The realities of biosolids for soil carbon sequestration

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LOW CARBON LIVING CRC

Greenhouse Gas Emissions and Soil Carbon Sequestration
(South Australian case study)

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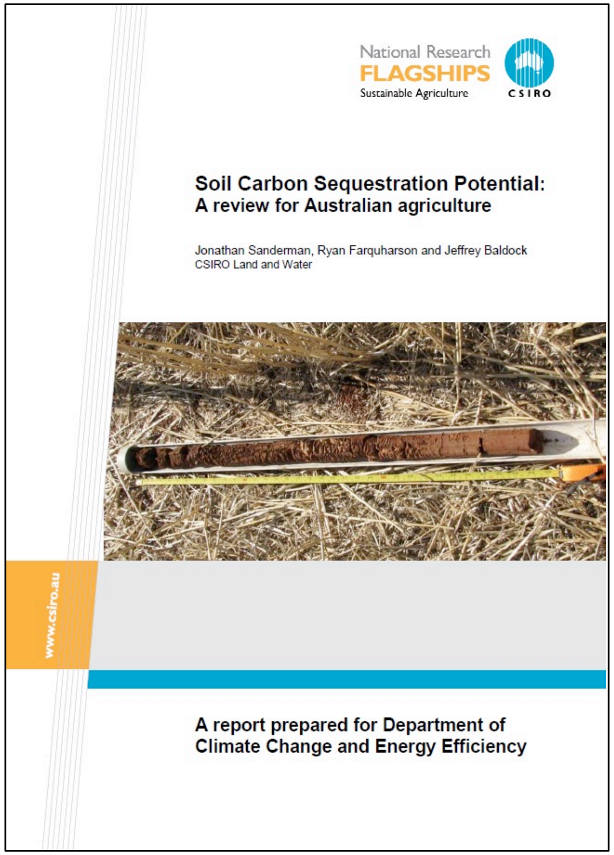
Government of South Australia · SA Water · University of South Australia · UNSW Australia · Hunter Water · suez environnement · Sydney Water

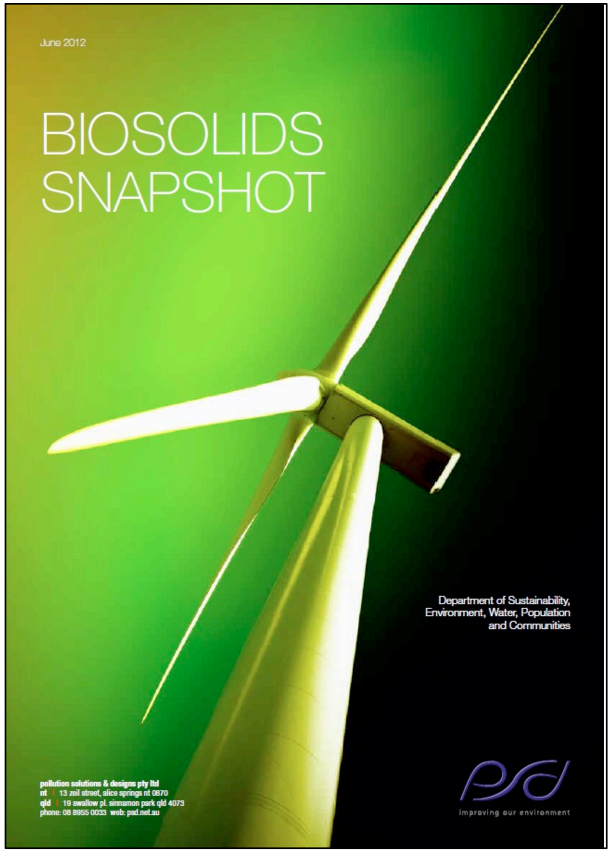
Research topics

1. Investigate greenhouse gas emissions (methane and nitrous oxide) from stockpiled biosolids at Bolivar Wastewater Treatment Plant

2. Investigate the viability of generating carbon credits via soil carbon sequestration of biosolids applied to broadacre cropland in SA

Discussed the viability of biosolids for soil carbon sequestration





Maximum theoretical potential of biosolids soil carbon sequestration in Australia

- International Biosolids Emissions Assessment Model (BEAM) - default sequestration value of 0.068 tonne C tonne^{-1} biosolids
    - Comparable 34-year study by Tian et al. (2009) - 0.064 tonne C tonne^{-1} biosolids
    - Comparable to study utilizing Bolivar WWTP biosolids by Bolan et al. (2013) - 0.087-0.103 tonne C tonne^{-1} biosolids.
- Australian biosolids production 310,000 dry tonnes annually (ANZBP 2015)
- Theoretical maximum sequestration value of 21,080 tonne C or 77,300 tonne CO_2-e offset annually
- 0.014% of annual national emissions or 0.68% of emissions from the waste sector.

The issue of sensitivity

- Agricultural norm in Australia is to apply biosolids at approximately 5 tonne ha^{-1} y^{-1} (dry weight) or 30-40 tonne ha^{-1} y^{-1} (wet weight)

Sample size		**Variance, s^2 (%^{2})**		
		0.013 (highest)	**0.005 (medium)**	**0.001 (lowest)**
n=3, v=2 (27 cores)	$t_{\alpha=0.05,v=2}$=4.303 $t_{\beta(1)=0.05,v=2}$=2.920	0.4755% 21.40 Mg C ha^{-1}	0.2949% 13.27 Mg C ha^{-1}	0.1319% 5.93 Mg C ha^{-1}
n=4, v=3 (36 cores)	$t_{\alpha=0.05,v=3}$=3.182 $t_{\beta(1)=0.05,v=3}$=2.353	0.3155% 14.20 Mg C ha^{-1}	0.1957% 8.81 Mg C ha^{-1}	0.0875% 3.94 Mg C ha^{-1}
n=30, v=29 (270 cores)	$t_{\alpha=0.05,v=29}$=2.045 $t_{\beta(1)=0.05,v=29}$=1.699	0.0779% 3.51 Mg C ha^{-1}	0.0483% 2.18 Mg C ha^{-1}	0.0216% 0.97 Mg C ha^{-1}
n=135, v=134 (1,215 cores)	$t_{\alpha=0.05,v=109}$=1.978 $t_{\beta(1)=0.05,v=109}$=1.656	0.0357% 1.60 Mg C ha^{-1}	0.0221% 1.00 Mg C ha^{-1}	0.0099% 0.45 Mg C ha^{-1}
n=350, v=349 (3,150 cores)	$t_{\alpha=0.05,v=279}$=1.967 $t_{\beta(1)=0.05,v=279}$=1.649	0.0220% 0.99 Mg C ha^{-1}	0.0137% 0.62 Mg C ha^{-1}	0.0061% 0.28 Mg C ha^{-1}

- Theoretical sequestration value of 0.34 tonne C ha^{-1} y^{-1}
- Applied for 39 years to achieve minimum detectability

Economic restrictions

- Carbon Pricing Mechanism AUD 24.15 $tonne^{-1}$ CO_2-e in 2013-14
- Emissions Reduction Fund AUD 11.82 $tonne^{-1}$ CO_2-e (CER 2017)
- To achieve a realistic minimum detectability with a 36 core (n=4 composite) sampling regime assuming medium variance (0.005%^{2}), the current industry application rate would need to be increased by a factor of 2.6 (to 13 tonne ha^{-1})for a 10 year annual application plan.
- 8.81 tonne C ha^{-1} of soil carbon sequestration or 32.31 tonne CO_2-e ha^{-1}
- AUD 15,276 for a 40 ha paddock
- Cumulative trucking cost for 10 years would be AUD 104,000 (AUD 20 $tonne^{-1}$ biosolids)
- Minimum breakeven carbon price required for biosolids carbon sequestration to be viable based solely on trucking costs is AUD 80 $tonne^{-1}$ CO_2-e

Alternative to soil carbon sequestration? (Inorganic fertiliser offset)

- 0.068 tonne C tonne^{-1} biosolids or 250 kg CO_2-e tonne^{-1} biosolids

Nutrient	Freshly dewatered biosolids		AAD biosolids		Stockpiled biosolids	
	Nutrient content (kg Mg^{-1} biosolids)	GHG emissions offset (kg CO_2-e Mg^{-1} biosolids)	Nutrient content (kg Mg^{-1} biosolids)	GHG emissions offset (kg CO_2-e Mg^{-1} biosolids)	Nutrient content (kg Mg^{-1} biosolids)	GHG emissions offset (kg CO_2-e Mg^{-1} biosolids)
Nitrogen (N)	48.877	171.070	21.716	76.006	13.240	46.340
Phosphorus (P)	24.422	8.548	14.564	5.097	11.929	4.175
Potassium (K)	4.562	1.369	8.954	2.686	8.061	2.418
	Total offset	**180.986**	**Total offset**	**83.790**	**Total offset**	**52.933**

- Nutrient value for dewatered biosolids by dry weight (for N and P) including the metals (Cu and Zn) would be approximately AUD 164 tonne^{-1} (Biosolids Snapshot 2012)

Biosolids as a resource

- Stockpiled biosolids nitrogen limited

Nutrient	Biosolids nutrient concentration/application		Wheat		Canola	
	Per Mg stockpiled biosolids (kg)	Biosolids applied at 5 Mg ha^{-1} (kg)	Removal of nutrients by harvesting 4Mg ha^{-1} grain (kg)	Cropping equivalent of nutrient supplied	Removal of nutrient by harvesting 2.5 Mg ha^{-1} crop (kg)	Cropping equivalent of nutrient supplied
Nitrogen (N)	13.240	66.200	84.000 [1]	0.8	100.000 [1]	0.7
Phosphorus (P)	11.929	59.645	10.000 [1]	6.0	16.071 [1]	3.7
Potassium (K)	8.061	40.305	15.000 [1]	2.7	23.214 [1]	1.7
Sulphur (S)	8.558	42.790	68.000 [3]	0.6	12.500 [3]	3.4
Zinc (Zn)	0.299	1.495	0.100 [2]	15.0	0.085 [2]	17.6
Copper (Cu)	0.299	1.495	0.020 [2]	74.8	0.010 [2]	149.5
Manganese (Mn)	0.263	1.315	0.176 [2]	7.5	0.125 [2]	10.5
Magnesium (Mg)	9.426	47.130	5.600 [4]	8.4	7.000 [4]	6.7
Molybdenum (Mb)	ND	-	0.0008 [2]	-	0.0008 [2]	-
Boron (B)	ND	-	0.008 [2]	-	0.033 [2]	-

1. N, P, K data from GRDC (2010)
2. Zn, Cu, Mn, Mb, B data from GRDC (2013)
3. S data for wheat from Crop Pro (2013) and canola from GRDC (2016)
4. Mg data for wheat from Department of Agriculture and Fisheries (2012) and canola from Santonoceto et al. (2002)

Conclusion

- Limitations to viability of biosolids for soil carbon sequestration under current reuse regime (fringe benefits likely, but won't be major driver)
- Carbon crediting via inorganic fertiliser offset technically and economically simpler to implement
- Biosolids as a true resource
  - Increase N (optimise biogas production, increase nutrient recovery, reduce GHG emissions, reduce operating costs e.g. aeration)
  - Reduces application rate: reduces metals loading etc.