), as above

23. *A feature of the cross tabulations suggested here is that the product and activity classes could potentially be linked to more than one ecosystem service group at the higher levels in the classification, although this could probably be resolved as more detailed sub-classes are defined*: Haines-Young & Potschin (2010) suggest a classification of sub-classes (their Table 4), which appears as if it would greatly reduce the problem identified and would still be sufficiently broad for different users to fit their own specific services into it. This was also an important feature in Maynard et al who insisted on developing generic ecosystem service descriptors for sub-service development by End Users of the Framework.

24. *… cross tabulation of CICES … assists in identifying the 'final outputs' of ecosystems, and thus potentially helps overcome the problem of 'double counting' in valuation studies. … In this context the exclusion of non-renewable, mineral outputs from the classification of services needs to be confirmed*: The Australian experience is that there is merit in identifying final ecosystem services, and this is being done in all major studies currently underway. It is noted that this requires careful consideration of the fact that some services might be final for some beneficiaries and intermediate for others.

25. Although different terminologies have been applied in the classification systems, the classification systems are not completely dissimilar. For example, the ecosystem functions (Table 1 Appendix 1) incorporated in the Maynard et al classification are highly comparable to the ecosystem services identified in Bennett, CICES, Goulburn Broken, Gwydir and TEEB (Table 2 Appendix 1) - Bennet, CICES and TEEB classifications refer to their services as 'final ecosystem services' or 'final outputs' of ecosystems. The ecosystem services developed in Maynard et al relate closely to the benefits identified in the Bennet and CICES classification systems (Table 3 Appendix 1) – this is not surprising as the definition of ecosystem services applied in Maynard et al[20] is the 'benefits people obtain from ecosystems'.

26. For ecosystem service assessment purposes Maynard et al[21] defined the boundaries of ecosystems primarily on structure and process (with other criteria secondary). Those ecosystems with similar characteristics were further grouped into what became 32 Ecosystem Reporting Categories, founded on the MA Reporting Categories and not dissimilar to the CICES categories. 19 ecosystem functions, *the biological, geochemical and physical processes and components that take place or occur within an ecosystem* and are necessary for the self-regulation of ecosystems (but may or may not provide benefits to people), were identified. The potential benefits people obtain from these functions (ecosystem services) were assessed without human capital inputs to the system. See point 29 for an example. Although Maynard et al do not use the terms 'intermediate and final services', Supporting Functions in their categorisation were considered as underpinning all other functions. They stress the need to clearly define between Supporting Functions, other functions (Provisioning, Regulating and Cultural Functions) and the services they provide to avoid double counting. Although the Maynard et al classification relied heavily on the MA for guidance, this distinction was considered blurred in the MA and therefore a new classification developed.

27. The issue of non-renewable, abiotic outputs from the environment is also complex. The original intentions of the ecosystem services approach were to focus attention on the benefits that come from well-functioning ecosystems and to see ecosystems included in broader planning processes along with economic and social issues. Abiotic components are part of ecosystems to the extent that they interact with the biotic components and should be considered in that context (i.e., as a component of functional ecosystems and therefore intermediate services). Similarly, it might be argued that some abiotic resources are made (e.g. coal), or concentrated (e.g. some minerals), with the aid of ecosystem processes, and thus it might be considered that ecosystems have made a contribution to the provision

[20] Maynard et al. (2010), as above
[21] Maynard et al. (2010), as above

of the good. On the other hand, when abiotic components like coal or minerals, are extracted by humans, the human input far outweighs the ecosystem input. This could be dealt with, as Haines-Young & Potschin (2010) suggest for other ecosystem services that require some human input to yield a benefit (see below), by establishing the "production function" and using that to apportion the roles of ecosystems and humans. These are important issues if the aim is to decide what contribution has been made by ecosystems (which might be an important function of national and international accounts), but to achieve the objective of integrated accounting it is important for the abiotic components to be considered. Simply excluding them from the CICES risks ignoring the interactions between abiotic and biotic components of ecosystems, and elements of the environment that some stakeholders (mining) value that can result in degradation of ecosystems and services. The Australian classifications do not consider non-renewable abiotic outputs.

28. *Cross-tabulation implies the need to develop some method of weighting to indicate the relative strengths of the different kinds of capital input to each product and activity*: Haines-Young & Potschin (2010) suggest that this requires development of 'production functions' so that the inputs from humans and ecosystems can be assessed. The different kinds of capital required to provide specific services is not fully assessed in the AU classification schemes. This approach was considered however in the study of ecosystem services in SEQ.

29. As resources were extremely limited a full assessment of all capital inputs into good and service provision was not possible in SEQ. Care was taken however in the development of the SEQ Framework to develop a classification that solely identifies the ecosystems performing functions and having potential to provide services with no human capital input. For example, the service 'recreation' as identified in the MA was considered to require human inputs such as equipment, machinery etc. However, ecosystems provide services such as 'recreational opportunities', regardless of whether equipment or machinery is available to utilise it the opportunity still exists. Maynard et al[22] apply a simple scoring system in the form of matrices (developed through Expert Panel processes) to assess the relative magnitude different ecosystems perform different ecosystem functions, the different functions provide different ecosystem services, and how the different services contribute to human well-being.

30. A comparison of the ecosystem functions incorporated into the Australia classifications is compared with those of CICES and TEEB in Table 1, Appendix 1 of this paper. This comparison shows that:
    - Bennett et al[23] do not make reference to ecosystem functions in their classification system; however they discuss ecosystem processes in relation to the provision of soil ecosystem services. As functions are not mentioned it is unclear if processes and functions are considered the same and were therefore not included in the table. Ecosystem processes are defined by Bennett et al[24] as '. . . inputs, losses, and transfers of material and energy'. Examples of processes include: soil structure maintenance (aggregation, bioturbation, cheluviation); organic matter cycling (litter comminution, decomposition, humification); nutrient cycling (mineral weathering, mineralization, nitrification); ion retention and exchange (cation exchange, anion adsorption); water cycling (infiltration, evaporation, percolation, groundwater flow); gas cycling (respiration, diffusion, denitrification, nitrogen fixation, methanogenesis); and soil biological life cycles (changes in biotic richness and composition). Bennett et al[25] recognise ecosystem processes as 'intermediate services', which they say is consistent with the MA approach of identifying 'Supporting Services' which have indirect use and should not be assessed to avoid double counting.

[22] Maynard et al. (2010), as above
[23] Bennett et al. (2010), as above
[24] Bennett et al. (2010), as above
[25] Bennett et al. (2010), as above

- The CICES framework separates ecosystem processes and functions in the cascade model (Figure 2, p. 7). CICES use ecosystem structure and processes as a way of defining ecosystem boundaries, and functions as the outcomes of the interactions between these two.
- SEEA classifies functions into three categories: Resource functions; Sink functions; Service functions (Survival and Amenity functions). No list of functions is provided.
- The SEQ Framework classifies 118 ecosystems into 32 Ecosystem Reporting Categories, predominantly on structure and process. Functions are categorised into four groups based on the MA: Provisioning Functions; Regulating Functions; Supporting Functions; and Cultural Functions. Supporting Functions were considered to underpin all other ecosystem functions. As identified in Table 2 (p. 5) of CICES these categories are comparable, although the 19 ecosystem functions incorporated in the SEQ Framework would require a more in-depth review of their descriptions to assess suitability to each classification.
- Wallace[26] uses the term ecosystem processes and ecosystem functions synonymously so they were incorporated in the table – he does not use the term ecosystem function as preference is given to the term processes. Ecosystem processes are defined as the complex interactions (events, reactions or operations) among biotic and abiotic elements of ecosystems that lead to a definite result. In broad terms, these processes involve the transfer of energy and materials.
- In all AU classifications, even though processes and functions may not be clearly identified and listed (e.g. in the Goulburn Broken or Gwydir classifications), processes and functions were recognised as important to ecosystem service provision.

31. *An examination of the extent to which the proposed CICES classes can be linked to classifications of land cover and land use has been considered in parallel to this study. The preliminary results presented in here suggest that at the CICES class level, cross tabulation between service classes and land cover and cover change data may be undertaken in a robust way*: We think that these conclusions will also apply in Australia, although time constraints have not allowed us to conduct a cross-tabulation.

32. An alternative approach to applying land use to assess ecosystem services was taken in SEQ[27], as it was considered ecosystem services were derived from 'ecosystems' rather land use. As the framework focuses on potential ecosystem service provision, 32 groups of ecosystems (Ecosystem Reporting Categories - ERCs) were identified, defined and assessed for their potential provision of services. 118 Regional Ecosystems[28] were applied and grouped based primarily on ecosystem structure and processes to form ERCs. The use of land use maps was avoided where possible (although they were often required to map cultivated and urban ecosystems), as it was identified different land uses may impart a different suit of functions and therefore ecosystem services. For example, an urban development may be located on a sandy aquifer or on the side of a steep slope – different functions and therefore potential to provide services are occurring in each location. The methodology to develop Regional Ecosystems is a simplified version of that applied under the GEOSS (Group on Earth Observation System of Systems) Global Ecosystems Task to develop consistent ecosystem maps of the world[29]. Should GEOSS maps have been available at the time of Framework development they would have been appropriate due to their ability to clearly identify the asset structure of ecosystems and therefore which components contribute most to ecosystem function and service provision. The lack of information on biodiversity is a recognised limitation of Regional Ecosystem and GEOSS mapping.

[26] Wallace (2007), as above
[27] Maynard et al. (2010), as above
[28] Queensland Herbarium (2011) Regional Ecosystem Description Database (REDD). Version 6.0b - January 2011, (January 2011) (Department of Environment and Resource Management: Brisbane).
[29] US Geological Survey (2011) (online) GEOSS Global Ecosystems: Overview Available: http://rmgsc.cr.usgs.gov/ecosystems/. Accessed 15 November 2011.

33. Also to support the SEQ Framework, a series of maps identifying where ecosystem services are being derived from across the region were developed. Maps of the 19 'ecosystem functions' identified and described in the Framework have been produced. Each of the 68 data layers identify a different pathway a function is being performed. Maps of 'change in ecosystem function', therefore change in the regions potential to provide ecosystem services, have been developed and included in State of Region reporting for SEQ. These maps under other classification systems could be considered 'final ecosystem service maps'. Baseline data sets required to apply a similar methodology at the national scale have also been identified.

34. Examples of the range of ecosystem service classifications developed and used in Australia are compared to the CICES and TEEB classifications in Table 2 in Appendix 1. This table shows:
    - Bennett et al[30] use the term 'final ecosystem goods and services' and 'ecosystem services' interchangeably throughout their classification/paper. The Bennet classification was done as a desktop study drawing on a range of published studies from around the world, mostly from Fisher et al 2009[31]. It identified final services and benefits. It would fit into the CICES.
    - CSIRO MDB study uses the TEEB framework with very minor modifications - TEEB has already been considered by Haines-Young & Potschin (2010).
    - Goulburn Broken and Gwydir classifications were developed by stakeholders; each are lists of services and would not be suitable for international accounts as they are place-specific and would need to be changed if new services were to be added or old ones reconceived. Each of them would fit within the proposed CICES.
    - The classification in the SEQ study (Maynard et al) was developed by stakeholders (business, industry, state and local governments, academia and non-government organisations – over 160 professionals have been involved in the development of the framework). Global classifications developed by de Groot et al[32] and the MA provided the foundations. It identifies 28 ecosystem services, attempting to assess the full range of services derived from ecosystems, but allowing generality across the service descriptors for flexible application by stakeholders in their own decision contexts and at various contexts and scales. It is the only one to systematically identify different ecosystems, the ecosystem functions performed in these ecosystems, and the services and benefits (in terms of human well-being) derived from the ecosystems. The model applied in Maynard et al[33] is comparable to the cascade model (Figure 2) developed in the CICES.
    - Wallace used the MA as his foundations, but expressed ecosystem services in terms of the contribution they made to human wellbeing.

35. Ecosystem services in the Australian classifications have been categorised as follows:
    - Bennett et al[34] have not categorised ecosystem services.
    - Ecosystem services in the Goulburn Broken study are categorised as: Primary Industries; Processing and Manufacturing; Housing and Construction; Electricity and Water; Service Industries; Environmental, Cultural, and Aesthetic Goods.
    - The Gwydir ecosystem services framework categorises services as: Production; Break-down and recycling of wastes; Ecosystem maintenance and regeneration.
    - Ecosystem service categories for CICES and in SEQ (Maynard et al) [35] are based on the MA. Both exclude the Supporting Services category. Supporting Services were considered supporting

[30] Bennett et al. (2010), as above
[31] Fisher B, Turner R, Morling, P (2009) Defining and classifying ecosystem services for decision making. Ecological Economics **68:**643–653.
[32] de Groot R, Wilson M, Boumans R (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics **41**(3):393–408
[33] Maynard et al. (2010), as above
[34] Bennett et al. (2010), as above
[35] Maynard et al. (2010), as above

ecosystem functions in Maynard et al[36] and incorporated into the list of functions. In Table 2, Appendix 1 ecosystem services have been colour coded based on CICES coding to show comparison: Orange = Provisioning Services; Green = Regulating Services; Blue = Cultural Services.

- The categories of services developed for TEEB also have followed the MA (Provisioning, Regulating and Cultural) and therefore have been colour coded in Table 2 Appendix 1 the same as CICES and SEQ to show similarities. However, TEEB also includes an additional category called Habitat Services which has been colour coded yellow.
- Wallace classifies ecosystem services according to the specific human values they support: Adequate resources; Protection from predators/disease/parasites; Benign physical and chemical environment; Socio-cultural fulfilment.

36. Table 3 in Appendix 1 shows the benefits derived from the provision of ecosystem services as identified in the AU classifications in comparison to CICES and TEEB classifications.
    - Only the Bennett[37] and the Goulburn Broken classification list the benefits derived from the ecosystem services.
    - The Goulburn Broken study uses the term 'goods' rather than benefits, but they are considered the same. These benefits are comparable to those benefits identified in CICES.
    - The benefits derived from ecosystems are inherent in the definition and list of services in the SEQ and Wallace classifications.

D. Prioritisation of ecosystem services

37. Table 4, Appendix 1 details how ecosystem services are prioritised in each of the Australian classification systems. It does not however list the services in priority order.
    - Few classification systems in Australia have established a prioritisation process or a list of prioritised ecosystem services. Some prioritisations are still a work in progress.
    - There is no similarity across the prioritisation criteria.

38. An alternative way of thinking than what is described in Table 4 is: there is an emerging body of research on ecosystem stewardship that seeks to bring the ideas of ecosystem services together with thinking about resilience, adaptive capacity and transformation of ecological and social systems[38]. This research might provide a useful input to prioritising ecosystems services. It focuses on thresholds beyond which the nature of a social-ecological system would change. That change could include the types and amounts of ecosystem services produced, the types of beneficiaries, and the ways in which ecosystem services are used. Managing resilience and adaptive capacity is about keeping the system away from those thresholds. Identifying thresholds that relate to key ecological processes that would affect ecosystem services delivery could be a way to identify which services (and which underlying processes and ecosystem assets) might require the most urgent attention.

E. Conclusions and questions

39. There is strong support for a common classification system for ecosystem services in Australia – the lack of consistency of approaches and great diversity of definitions and classifications used to date

[36] Maynard et al. (2010), as above
[37] Bennett et al. (2010), as above
[38] Chapin III FS*, et al.* (2009) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. *Trends in Ecology and Evolution* 25:241-249

highlights this need. Finalisation of the CICES should provide this; and the Australian experience of developing ecosystem service classifications fits broadly within the CICES.

40. In the AU and CICES classification systems 4 key areas have been identified where there is divergence in the interpretation and classification of ecosystem services. These are: a) the need to connect ecosystem processes and functions to ecosystem services, b) the definition of ecosystem services, c) which ecosystem services should be incorporated into the classification, d) the nature of the ecosystem services classification system. These 4 key areas are addressed briefly in the following points. It is recognised that these key areas are interrelated.

41. *Connecting ecosystem processes and ecosystem functions to ecosystem services* – Although ecosystem processes and functions are recognised as important to providing ecosystem services and maintaining the capacity to do so, Bennett, Goulburn Broken and Gwydir do not specifically identify these in their classifications, as their definition of ecosystem services includes processes. Maynard et al identify ecosystem functions as important for maintaining self-regulating ecosystems (for biodiversity's own sake), they state ecosystem functions may or not provide benefits to people. This definition is strongly related to ecological resilience concepts, recognising the need to identify ecological thresholds to sustainably manage ecosystems for both biodiversity and ecosystem services.

42. Consideration of intermediary and final services, as well, who the beneficiaries of ecosystem services are and what services they receive and value is likely to lead to better consideration of a wide range of government policies, including population, immigration, water, conservation and food security policies. However, criticisms have included that the recent terminology applied (i.e. intermediate and final services) and technical understanding required to apply this approach (i.e. when is a service intermediate or final) creates barriers between science, policy, planners, managers and the community, as different stakeholders likely to apply ecosystem services classifications/frameworks vary in their capacity to understand and apply information. The KISS (Keep It Simple Stupid) principle should be applied when developing a classification to assess ecosystem services, and broad consultation with End Users of the classification is highly recommended.

43. *The definition of ecosystem services* –Recent debate over the nomenclature of ecosystem services (Bennett[39]Fisher et al[40]; Wallace[41]), has led to recommendations that the social purpose or decision context of a policy question should dictate the choice of ecosystem service classification systems. The definition of ecosystem services applied in the Bennett, Goulburn Broken, Gwydir and TEEB classifications is comparable to that recommended in the CICES classification. The decision contexts these classifications were developed for were related to economic valuations of ecosystem services – where the SEQ, Wallace and MA were focused on broader and more generic applications of ecosystem services and communicating the concept to a diverse group of stakeholders (e.g. the SEQ Framework was developed through consultation with Local Government Planners, Community Groups, State Government resource agencies, business and industry, … for their own application, which often extends beyond economic valuations).

44. Bennett, Goulburn Broken and Gwydir identify services based on the processes of the ecosystems that contribute to goods that are produced through both natural and human capital (although the human capital components are not identified), while benefits are outcomes of the ecosystem services and have a straight relation to human welfare (and this way has an economic meaning). The Maynard et al classification determine ecosystem services by identifying 'what it is' people value about the ecosystem functions being performed without human inputs to produce the benefit (see point 28),

[39] Bennett et al. (2010), as above
[40] Fisher et al. (2009), as above
[41] Wallace (2008), as above

and then identify how people value/ benefit from these goods and services based on their contribution to constituents of human well-being (not necessarily having an economic meaning e.g. maintaining social cohesion).

45. Fisher et al[42] recommend keeping services and benefits separate, principally because multiple services can contribute to the same benefit, and that only benefits should be aggregated in valuation exercises to avoid double counting. This statement is supported in the Bennett, Goulburn Broken and Gwydir classification systems – albeit the Bennett classification is based on Fisher et al. Although terminology is different, Maynard et al[43] support this statement in terms of ecosystem functions and ecosystem services i.e. it takes more than 1 function to provide a service and each function can contribute to more than 1 ecosystem service (see point 26).

46. *Which ecosystem services should be incorporated into the classification* - There is great diversity in the list of ecosystem services developed in the Australian classification systems. This diversity exists due to the decision contexts and End Users of the classification system (e.g. for agricultural assessments or planning purposes); the definition of ecosystem services applied (i.e. whether services are defined as ecological outputs or benefits); whether the frameworks attempt to assess actual or potential service provision; and whether human capital inputs or just natural capital inputs were assessed within the classifications/ frameworks. It is recognised that these reasons are interrelated.

47. Regardless of the definition applied in the 7 classification systems presented in the Appendix, the most common services incorporated (services >4) include: food (5), the provision of water (5), pollination (5), the regulation of pest and disease (7), genetic resources (5), maintaining productive soils (6), water flow regulation (5) and climate regulation (5). To be counted in this assessment these specific terms needed to be stated – however it is recognised that some of these services could be considered sub-services in the other classifications. The most common services included were provisioning and regulating services.

48. No cultural services were common across the classifications identifying a) 3 of these classifications had an agricultural focus (Bennett, Goulburn Broken, Gwydir) so the services selected/identified were those most pertinent in this context (see point 43), b) those services commonly being included were those most easy to measure due to available data, c) those services most easily measured in quantitative terms were assessed rather than those that require more qualitative measures and d) the ecological nature of the ecosystem service definition restricted the input of cultural values from the classifications.

49. *The nature of the classification systems* - A characteristic of the application of ecosystem services approaches in Australia has been strong engagement with communities (and other stakeholders) to develop their own classifications, based on their own perceptions of what services they perceive. These studies have all concluded that application of ecosystem services approaches at regional scales and below is greatly facilitated by processes that allow stakeholders to 'discover' ecosystem services for themselves.

50. The CICES themes, classes and groups proposed in Table E.2 of Haines-Young & Potschin (2010) and the services in Maynard et al show the need to allow flexibility for stakeholders to identify and name (sub) services of importance to them. The proposed CICES would not discourage the sort of regional and community-level application of ecosystem services approaches described in Australia and would probably facilitate it by giving stakeholders a framework to use as a starting point.

[42] Fisher et al. (2009), as above
[43] Maynard et al. (2010), as above

51. There is great similarity between the ecosystem service categories developed by CICES, TEEB and Maynard et al. Haines-Young & Potschin (2010) also show the similarity between CICES and the SEEA functional types. Bennett et al[44] recognise ecosystem processes as 'intermediate services', which they say is consistent with the MA approach of identifying Supporting Services and therefore exclude Supporting Services from their assessment. Although terminologies are different, this is consistent with findings in CICES and Maynard et al[45] who also exclude Supporting Services. It is recommended that Supporting Services be recognised as having indirect use and be classed accordingly (depending on final terminology) and not be assessed in an accounting framework to avoid double counting.

52. In conclusion, issues yet to be resolved in the classifications reviewed include:
    - What is the appropriate terminology to be applied (ecosystem processes, ecosystem functions, intermediate services, final ecosystem goods, final ecosystem goods and services, ecosystem services, benefits) that will resonate with a wide range of stakeholders/disciplines to allow the classification developed to have application in integrated environmental-economic accounts, and to those who might incorporate this classification in wider ecosystem service frameworks and implement it in real world activities?
    - How to account for ecosystem services, the benefits of which are evident at multiple scales?
    - How to account for ecosystem services and benefits that are not yet recognised?
    - How to account for ecosystem services, the benefits of which are in the future?

[44] Bennett et al. (2010), as above
[45] Maynard et al. (2010), as above

Appendix 1.

Table 1: Lists of 'functions' in the ecosystem service classification systems (alphabetical order).

CICES	Bennett	Goulburn Broken	Gwydir	South East Queensland Ecosystem functions are the biological, geochemical and physical processes and components that take place or occur within an ecosystem.	TEEB Ecosystem functions are a subset of the interactions between structure and processes that underpin the capacity of an ecosystem to provide goods and services.	Wallace* The complex interactions (events, reactions or operations) among biotic and abiotic elements of ecosystems that lead to a definite result.
Structure and processes are used to define the ecosystem –a discrete set of functions is not defined in CICES – Ecosystem services are categorised along functional lines as in the MA, which also correspond to the 3 types of functions in SEEA (see service definitions in Table 2)	Processes only are identified in this classification – the term ecosystem function is not applied in this classification (see point 30)	Ecosystem processes and functions are not applied in this classification (see point 30)	Ecosystem processes and functions are not applied in this classification (see point 30)	Gas regulation	Primary production	Biological regulation
				Climate regulation	Decomposition	Climate regulation
				Disturbance regulation	Nitrogen cycling	Disturbance regimes
				Water regulation	Hydrologic cycle	Gas regulation
				Soil retention	Soil formation	Management of ''beauty'' at landscape and local scales.
				Nutrient regulation	Biological control	Management of land for recreation
				Waste treatment and assimilation		Nutrient regulation
				Pollination		Pollination
				Biological control		Production of raw materials for clothing, food, construction,
				Barrier effect of vegetation		Production of raw materials for energy,
				Supporting habitats		Production of medicines
				Soil Formation		Socio-cultural interactions
				Food - Biomass that sustains living organisms		Soil formation
				Raw materials		Soil retention
				Water supply		Waste regulation and supply
				Genetic resources		Economic processes
				Provision of shade and shelter		
				Pharmacological resources		
				Landscape opportunity		

*Wallace uses the term processes rather than functions but recognises them as the same.

Table 2: List of 'services' in the ecosystem service classification systems (alphabetical order).

Bennett Ecosystem services are defined as processes that become services if there are humans that benefit from them.	**CICES** Ecosystem goods and services are the contributions that ecosystems make to human well-being, and arise from the interaction of biotic and abiotic processes.	**Goulburn Broken** Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life.	**Gwydir*** Ecosystem services are the ecological conditions and processes that maintain natural assets (ecosystems) and use those assets to produce goods that people want and need.	**SEQ** Ecosystem services are the benefits people obtain from ecosystems.	**TEEB**** Ecosystem services are the direct and indirect contributions of ecosystems to human well-being.	**Wallace** Ecosystem services are the benefits people obtain from ecosystems.
Provision of marketable goods	Freshwater plant and animal foodstuffs	Pollination	Natural pest control	Food	Food	Food
Soil structure stabilization	Marine plant and animal foodstuffs	Life-fulfilling Services	Pollination	Water for Consumption	Water	Oxygen
Gas regulation	Potable water	Regulation of Climate	Maintenance of soil health	Building and Fibre	Raw Materials	Water
Carbon sequestration	Biotic materials	Pest Control	Water filtration	Fuel	Genetic resources	Energy
Water quality regulation	Abiotic materials	Genetic Resources	Prevention of soil erosion	Genetic Resources for Cultivated Products	Medicinal resources	Dispersal aids
Water yield	Renewable biofuels	Maintenance and Regeneration of Habitat	Maintenance of river flows	Biochemicals, Medicines and Pharmaceuticals	Ornamental resources	Protection from predators
Water flow regulation	Renewable abiotic energy sources	Provision of Shade and Shelter	Maintenance of groundwater levels and quality	Ornamental Resources	Air quality regulation	Protection from disease and parasites
Weather regulation	Bioremediation	Filtration and Erosion Control	Maintenance and regeneration of habitat	Transport Infrastructure	Climate regulation	Temperature
Remediation of wastes and pollutants	Dilution and sequestration	Maintenance of Soil Health	Maintenance and provision of natural genetic resources	Air Quality	Moderation of extreme events	Moisture
Habitat provision/genetic resource maintenance	Water flow regulation	Regulation of River Flows and Groundwater Levels	Provision of shade and shelter	Water Quality	Waste treatment	Chemical

Bennett	CICES	Goulburn Broken*	Gwydir	SEQ	TEEB	Wallace
	Mass flow regulation	Waste Absorption and Breakdown	Waste absorption and breakdown	Arable Land	Erosion prevention	Spiritual and philosophical contentment
	Atmospheric regulation			Buffering Against Extreme Events	Maintenance of soil fertility	A benign social group
	Water quality regulation			Pollination	Pollination	Recreation/leisure
	Pedogenesis and soil quality regulation			Reduce Pests and Disease	Biological control	Meaningful occupation
	Lifecycle maintenance & habitat protection			Productive Soils	Maintenance of life cycles of migratory species	Aesthetics
	Pest and disease control			Noise Abatement	Maintenance of genetic diversity	Opportunity values
	Gene pool protection			Iconic Species	Aesthetic information	
	Aesthetic, Heritage			Cultural Diversity	Opportunities for recreation & tourism	
	Religious and spiritual			Spiritual and Religious Values	Inspiration for culture, art and design	
	Recreation and community activities			Knowledge Systems	Spiritual experience	
	Information & knowledge			Inspiration	Information for cognitive development	
				Aesthetic Values		
				Affect on Social Interactions		
				Sense of Place		
				Iconic Landscapes		
				Recreational Opportunities		
				Therapeutic Landscapes		

* The list of services incorporated into the Gwydir framework are based on the priority services identified in the Goulburn Broken framework

** Note that the current CSIRO MDB project is using TEEB

Table 3: List of 'benefits' in the ecosystem service classification systems (alphabetical order).

Bennett	CICES	Goulburn Broken*	Gwydir	SEQ	TEEB	Wallace
Rural economic activity	See Table 4 in CICES for an extensive list of benefits	Dairying	Benefits not included into this classification	Services are based on benefit lines (see service definition in Table 2)	Ecological	Services are based on benefit lines (see service definition in Table 2)
Future choices		Fruit and grapes			Social	
Clean air		Vegetables			Economic	
Favourable climate		Grazing				
Water quality		Crops				
Water volume		Hay and seed production				
Protection of physical assets		Intensive animals				
Novel products		Apiculture				
Pollution control		Forests				
Disease and pest control		Mining				
Reduced pesticide use		Wood products				
Soil inoculation potential		Urban and rural real estate				
Ecosystem resilience		Water Production (Surface and sub surface)				
Aesthetics		Hydroelectricity				
		Wholesale and retail trade				
		Transport and communication				
		Finance and business services				
		Housing services				
		Public administration				
		Community services				
		Entertainment and Recreation				
		Biodiversity				
		Aesthetic values				
		Cultural values				
		Option Values				

* The Goulburn Broken classifications uses the term 'goods' rather than benefits, They are considered the same in this classification.

Table 4: The process (being) applied to prioritise ecosystem services in each of the frameworks.

Bennett	Criteria for identifying priority public benefits from soil management were examined, namely, likelihood, degree, consequence, scale, direction, time lag, and valuation. 'Likelihood' is the probability that a benefit will be produced, and can conceivably range from unlikely to highly likely for any benefit, depending on the context. 'Degree' is the size of the change in benefit, which could be quantitatively predicted but, in the absence of robust data, will often be estimated within a range from small to large (either positive or negative). Benefit changes that are likely and detectable warrant the application of the remaining criteria. Benefits flowing from services were scored (-3 to +3) based on the net change in benefit from current to changed practices.
CICES	Not prioritised
Goulburn Broken	Community workshops were conducted to assess the relative importance of each ecosystem service to each landuse/ industry in the Catchment. Criteria used to prioritise ecosystem services include: 1/ overall importance/impact; 2/ importance at the margin (i.e. the importance of a small change in the provision of a service); and 3/ manageability. Ecosystem services were given a high, medium or low ranking.
Gwydir	Not prioritised
SEQ	Based on a well-being index developed for the SEQ Ecosystem Services Framework (Breathing, Drinking, Nutrition, Shelter, Physical Health, Mental Health, Secure and Continuous Supply of Resources, Security of Person, Security of Property, Security of Health, Secure Access to Services, Family Cohesion, Social Cohesion, Social and Economic Freedom, and Self Actualisation), an assessment of the relative importance of each ecosystem service in terms of the well-being of the SEQ community was conducted through an Expert Panel process. Also, an assessment of the relative importance of each ecosystem service in terms of individual well-being is being conducted through community workshops in each of the 11 local government areas in the SEQ region. Community workshops are expected to identify context dependencies and better identify beneficiaries. When complete, aggregation of the individual well-being results will be analysed against those of community well-being developed through the Expert Panel, providing insights into community perceptions (subjective) with those of expert opinion (objective). This is still a work in progress. A 10 point scoring system is being applied.
TEEB	Not prioritised
Wallace	Not prioritised