Experimental estimates of soil water use in Australia:

Draft for discussion

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1.0 Introduction

1. Soil water use is one of the components of the System of Environmental – Economic Accounts (SEEA 2012) as well as the SEEA-Water (SEEA-Water), not currently included in the Water Account, Australia (ABS cat. no. 4610.0). Estimates of soil water use are one of the most undeveloped components of the water account[2]. This paper has attempted to draw together much of the Australian based science and applying statistical technics to estimate soil water use by plant in the Australian economy.

1.1 Definitions

3. Soil water is defined in SEEA-water as:

"6.17. Soil water consists of water suspended in the uppermost belt of soil, or in the zone of aeration near the ground surface, that can be discharged into the atmosphere by evapotranspiration."[1]

4. Soil water use is defined in SEEA 2012 as:

"Abstraction of soil water refers to the uptake of water by plants and is equal to the amount of water transpired by plants plus the amount of water that is embodied in the harvested product"[2]

5. The Australian economy is defined in the System of National Accounts to be[3]:

"In the SNA, production is understood to be a physical process, carried out under the responsibility, control and management of an institutional unit, in which labour and assets are used to transform inputs of goods and services into outputs of other goods and services. All goods and services produced as outputs must be such that they can be sold on markets or at least be capable of being provided by one unit to another, with or without charge. The SNA includes within the production boundary all production actually destined for the market, whether for sale or barter. It also includes all goods or services provided free to individual households or collectively to the community by government units or NPISHs."

1.2 Background

6. In Australian science there is a range of different terms used to describe water use efficiency, coefficients of water use, water uptake by plants, evapotranspiration and so on. Most information available

[1] SEEA-W
[2] SEEA 2012, para 3.198
[3] SNA, para 1.40

is from case studies or groups of case studies. One of the by-products of this research is highlighting the scientific-statistical nexus. All of these estimates would not be possible without the dedicated scientific research on soil and water that has taken place over the last few decades.

7. Confounding the estimates of soil water use is the use of irrigation in many areas of Australia. The irrigation of crops smooths out the fluxes due to variable rainfall patterns, driven by long-term (ie extend over several years) weather cycles, and in particular the El Nino and La Nina weather patterns. Irrigation water (or surface water use) must be deducted from estimates of soil water use (i.e. water from rain), so as not to double count in aggregates of total water use by crops and pastures (i.e. surface water use + ground water use + soil water use = total water use).

8. The primary industries that manage plant species in Australia are those that have agricultural and forestry activities. The exception to this is grass grown in urban and semi urban environments, for example urban parkland and recreational areas (e.g. golf courses) which are also within the production boundary of the economy.

9. One of the key policy needs for this data is the need for regional estimates of water use, rather than for national or state based estimates. However, the data doesn't necessarily support this level of detail, so only broad administrative regions are estimated here, although the methodology is sound and could be used for more detailed regional estimates.

2.0 Methodology for estimating soil water use

10. Fortunately for Australia, water use coefficients observed from different studies tend to be similar. As such a convenient assumption is that an average or lowest case figure will suffice for use in constructing conservative estimates of soil water use.

11. Taking this as the starting point, the methodology for measuring soil water use is fairly straightforward. For each agricultural of forestry commodity it is:

> Water use efficiency (WUE) = yield (kg of plant species harvested per ha) ÷ {water use (mm) x area (ha)}[4]

12. This formula assumes that there is sufficient water moisture content in the soil to allow transpiration. For Australia this is about 100mm of rainfall (or about 1ML per hectare), though this base moisture level can vary between 80 and 140 mm.

13. Configuring this to calculate the water used for a particular plant we have:

> Soil water use (ML) = final yield (kg of plant species harvested per ha) x (1 ÷ WUE) x total area planted (ha)

14. For some plants (e.g. plantations, horticulture) the water use coefficient is not in a WUE context and adjustments are made to the formula to compensate for water use per year in the case of horticulture, water use for plantation growth and water use per tree for orchards. These adjustments are mentioned below under the specific methods for each group of plants (e.g. crops, pastures, orchards).

2.1 Date sources: agriculture – crops

15. The Australian Bureau of Statistics produces detailed and robust estimates of agricultural commodities[5], including the area planted and tonnes harvested. This data source also provides detailed regional data down to detailed statistical geographic and national resource management regions.

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[4] French, RJ., Schultz, J.E. (1984). *Water use efficiency of wheat in a Mediterranean type environment: The relation between yield water use and climate*. Australian Journal of Agricultural Research (35) 743-764.

Table 1. Water use efficiency for selected broadacre crops.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	kg/mm•ha	kg/mm•ha	kg/mm•ha	kg/mm•ha	kg/mm•ha	kg/mm•ha	kg/mm•ha	kg/mm•ha
Wheat for grain	15.5	20	15	18	18	22	n/a	15.5
Oats for grain	22	22	22	22	22	22	n/a	22
Barley for grain	10	18	13	18	18	18	n/a	n/a
Sorghum for grain	15	n/a	15	n/a	n/a	n/a	n/a	n/a
Cotton	2.8	n/a	2.8	n/a	n/a	n/a	n/a	n/a
Lupins for grain or seed	13	13	13	13	13	13	n/a	n/a
Canola	13	13	13	13	13	13	n/a	n/a
Sugar cane	73	n/a	73	n/a	n/a	n/a	n/a	n/a
Cereal cut for hay	12	12	12	12	12	12	12	12
Pasture cut for hay	30	30	30	30	30	30	30	30

Source: Multiple data sources, see appendix 1.

Note: water use efficiency coefficient is denoted in yield per mm or $\frac{kg}{mm \times ha}$

2.2 Data sources and methods: agriculture – pasture

16. One of Australia's most wide ranging agricultural activities involves both native (indigenous) and modified (specific bred) grasslands for sheep, beef cattle and dairy cattle. There are other animals used (e.g. alpacas, goats) but these are quite small in number compared to cattle and sheep. .

17. An Australia wide land account is not yet available so alternative sources of information on land use/cover need to be used. In Australia both the Australian Collaborative Land Use and Management Program (ACLUMP)[6] and the annual ABS Agricultural Survey, with a census every 5 years provide such information. The classification used in the Agricultral Survey divides Australian land use into a number of classifications, including native pasture and modified pasture. The ACLUMP data is not regularly produced and was last produced for the year 2007-08. For pasture data there is a large variation in the estimates of soil water use obtained from using ACUMP and the Agricultural Survey (see table 2). ACLUMP data was rejected in favour of the more regular series of data from the ABS. ACLUMP estimates are higher and would add approximately 100,000 GL per annum to the estimates of soil water use in Australia.

[5] See: Agricultural commodities, Australia (ABS cat. no. 7121.0)

[6] http://adl.brs.gov.au/landuse/index.cfm?fa=main.aboutACLUMP

Table 2. Area of native and modified pasture, Australia

Year	Type of pasture	ABS	ACLUMP
		Area (ha)	Area (ha)
2005-06	Native	326,566,000	
	Modified	58,171,000	
2006-07	Native	323,053,000	
	Modified	57,545,000	
2007-08	Native	319,540,000	457,203,300
	Modified	56,919,000	38,985,500
2008-09	Native	316,027,000	
	Modified	56,293,000	
2009-10	Native	312,514,000	
	Modified	55,667,000	
2010-11	Native	309,001,000	
	Modified	55,042,000	

Source: Modelled data from the 2004-05 and 2010-11 Agricultural commodities (ABS cat. no. 7121.0) and ACLUMP (http://adl.brs.gov.au/landuse/index.cfm?fa=main.reporting)

18. Water use efficiency in native and modified pasture varies greatly, which is also reflected in the stock per hectare of the different types of pasture. The literature indicates that modified pasture is very prolific and native pasture tends to be slow growing (table 3)[7].

Table 3. Water use efficiency by pasture

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	kg/mm.ha	kg/mm.ha	kg/mm.ha	kg/mm.ha	kg/mm.ha	kg/mm.ha	kg/mm.ha	kg/mm.ha
Native pasture	5	4	4	4	4	4	4	4
Modified pasture	30	30	30	30	30	30	30	30

Source: multiple sources, see appendix 1.

19. One of the key assumptions for pasture is that all modified pasture should be included in soil water use and only native pasture that is actually consumed by livestock should be included. Grass consumption figures can be derived from total sheep and cattle (beef and dairy) numbers[8], using a coefficient for their daily grass consumption and then using a weighted average to allocate between native and modified pasture based on the expected yield of the type of grasslands. The weight consumed then forms the yield from native pasture and soil water use can be found from the water use efficiency of native grass and the area from ACLUMP.

20. One of the limitations is the availability of land use changes over time or total land use in a time series. Hence, land use figures between 2004-05 and 2010-11 are modelled from existing data based on the agricultural census and published in Agricultural commodities (ABS cat. no. 7121.0), see table 2.

[7] Pers comm S Murphy, NSW Department of Primary Industries.
[8] From Agricultural commodities, Australia (ABS cat. no. 7121.0)

2.3 Data sources and methods: agriculture – orchards

21. The difference in measuring soil water use for orchards is that typically only annual soil water use per tree is available from Australian research papers and the Food and Agricultural Organisation[9]. The number of trees of major orchard species grown is available annually from ABS agricultural statistics[10].

Table 4. Annual water use by selected orchard species.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	mm/ha	mm/ha	mm/ha	mm/ha	mm/ha	mm/ha	mm/ha	mm/ha
Oranges	800	800	800	800	800	n/a	n/a	n/a
Mandarins	800	800	800	800	800	n/a	800	n/a
Apples	500	500	500	500	500	500	n/a	500
Pears (inc Nashi)	500	500	500	500	500	500	n/a	n/a
Mangoes	800	n/a	800	n/a	800	n/a	800	n/a
Peaches	1251	1251	1251	1251	1251	1251	n/a	n/a
Macadamias	500	n/a	500	n/a	500	500	n/a	n/a
Other orchard fruit and/or nuts	350	350	350	350	350	350	350	350

Source: (1986) Brouwer, C. and Hiebloem, M., Irrigation Water Management: Irrigation Water Needs, Chapter 3 table 14, Indicative values of crop water needs and sensitivity to drought. Irrigation water management – training manual no.3, FAO. Online: http://www.fao.org/docrep/S2022E/s2022e00.htm#Contents

22. Commodity statistics are available through Agricultural commodities, Australia (ABS cat. no. 7121.0). This data gives the number of trees, but not the area. A transformation to the number of hectares was applied to the data using the following conversion factors (table 5). There is no consistent source of orchard tree density in Australia hence these factors were developed from a wide range of sources including State government agriculture and primary industry websites. As yet there is no state by state version of this table.

Table 5. Tree densities by selected species.

Fruit and Nut species	Trees/ha
Citrus	800
Apples	2000
Pears (including Nashi)	2000
Other orchard fruit - Mangoes	400
Stone fruit - Peaches	2000
Nuts - Macadamias	250
Other orchard fruits and nuts	800

Derived from ABS Agricultural commodities data (ABS Cat. no. 7121.0) and state department of primary industries (NSW, Qld, Vic) factsheets on tree species.

[9] Chapter 3, Table 14, Indicative values of crop water needs and sensitivity to drought. Irrigation Water Management: Irrigation Water Needs, FAO, Online: http://www.fao.org/docrep/S2022E/s2022e07.htm (Extracted 20 August 2012)
[10] Agricultural commodities, Australia (ABS cat. no. 7121.0)

23. Annual water use can be calculated from the area of trees by annual water use per species. Regional and annual variation is calculated from the number of trees within each state.

2.4 Data sources and methods: agriculture – other horticulture

24. Water use co-efficients for other types of horticulture are presented in table 6. These are available from a small, incomplete set of sources including state departments of agriculture or primary industries and the FAO. State variations in water use are not widely available so international water use is used for this exercise.

Table 6. Annual water use by state, selected horticultural species.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr
Strawberries	1200	1200	1200	1200	1200	1200	n/a	n/a
Bananas	1200	n/a	1200	n/a	1200	n/a	1200	n/a
Grapevines	500	500	500	500	500	500	500	500
All other fruit	700	700	700	700	700	700	700	n/a
Carrots	600	600	600	600	600	600	n/a	n/a
Potatoes	500	500	500	500	500	500	n/a	n/a
Tomatoes	400	400	400	400	400	400	400	n/a
Onions	350	350	350	350	n/a	n/a	350	n/a

Source: (1986) Brouwer C and Hiebloem M, Irrigation Water Management: Irrigation Water Needs,Chapter 3 table 14, Indicative values of crop water needs and sensitivity to drought. Irrigation water management – training manual no.3, FAO. Online: http://www.fao.org/docrep/S2022E/s2022e00.htm#Contents

25. Commodity statistics for these and other species can be found in Agricultural commodities, Australian (ABS Cat. no. 7121.0).

26. As the water use figures are for the entire growing season and the number of hectares planted are available from the ABS the calculations are fairly straightforward. One of the limitations to this estimate is the impact of seasonal variability in rainfall from drought which may impact on the yield but not the area planted. Therefore, this component could be improved by using a water use efficiency coefficient to incorporate the impact of yield.

2.5 Data sources and methods: forestry – plantations

27. There are limited sources of data available for water use efficiency in plantations species[11]. One study has examined a wide range of regions, which could be used as a proxy for the remainder of the state[12], these estimates are presented in table 7.

[11] Pers comm. Dr Don White, CSIRO

[12] D. White, M. Battaglia, J. Bruce, R. Benyon, C. Beadle, J. McGrath, J. Kinal, S. Crombie and T. Doody. *Water-use efficient plantations – separating the wood from the leaves.* Final report received by Forest and Wood Products Australia in December, 2009.

Table 7. Water use efficiency by type of plantation, state.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Plantation	m3/ML	m3/ML	m3/ML	m3/ML	m3/ML	m3/ML	m3/ML	m3/ML
Broadleaf	4	4	4	3	4	2.5	4	4
Coniferous	4	4	4	4	4	4	4	4

Source: Pers. Comm. D. White, CSIRO and (2009) White D, et al. Water-use efficient plantations – separating the wood from the leaves, Report for Forest & Wood Products Australia.

28. The Australian Bureau of Agricultural and Resources Economics and Sciences collects most of the information about plantations and forests in Australia. The National Plantation inventory and more recently the National Forestry Statistics are the source of information on the area of plantations in Australia. The National Forestry Inventory from the Bureau of Rural Sciences (now amalgamated with ABARES) points to some data for average growth rates of plantations species in a consolidated format and these are reproduced in table 8. (Note: a lower bound estimate was used on growth rates).

Table 8. Growth rates of plantation species, by state.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr
Growth rates - broadleaf	15	15	15	15	15	15	15	15
Growth rates - coniferous	14	18	14	14	14	18	14	14

Source: (2005) Australian Forestry Plantations – planting for the future, Australian government, Online: http://www.daff.gov.au/__data/assets/pdf_file/0007/37573/plantations_snapshot_english.pdf

29. Once the growth for a particular year is known then the calculation is fairly straightforward.

Total soil water use = growth of plantation x water use efficiency^{-1}.

30. The main assumption here is that new plantings over the year do not contribute to growth in that year, but they do contribute to the year after, likewise removals are counted within against the total but not from ongoing years. This should balance out the impact of removals and new plantings, but it is an area of improvement for the model.

2.6 Data sources and methods: households – residential

31. Water use efficiency of residential turf was taken from Turf Australia[13], an industry body focused on quality lawns for Australia (see table 9). This mostly suits urban intensive land use. Native grass water use efficiency was chosen for rural residential land use. Further work could be done on calculating the area of rural residential that have a modified pasture (or turf) instead of local species of grass.

[13] Online: http://www.turfaustralia.com.au/documents/item/37

Table 9. Turf replacement watering by state.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	mm/wk	mm/wk	mm/wk	mm/wk	mm/wk	mm/wk	mm/wk	mm/wk
Turf replacement watering	12	21	21	21	24	9	21	12

Turf Australia factsheet, Turf-watering. Extracted (21/09/2012). Online: http://www.turfaustralia.com.au/documents/item/37

32. One of the key assumptions for this component was the proportion of land available for grass and other species. For urban residential 1/8th of land was allocated for green space and for rural residential 7/8th of land was allocated for green space. Additional data to confirm this allocation is needed. One study using satellite imaging has detected between 10 to 15% of inner urban environments are dedicated to green space[14]. The allocation for rural residential is likely to be an underestimate.

33. The next assumption is to take out for residential use of soil water which is applied from mains to remove a source of potential double counting. The ABS collected information on water use by households via their Water Account, Australia (ABS Cat. no. 4610.0). A skirmish through state water agencies found some estimated proportions of household water use on green space. This was then offset against the soil water use calculated from multiplying turf replacement water by area under green space in urban residential by 52 weeks.

34. Rural residential is calculated by:

A notional yield per hectare[15] x water use efficiency of native pastures x number of hectares of rural residential available for green space.

2.7 Total soil water use

35. Total water use is an aggregate of all the components mentioned above. This number is soil water use using both natural and irrigated sources. To calculate a net irrigated soil water use value:

Non-irrigated soil water use = total soil water use – irrigated water (from surface and groundwater sources) – household water use (for gardens & lawns)

3.0 Results

36. The results are presented in tables 10- 13. Queensland is the state with the largest use of soil water in Australia accounting for 30% of soil water use. The main features of water use in this state are soil water use from native pasture (88% of state total) and by food producing plant species (9% of state total, of which over half is attributed to banana crops).

[14] See: Guy Barnett, Michael Doherty, Matthew Beaty. Urban Greenspace: Connecting People and Nature http://www.griffith.edu.au/__data/assets/pdf_file/0007/81376/environmental-city-13-barnett.pdf

[15] Online: http://www.pasturepicker.com.au/Html/index.htm#A

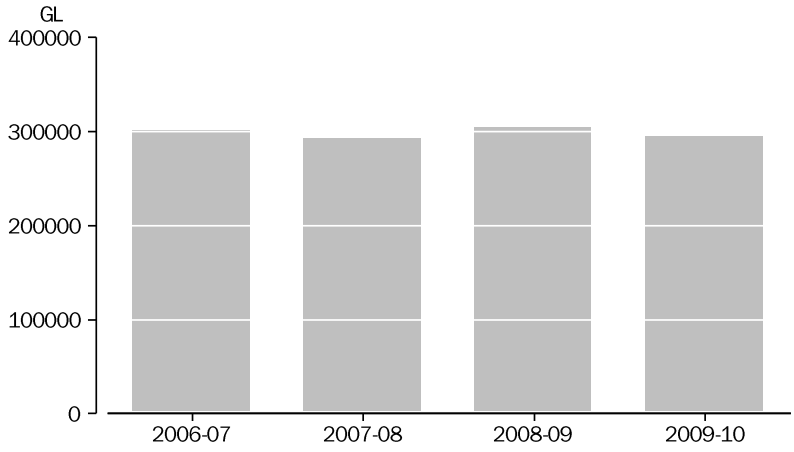
Table 10. Total soil water use by state

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
	GL	GL	GL	GL	GL	GL	GL	GL	**GL**
2006-07	60,112	22,034	89,278	34,341	65,248	4,895	25,868	135	**301,911**
2007-08	56,514	23,337	90,629	31,641	58,206	4,756	27,524	132	**292,740**
2008-09	62,841	23,885	96,841	33,860	59,233	4,983	23,196	139	**304,977**
2009-10	59,330	24,910	88,626	32,270	56,716	4,947	28,379	123	**295,302**

Table 11. Non-irrigated soil water use by state

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
	GL	GL	GL	GL	GL	GL	GL	GL	GL
2006-07	57,507	20,385	87,438	33,375	64,955	4,632	25,848	135	**294,275**
2007-08	54,837	22,005	88,786	30,760	57,921	4,504	27,508	132	**286,455**
2008-09	60,931	22,690	94,783	33,032	59,007	4,721	23,174	139	**298,476**
2009-10	57,327	23,405	86,802	31,558	56,464	4,665	28,361	123	**288,706**

Figure 1. Total soil water use (including irrigation), Australia



37. The decrease between 2008-09 and 2009-10 was driven by a substantial decrease in cattle and sheep over the corresponding time. Australia had a drought leading up until November 2008-09 which would go some way to explain the depressed soil water use number in 2007-08 and elevated soil water use in 2008-09. One of the leading contributors to declining soil water use of the time period is the decrease in cattle and sheep on pasture over this time period.

Figure 2. Net soil water use, Australia

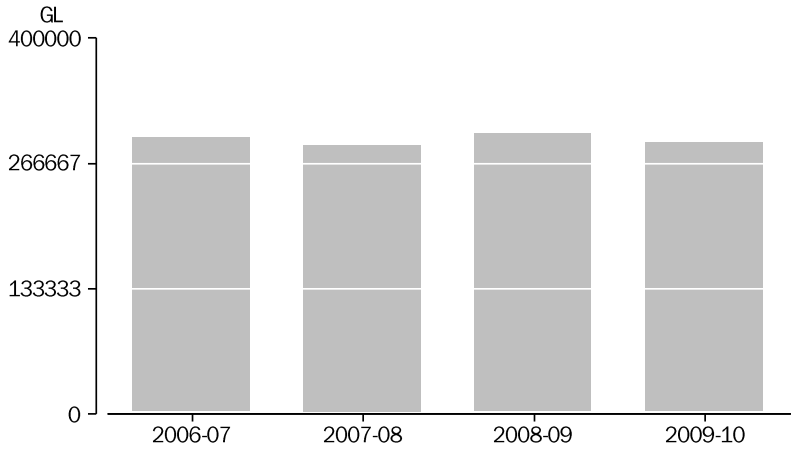


Table 12. Total water availability from rainfall.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
	GL	GL	GL	GL	GL	GL	GL	GL	GL
2007	434,959	139,198	1,134,429	211,601	965,275	71,001	866,465	1,281	**3,820,395**
2008	418,938	114,634	1,158,639	185,028	972,856	67,458	723,626	1,234	**3,643,596**
2009	398,111	121,457	1,188,037	197,822	831,350	103,231	684,548	1,173	**3,520,605**
2010	652,839	196,515	1,959,310	361,198	854,092	94,713	1,268,030	1,923	**5,388,525**
2011	533,485	182,186	1,435,329	347,419	1,523,720	98,938	1,312,499	1,572	**5,419,272**

Table 13. Proportion of non-irrigated soil water use of total rainfall*.

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
	GL	GL	GL	GL	GL	GL	GL	GL	GL
2006-07	13%	15%	8%	16%	7%	7%	3%	11%	**8%**
2007-08	13%	19%	8%	17%	6%	7%	4%	11%	**8%**
2008-09	15%	19%	8%	17%	7%	5%	3%	12%	**8%**
2009-10	9%	12%	4%	9%	7%	5%	2%	6%	**5%**
*note calendar year and financial years combined									

3.1 Comparison with previous published estimates of water use

38. In previous publication of the ABS' water account (ABS cat. no. 4610.0) water consumption (defined by the sum of distributed water use, self-extracted water use and reuse water use less water supplied to other users and less in-stream use) was 13,400 GL in 2009-10 and 14,100 GL in 2008-09. By comparison, non-irrigated soil water use is estimated to be 21 times this value (288,700 GL).

39. The majority of soil water use is in Agriculture and forestry operations (94% and 3% respectively in 2009-10). This compares to current water consumption estimates (which includes surface water, ground water and reuse water only) of 7,000GL in Agriculture and forestry for the same year. Irrigation accounts for 94% or over 6,500GL of annual use.

3.2 Release experimental estimates of soil water use data?

40. The results for soil water use are not of sufficient quality to be released in main supply and use tables of the current annual publication Water Account, Australia (ABS cat. no. 4610.0). There are four main options for releasing these data:

1. Release the data as a standalone ABS discussion paper. The paper would include a table of soil water use as supplementary information to the water accounts in the form of its own section in the publication (e.g. as a feature article).
2. Release the data as a standalone table of soil water water use as supplementary information to the water accounts in the form of its own section in the publication (e.g. as a feature article).
3. Release that data as a special section in the regular publication as an experimental integrated table incorporating soil water use with the main supply and use tables as per the current format of the Water Account, Australia. That is, the estimates of soil water use would be added to the estimates of self- extracted water which currently only include estimates of surface water and groundwater use.
4. Release that data as a special section in the regular publication as an experimental integrated table incorporating soil water use with the supply and use tables as per the SEEA-Water or SEEA 2012 suggested tables. This would need to be done with other table modifications to ensure that the ABS water accounts were in better agreement with the SEEA-Water or SEEA 2012 tables (e.g. a changed definition of consumption and addition of estimates of returns to environment for additional industries).

A combination of approaches could be used.

Appendix 1. Water use efficiency references, broadacre crops and pasture

Table A1. Water use efficiencies by state and crop.

Crop	State/region	WUE	Online source
Wheat	Tas	Max 22	http://www.regional.org.au/au/asa/2010/crop-production/soil-water/7035_acunat.htm#TopOfPage
Wheat	Qld	between 10 and 20	http://www.dpi.qld.gov.au/26_3518.htm
Sorghum	NSW	15 kg/ha/mm	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/summer-crop-production-guide-2011.pdf
Maize	NSW,	16–18 kg grain/ha/mm	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/summer-crop-production-guide-2011.pdf
Barley	NSW, Qld	5-20 (10-15 managed)	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Chickpea	NSW, Qld	3-10 (8-10 managed)	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Sorghum	NSW, Qld	5-20 (10-15 managed)	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Sunflower	NSW, Qld	2-8 (7 managed)	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Mungbean	NSW, Qld	2-6	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Cotton	NSW, Qld	around 0.0125 bales/ha/mm	http://www.grdc.com.au/director/events/factsheets?item_id=4824DA5A0B76E87CCF35AF5898BE18BC&pageNumber=8 and http://www.apsim.info/Wiki/public/Upload/ApSoil/SoilMatters/pdf/mod32.pdf
Wheat	WA,	18.0	http://www.agric.wa.gov.au/objtwr/imported_assets/content/_archive/tr032.pdf

Table A1, continued			
Barley	WA,	17.8	http://www.agric.wa.gov.au/objtwr/imported_assets/content/_archive/tr032.pdf
Peas	WA	12.7	http://www.agric.wa.gov.au/objtwr/imported_assets/content/_archive/tr032.pdf
Wheat	W.	10.4 kg/ha/mm	"
Wheat	Vic	20	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Barley	Vic	18	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Oats	Vic	22	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Triticale	Vic	18	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Canola	Vic	10	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Grain legumes	Vic	12	http://www.dpi.vic.gov.au/agriculture/farming-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/water-balance
Canola	NSW,	11-15	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Lupins	NSW	13	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Field pea	NSW	10-15	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Faba bean	WA	10-15	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf

Table A1, continued			
Pasture	NSW	30	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Lucerne	Australia	12	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Canola	Australia	11-15	http://www.australianoilseeds.com/__data/assets/pdf_file/0013/4612/Water_use_efficiency_of_dryland_canola.pdf
Canola	Sth Qld	3 - 18 (13 median)	http://www.australianoilseeds.com/__data/assets/pdf_file/0013/4531/WATER_USE_EFFICIENCY_NORTH.pdf
Wheat	Sth Qld	7 - 21 (15 median)	http://www.australianoilseeds.com/__data/assets/pdf_file/0013/4531/WATER_USE_EFFICIENCY_NORTH.pdf
Wheat	NSW	15	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Wheat	NSW,	16	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/303292/water-use-by-crops-and-pastures-in-southern-NSW.pdf
Rice	NSW	7.1-8.1	http://ses.library.usyd.edu.au/handle/2123/134
Sugar cane	Qld	73	http://www.irrigation.org.au/assets/pages/6E9E6203-1708-51EB-A65470E3F41123EB/Irrigation%20Insights%20efficiency%20PR030566.pdf
Native pasture	Qld (pre 1996)	1-6	http://www.southwestnrm.org.au/sites/default/files/uploads/ihub/chapter-3.pdf
Pasture	Nth Qld	3-6.5	http://www.regional.org.au/au/asa/2008/concurrent/managing-pastures/5916_owensjs.htm