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Comparative effect of alternative fertilisers on pasture production, soil properties and soil microbial community structure

Fiona J. Leech[A,B,C], *Alan E. Richardson*[B], *Michael A. Kertesz*[C], *Beverley A. Orchard*[D], *Samiran Banerjee*[B,E] *and Phillip Graham*[F]

[A]South East Local Land Services, PO Box 10, Yass, NSW 2582, Australia.

[B]CSIRO Agriculture & Food, PO Box 1700, Canberra, ACT 2601, Australia.

[C]Sydney Institute of Agriculture, School of Life and Environmental Sciences, University of Sydney, Sydney, NSW 2006, Australia.

[D]Formerly: Wagga Wagga Agricultural Institute, Private Mail Bag, Wagga Wagga, NSW 2650, Australia.

[E]Department of Microbiological Sciences, North Dakota State University, Fargo 58102, ND, USA.

[F]Formerly: NSW Department of Primary Industries, PO Box 10, Yass, NSW 2582, Australia.

[G]Corresponding author. Email: fiona.leech@lls.nsw.gov.au

SUPPLEMENTARY MATERIALS

Supplementary Table S1: Nutrient composition of fertilizers trialled over the period 2009 to 2014. (a) Average dry matter percentage and nutrient content of dry products; (b) Average nutrient content of liquid products

(a) Nutrient content of dry products

Treatment	Dry Matter (%)	Carbon (%)	Total P (%)	Sulphur (%)	Nitrogen (%)	Potassium (%)	Molybdenum (%)
Single Super	-	-	8.8	11.0	-	-	0.025
Agri-ash	-	3.43	6.6	0.85	-	0.39	0.000837
SEP Pig Manure	50	16.41	3.99	0.76	2.19	0.42	0.000605
BioAg Blend*	96	3.10	6.79	3.29	0.04	0.09	0.000655
EFF/ Dical 64**	-	0.35	21.18	0.34	0.05	0.01	0.000155
YLAD Compost Mineral Blend	77	7.02	1.25	2.17	0.57	0.48	0.00034
Groundswell Compost	64	13.12	0.35	0.25	1.2	1.0	0.000174
Triomin/ Eco-min Balance	-	2.74	0.42	0.14	0.41	0.27	0.000133
Urea	-	-	-	-	46		-

* In year 6 of the study (2014) additional Molybdenum (Mo) was added to BioAg Blend to ensure Mo was applied at 50 grams ha^{-1}.

** Dical 64 component of EFF/Dical 64 treatment was a dry granular product and only applied in the latter four years of the study. Nutrient composition testing occurred in each of these last four years.

(b) Nutrient content of liquid products

Treatment	Total P (mg L^{-1})	Sulphur (mg L^{-1})	Nitrogen (mg L^{-1})	Potassium (mg L^{-1})	Molybdenum (mg L^{-1})
EFF/ Dical 64***	38642	7810	3454	2319	194
YLAD Compost Tea	247	434	994	858	0.15

***Ecology Fluid Fertilizer (EFF) component of EFF/Dical 64 treatment was a liquid product and only applied in the first two years of the study. Nutrient composition testing only occurred in each of these first two years.

Supplementary Table S2. (a) Soil pH, (b) aluminium percent, (c) cation exchange capacity (CEC), (d) available P and (e) extractable S in soil (0-10 cm) at the Glenroy, Kia-Ora and Te Kooti sites over the trial period

Results from 2008 (initial year prior to establishment of treatments) through to 2014 (Glenroy and Kia-Ora) or 2013 (Te Kooti) are presented. Values within a row followed by the same letter superscript are not significantly different (P<0.05). Fertilizer treatments differing from the control (nil fertilizer) are marked in bold.

(a) Soil pH

Site	Soil Parameter	Year	Treatment										
			Control	Single Super	Agri-ash	SEP Pig Manure	BioAg Blend	EFF/ Dical 64	YLAD Compost Mineral Blend	Groundswell Compost	Triomin/ Eco-min Balance	YLAD Compost Tea	Urea
Glenroy	pH	2008	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}	4.15^{a}
		2009	4.05^{a}	4.02^{a}	**4.46^{b}**	4.10^{a}	4.25^{ab}	4.07^{a}	4.19^{a}	4.12^{a}	4.11^{a}	4.07^{a}	4.00^{a}
		2010	4.29^{a}	4.37^{ab}	**5.28^{d}**	4.46^{abc}	**4.57^{bc}**	4.39^{ab}	**4.65^{c}**	4.37^{ab}	4.39^{ab}	4.37^{ab}	4.31^{a}
		2011	4.40^{a}	4.40^{a}	**5.18^{b}**	4.45^{a}	4.59^{a}	4.51^{a}	**4.94^{b}**	4.53^{a}	4.50^{a}	4.47^{a}	4.37^{a}
		2012	4.37^{a}	4.24^{a}	**4.86^{b}**	4.42^{a}	4.45^{a}	4.33^{a}	**4.94^{b}**	4.41^{a}	4.41^{a}	4.35^{a}	4.32^{a}
		2013	4.34^{ab}	4.27^{a}	**4.82^{c}**	4.40^{ab}	4.47^{b}	4.32^{ab}	**4.82^{c}**	4.36^{ab}	4.40^{ab}	4.37^{ab}	4.27^{a}
		2014	4.47^{a}	4.35^{a}	**4.84^{b}**	4.47^{a}	4.50^{a}	4.34^{a}	**4.76^{b}**	4.46^{a}	4.44^{a}	4.36^{a}	4.36^{a}
Kia-Ora	pH	2008	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}	4.02^{a}
		2009	3.87^{ab}	3.86^{ab}	**4.81^{c}**	3.97^{ab}	3.96^{ab}	3.81^{a}	4.03^{b}	3.86^{ab}	3.86^{ab}	3.91^{ab}	3.90^{ab}
		2010	4.27^{a}	4.26^{a}	**4.76^{c}**	4.30^{ab}	4.33^{ab}	4.20^{a}	**4.43^{b}**	4.30^{ab}	4.26^{a}	4.32^{ab}	4.26^{a}
		2011	4.29^{a}	4.35^{a}	**4.76^{b}**	4.33^{a}	4.41^{a}	4.30^{a}	**4.79^{b}**	4.40^{a}	4.36^{a}	4.38^{a}	4.33^{a}
		2012	4.37^{a}	4.35^{a}	4.66^{ab}	4.53^{ab}	4.50^{ab}	4.43^{a}	**4.96^{b}**	4.43^{a}	4.40^{a}	4.68^{ab}	4.46^{a}
		2013	4.29^{a}	4.30^{a}	**4.57^{bc}**	4.40^{ab}	4.40^{ab}	4.28^{a}	**4.73^{c}**	4.37^{a}	4.43^{ab}	4.38^{ab}	4.36^{a}
		2014	4.38^{a}	4.49^{ab}	**4.69^{bc}**	4.48^{ab}	4.47^{ab}	4.42^{ab}	**4.84^{c}**	4.51^{ab}	4.50^{ab}	4.58^{abc}	4.35^{a}
Te Kooti	pH	2008	4.03^{a}	4.10^{a}	4.10^{a}	4.03^{a}	4.07^{a}	4.10^{a}	4.13^{a}	4.20^{a}	4.13^{a}	4.20^{a}	4.00^{a}
		2009	3.87^{a}	3.90^{a}	**4.83^{b}**	3.90^{a}	4.20^{a}	3.90^{a}	4.27^{a}	4.10^{a}	4.00^{a}	3.97^{a}	3.87^{a}
		2010	4.23^{a}	4.27^{ab}	**4.60^{c}**	4.30^{ab}	4.40^{abc}	4.30^{ab}	**4.47^{bc}**	4.40^{abc}	4.37^{ab}	4.30^{ab}	4.23^{a}
		2011	4.27^{a}	4.28^{a}	4.63^{ab}	4.27^{a}	4.42^{ab}	4.35^{a}	**4.74^{b}**	4.51^{ab}	4.38^{ab}	4.53^{ab}	4.27^{a}
		2012	4.20^{ab}	4.19^{a}	**4.55^{cd}**	4.30^{ab}	4.34^{ab}	4.26^{ab}	**4.58^{d}**	4.41^{bcd}	4.37^{abc}	4.29^{ab}	4.23^{ab}
		2013	4.31^{a}	4.27^{a}	**4.67^{c}**	4.33^{a}	4.43^{ab}	4.34^{a}	**4.63^{bc}**	4.46^{abc}	4.42^{ab}	4.34^{a}	4.30^{a}

(b) Aluminium percent

Site	Soil Parameter	Year	Treatment										
			Control	Single Super	Agri-ash	SEP Pig Manure	BioAg Blend	EFF/ Dical 64	YLAD Compost Mineral Blend	Groundswell Compost	Triomin/ Eco-min Balance	YLAD Compost Tea	Urea
Glenroy	Al (%)	2008	28.03^{a}	27.43^{a}	24.61^{a}	22.61^{a}	25.81^{a}	23.61^{a}	27.54^{a}	24.21^{a}	19.37^{a}	22.30^{a}	25.39^{a}
		2009	28.89^{d}	26.00^{cd}	**11.43^{a}**	20.59^{bcd}	**13.70^{ab}**	21.26^{bcd}	**19.81^{abc}**	22.48^{cd}	**19.56^{abc}**	22.44^{bcd}	24.07^{cd}
		2010	26.43^{c}	25.30^{c}	**2.59^{a}**	19.72^{bc}	**13.65^{b}**	22.39^{c}	**12.29^{b}**	23.19^{c}	19.77^{bc}	23.57^{c}	25.28^{c}
		2011	23.66^{bc}	22.68^{d}	**2.75^{a}**	19.23^{cd}	**13.21^{d}**	18.57^{cd}	**5.12^{ab}**	19.22^{cd}	19.34^{cd}	22.33^{d}	22.10^{d}
		2012	21.75^{de}	23.08^{e}	**5.29^{ab}**	**12.32^{abc}**	13.40^{bcd}	17.63^{cde}	**3.91^{a}**	15.54^{cde}	13.08^{abcd}	19.21^{cde}	20.49^{cde}
		2013	23.74^{d}	22.57^{cd}	**4.65^{a}**	15.02^{bcd}	**12.71^{ab}**	16.68^{bcd}	**4.70^{a}**	16.20^{bcd}	**13.41^{abc}**	14.92^{bcd}	22.98^{d}
		2014	21.86^{d}	21.81^{d}	**4.88^{a}**	13.35^{abcd}	**12.45^{abc}**	17.07^{cd}	**5.31^{ab}**	17.44^{cd}	14.22^{bcd}	18.76^{cd}	21.28^{cd}
Kia-Ora	Al (%)	2008	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}	31.24^{a}
		2009	26.65^{bc}	26.39^{bc}	**0.98^{a}**	19.90^{b}	23.03^{bc}	31.52^{c}	19.38^{b}	26.38^{bc}	27.24^{bc}	27.77^{bc}	26.20^{bc}
		2010	29.00^{c}	26.71^{bc}	**9.72^{a}**	25.76^{bc}	23.23^{bc}	32.96^{c}	**17.83^{ab}**	28.45^{c}	28.23^{c}	23.14^{bc}	27.14^{bc}
		2011	29.28^{b}	23.33^{b}	**6.15^{a}**	23.82^{b}	20.89^{b}	28.48^{b}	**6.71^{a}**	21.72^{b}	22.02^{b}	23.22^{b}	25.91^{b}
		2012	18.70^{c}	18.91^{c}	**3.78^{a}**	13.63^{bc}	**10.62^{ab}**	17.46^{bc}	**3.38^{a}**	15.18^{bc}	16.31^{bc}	**9.95^{ab}**	17.06^{bc}
		2013	17.58^{bc}	16.69^{bc}	**5.18^{a}**	11.28^{ab}	14.21^{bc}	21.66^{c}	**3.37^{a}**	14.75^{bc}	11.50^{ab}	14.31^{bc}	17.53^{bc}
		2014	19.32^{c}	15.27^{c}	**5.77^{ab}**	12.12^{abc}	13.73^{bc}	18.47^{c}	**4.28^{a}**	13.20^{bc}	13.55^{bc}	16.08^{c}	19.99^{c}
Te Kooti	Al (%)	2008	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}	20.33^{a}
		2009	22.46^{bc}	22.01^{bc}	**2.78^{a}**	22.79^{bc}	13.94^{bc}	23.84^{c}	12.53^{ab}	17.58^{bc}	23.17^{c}	23.37^{c}	20.80^{bc}
		2010	21.79^{bc}	22.68^{c}	**9.33^{a}**	19.13^{bc}	14.31^{ab}	21.17^{bc}	14.19^{ab}	16.08^{abc}	19.07^{bc}	22.37^{c}	23.13^{c}
		2011	23.46^{b}	24.35^{b}	**9.20^{a}**	23.79^{b}	17.31^{ab}	21.84^{b}	**8.69^{a}**	14.18^{ab}	21.84^{b}	15.87^{ab}	22.80^{b}
		2012	19.46^{b}	19.35^{b}	**6.87^{a}**	13.79^{ab}	12.98^{ab}	16.84^{b}	**6.29^{a}**	12.52^{ab}	14.04^{ab}	16.80^{b}	16.13^{b}
		2013	15.79^{bc}	18.01^{c}	**5.80^{a}**	13.46^{bc}	10.31^{ab}	15.84^{bc}	**5.89^{a}**	11.95^{abc}	12.24^{abc}	16.04^{bc}	13.80^{bc}

(c) Cation Exchange Capacity (CEC)

Site	Soil Parameter	Year	Treatment										
			Control	Single Super	Agri-ash	SEP Pig Manure	BioAg Blend	EFF/ Dical 64	YLAD Compost Mineral Blend	Groundswell Compost	Triomin/ Eco-min Balance	YLAD Compost Tea	Urea
Glenroy	CEC (cmol(+)/kg)	2008	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}	2.64^{a}
		2009	2.50^{a}	2.85^{a}	3.05^{a}	2.93^{a}	3.00^{a}	2.96^{a}	2.98^{a}	2.68^{a}	2.64^{a}	2.44^{a}	2.63^{a}
		2010	2.57^{ab}	2.76^{b}	**4.05^{d}**	2.84^{bc}	2.86^{bc}	2.64^{ab}	**3.25^{c}**	2.50^{ab}	2.47^{ab}	2.28^{a}	2.52^{ab}
		2011	2.64^{a}	3.17^{ab}	**4.11^{c}**	3.10^{a}	3.15^{ab}	2.94^{a}	**3.80^{bc}**	2.81^{a}	2.75^{a}	2.56^{a}	2.76^{a}
		2012	2.59^{ab}	2.84^{ab}	**3.96^{c}**	3.37^{bc}	2.75^{ab}	2.86^{ab}	**3.87^{c}**	2.74^{ab}	2.74^{ab}	2.22^{a}	2.46^{a}
		2013	2.54^{a}	2.97^{ab}	**3.81^{c}**	2.87^{a}	2.79^{a}	2.84^{a}	**3.73^{bc}**	2.71^{a}	2.49^{a}	2.40^{a}	2.36^{a}
		2014	3.08^{a}	3.49^{ab}	**4.44^{bc}**	3.86^{ab}	3.45^{ab}	3.47^{ab}	**5.14^{c}**	3.16^{a}	3.10^{a}	2.85^{a}	3.16^{a}
Kia-Ora	CEC (cmol(+)/kg)	2008	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}
		2009	2.71^{a}	2.88^{a}	**4.05^{b}**	2.89^{a}	2.72^{a}	2.48^{a}	3.03^{a}	2.91^{a}	2.79^{a}	2.49^{a}	2.59^{a}
		2010	2.51^{a}	2.79^{ab}	**3.26^{b}**	2.55^{a}	2.66^{ab}	2.50^{a}	2.97^{ab}	2.69^{ab}	2.54^{a}	2.53^{a}	2.53^{a}
		2011	2.67^{a}	3.20^{abc}	**3.66^{bc}**	2.73^{a}	2.86^{ab}	2.67^{a}	**3.94^{c}**	3.01^{ab}	3.03^{ab}	2.75^{a}	2.55^{a}
		2012	2.55^{a}	3.15^{ab}	**3.78^{bc}**	2.76^{a}	3.12^{ab}	2.61^{a}	**4.33^{c}**	2.88^{a}	2.66^{a}	2.32^{a}	2.55^{a}
		2013	2.45^{ab}	2.55^{ab}	3.22^{bc}	2.56^{ab}	2.51^{ab}	2.43^{a}	**3.53^{c}**	2.53^{ab}	2.66^{ab}	2.43^{a}	2.26^{a}
		2014	3.28^{a}	3.99^{ab}	**4.27^{bc}**	3.91^{ab}	4.11^{ab}	3.65^{ab}	**5.11^{c}**	3.85^{ab}	3.36^{ab}	3.41^{ab}	3.26^{a}
Te Kooti	CEC (cmol(+)/kg)	2008	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}	2.56^{a}
		2009	2.73^{a}	2.94^{a}	**4.51^{b}**	2.86^{a}	3.26^{a}	2.68^{a}	3.55^{a}	3.28^{a}	2.75^{a}	2.62^{a}	2.90^{a}
		2010	2.66^{ab}	2.64^{ab}	3.35^{b}	2.82^{ab}	3.12^{ab}	2.64^{ab}	3.15^{b}	3.25^{b}	2.71^{ab}	2.32^{a}	2.66^{ab}
		2011	2.73^{ab}	2.67^{ab}	**3.51^{d}**	2.76^{ab}	3.02^{bcd}	2.74^{ab}	**3.42^{cd}**	3.15^{bcd}	2.88^{abc}	2.39^{a}	2.66^{ab}
		2012	2.60^{a}	2.70^{ab}	**3.68^{c}**	2.99^{abc}	3.02^{abc}	2.61^{a}	**3.52^{bc}**	3.12^{abc}	2.85^{abc}	2.49^{a}	2.63^{a}
		2013	2.50^{ab}	2.57^{abc}	**3.45^{d}**	2.72^{abc}	2.99^{bcd}	2.58^{abc}	**3.32^{d}**	**3.05^{cd}**	2.65^{abc}	2.29^{a}	2.66^{abc}

(d) Available P

Site	Soil Parameter	Year	Treatment										
			Control	Single Super	Agri-ash	SEP Pig Manure	BioAg Blend	EFF/ Dical 64	YLAD Compost Mineral Blend	Groundswell Compost	Triomin/ Eco-min Balance	YLAD Compost Tea	Urea
Glenroy	P (mg kg^{-1})	2008	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}	7.47^{a}
		2009	9.68^{a}	11.04^{a}	10.49^{a}	**22.80^{b}**	10.35^{a}	10.50^{a}	9.77^{a}	10.79^{a}	12.17^{a}	10.07^{a}	9.84^{a}
		2010	8.80^{ab}	11.24^{bc}	**13.97^{c}**	**21.74^{d}**	9.06^{ab}	8.56^{ab}	9.04^{ab}	9.73^{ab}	9.25^{ab}	8.03^{a}	7.64^{a}
		2011	7.98^{a}	**12.00^{bcd}**	**13.31^{cd}**	**16.10^{d}**	8.18^{a}	10.62^{abc}	8.07^{a}	8.16^{a}	9.13^{ab}	7.85^{a}	7.58^{a}
		2012	9.88^{ab}	**14.39^{c}**	**15.03^{c}**	**30.27^{d}**	9.89^{ab}	12.35^{bc}	9.59^{ab}	9.75^{ab}	9.46^{ab}	8.75^{a}	8.45^{a}
		2013	8.52^{ab}	**14.15^{d}**	**13.70^{cd}**	**25.85^{e}**	8.49^{ab}	10.33^{bc}	9.37^{ab}	9.41^{ab}	8.56^{ab}	8.14^{ab}	7.77^{a}
		2014	6.53^{a}	**14.45^{b}**	**13.02^{b}**	**22.52^{c}**	6.95^{a}	**11.78^{b}**	6.74^{a}	6.87^{a}	6.31^{a}	6.26^{a}	5.82^{a}
Kia-Ora	P (mg kg^{-1})	2008	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}	6.93^{a}
		2009	7.77^{ab}	8.81^{ab}	12.01^{bc}	**19.26^{c}**	8.11^{ab}	7.98^{ab}	8.28^{ab}	5.18^{a}	7.48^{ab}	7.77^{ab}	7.84^{ab}
		2010	7.37^{a}	8.19^{a}	**14.05^{b}**	**13.83^{b}**	7.82^{a}	6.84^{a}	7.37^{a}	7.05^{a}	7.04^{a}	7.02^{a}	7.70^{a}
		2011	7.07^{a}	8.18^{ab}	**18.17^{c}**	**12.30^{bc}**	10.42^{ab}	8.88^{ab}	7.83^{ab}	7.73^{ab}	9.15^{ab}	6.75^{a}	6.87^{a}
		2012	9.59^{abc}	12.64	**27.73^{d}**	**25.33^{d}**	11.05^{abc}	11.98^{bc}	10.40^{abc}	9.67^{abc}	9.56^{ab}	8.78^{a}	9.63^{abc}
		2013	7.69^{a}	10.23^{a}	**18.61^{b}**	**21.79^{b}**	9.19^{a}	10.04^{a}	9.05^{a}	8.88^{a}	7.86^{a}	7.61^{a}	7.78^{a}
		2014	5.47^{a}	**8.57^{bc}**	**15.93^{d}**	**15.22^{d}**	**7.90^{bc}**	**9.93^{c}**	6.51^{ab}	6.53^{ab}	5.80^{a}	5.12^{a}	5.37^{a}
Te Kooti	P (mg kg^{-1})	2008	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}	8.71^{a}
		2009	9.43^{a}	14.15^{ab}	**14.83^{bc}**	**21.85^{c}**	10.10^{ab}	10.40^{ab}	10.90^{ab}	10.50^{ab}	9.89^{ab}	11.79^{ab}	10.56^{ab}
		2010	10.77^{ab}	13.37^{bc}	**14.37^{cd}**	**18.00^{d}**	11.15^{abc}	10.41^{ab}	9.95^{a}	11.01^{abc}	10.99^{abc}	10.55^{ab}	10.31^{ab}
		2011	9.90^{ab}	12.61^{b}	**17.15^{c}**	**17.05^{c}**	10.36^{ab}	10.80^{ab}	10.46^{ab}	10.82^{ab}	10.32^{ab}	9.40^{a}	8.78^{a}
		2012	10.62^{a}	**15.38^{bc}**	**19.89^{c}**	**33.20^{d}**	11.82^{ab}	14.37^{abc}	11.64^{ab}	11.61^{ab}	12.13^{ab}	11.87^{ab}	10.33^{a}
		2013	15.23^{ab}	20.44^{bc}	**29.04^{cd}**	**30.35^{d}**	15.41^{ab}	19.14^{ab}	15.13^{ab}	16.71^{ab}	15.38^{ab}	13.83^{a}	14.76^{ab}

(e) Extractable S

Site	Soil Parameter	Year	Treatment										
			Control	**Single Super**	**Agri-ash**	**SEP Pig Manure**	**BioAg Blend**	**EFF/ Dical 64**	**YLAD Compost Mineral Blend**	**Groundswell Compost**	**Triomin/ Eco-min Balance**	**YLAD Compost Tea**	**Urea**
Glenroy	S (mg kg^{-1})	2008	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}	3.61^{a}
		2009	3.00^{a}	4.32^{ab}	**5.06^{b}**	3.79^{ab}	2.67^{a}	3.29^{a}	3.50^{ab}	3.48^{ab}	3.24^{a}	2.98^{a}	2.75^{a}
		2010	2.76^{a}	**3.95^{b}**	**5.52^{c}**	3.05^{ab}	3.47^{ab}	2.83^{a}	2.87^{ab}	2.65^{a}	3.51^{ab}	2.58^{a}	2.58^{a}
		2011	3.04^{a}	**5.57^{b}**	4.72^{ab}	3.54^{ab}	3.23^{a}	3.69^{ab}	**5.56^{b}**	2.84^{a}	4.06^{ab}	3.25^{a}	2.91^{a}
		2012	2.03^{a}	**4.78^{b}**	2.29^{a}	2.65^{a}	2.50^{a}	2.19^{a}	**4.40^{b}**	2.21^{a}	2.21^{a}	1.93^{a}	1.72^{a}
		2013	1.86^{a}	**8.02^{b}**	2.19^{a}	2.09^{a}	2.44^{a}	3.06^{a}	3.84^{a}	1.94^{a}	2.11^{a}	2.15^{a}	1.92^{a}
		2014	2.03^{a}	**8.98^{b}**	2.26^{a}	2.22^{a}	3.87^{a}	3.29^{a}	2.97^{a}	2.38^{a}	2.17^{a}	2.65^{a}	1.92^{a}
Kia-Ora	S (mg kg^{-1})	2008	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}	2.90^{a}
		2009	2.56^{a}	**3.61^{b}**	**7.77^{c}**	2.92^{ab}	2.15^{a}	2.26^{a}	2.33^{a}	2.34^{a}	2.41^{a}	2.06^{a}	2.15^{a}
		2010	2.46^{a}	2.84^{a}	2.57^{a}	2.37^{a}	2.62^{a}	2.36^{a}	3.10^{a}	2.38^{a}	2.75^{a}	2.63^{a}	2.72^{a}
		2011	2.10^{a}	3.17^{a}	2.50^{a}	2.15^{a}	2.18^{a}	2.70^{a}	3.43^{a}	2.08^{a}	2.55^{a}	2.19^{a}	2.15^{a}
		2012	1.70^{a}	2.11^{a}	2.17^{a}	1.72^{a}	1.68^{a}	1.43^{a}	2.50^{a}	1.71^{a}	1.78^{a}	1.33^{a}	1.25^{a}
		2013	2.06^{a}	4.67^{a}	2.17^{a}	2.02^{a}	2.05^{a}	2.03^{a}	2.40^{a}	1.98^{a}	1.98^{a}	1.96^{a}	1.98^{a}
		2014	2.00^{a}	**4.01^{b}**	2.04^{a}	2.06^{a}	2.12^{a}	2.20^{a}	3.00^{ab}	2.00^{a}	2.04^{a}	1.87^{a}	2.01^{a}
Te Kooti	S (mg kg^{-1})	2008	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}	4.41^{a}
		2009	3.19^{a}	**6.70^{b}**	**7.32^{b}**	3.57^{a}	3.29^{a}	3.03^{a}	3.81^{a}	3.51^{a}	3.86^{a}	3.40^{a}	3.64^{a}
		2010	4.31^{a}	5.26^{a}	4.06^{a}	4.81^{a}	4.67^{a}	4.76^{a}	4.21^{a}	4.25^{a}	4.98^{a}	3.93^{a}	3.54^{a}
		2011	3.55^{ab}	4.78^{b}	3.49^{ab}	3.13^{a}	3.16^{a}	3.37^{a}	4.11^{ab}	3.65^{ab}	3.39^{ab}	4.00^{ab}	2.77^{a}
		2012	1.99^{a}	2.94^{a}	2.06^{a}	2.33^{a}	2.36^{a}	2.03^{a}	2.94^{a}	2.38^{a}	1.99^{a}	2.63^{a}	2.07^{a}
		2013	3.02^{ab}	5.31^{b}	2.69^{a}	2.80^{a}	3.09^{ab}	3.23^{ab}	2.91^{a}	2.78^{a}	2.83^{a}	2.97^{ab}	2.54^{a}

Supplementary Table S3. Annualised cost of fertilizer supplied from Yass, NSW and spread on farm ($ ha^{-1}) for period 2009-2014 (all costs in Australian dollars and are GST exclusive)

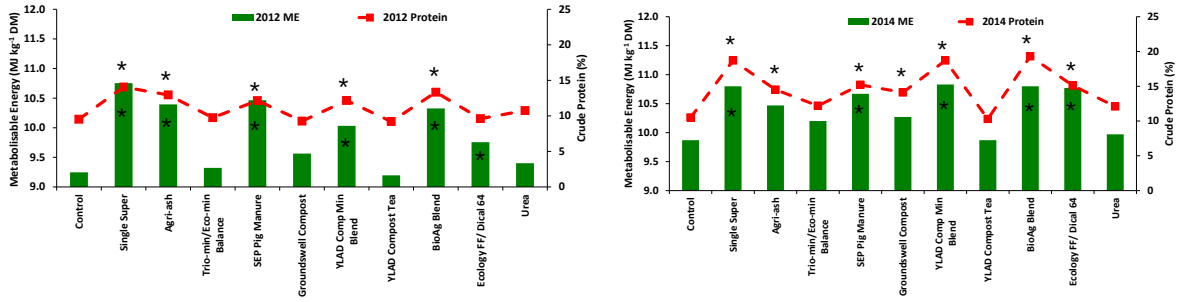
Fertilizer Product	Annualised cost of product; supplied from Yass & spread on farm ($ ha^{-1})							
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**Average annualised cost ($ ha^{-1} yr^{-1})**	**Application frequency**
Single Super	44.33	43.50	51.63	46.50	49.75	47.25	47.16	Annually
Agri-ash	35.33	35.33	35.33	50.42	53.75	59.58	44.95	1 in 6 years
Trio-min/Eco-min Balance	170.50	121.00	128.37	130.68	135.40	136.95	137.15	Annually
SEP Pig Manure	68.05	68.05	68.05	80.00	80.33	80.33	74.14	1 in 3 years
Groundswell Compost	116.00	116.00	116.00	117.50	122.00	130.50	119.67	1 in 2 years
YLAD Compost Mineral Blend								
Glenroy	188.80	194.25	195.21	115.84	115.00	101.66	151.79	Annually
Kia-Ora	188.80	194.25	221.32	147.74	115.00	109.37	162.75	Annually
Te Kooti	188.80	194.25	195.21	133.35	115.00	n/a	165.32	Annually
YLAD Compost Tea	39.30	39.30	39.50	39.50	39.50	39.50	39.43	Annually
BioAg Blend	134.74	49.50	52.85	53.90	55.65	59.55	67.70	1 in 2 years
Ecology Fluid Fertilizer/Dical 64	59.00	59.00	69.84	70.24	77.37	77.37	68.80	Annually
Urea	71.70	20.67	71.00	75.00	74.50	67.00	63.31	Annually

Supplementary Table S4. Rate of product and nutrient applied to the 'All Nutrient plus (+) and minus (-) nitrogen (N)' treatments established in 2013 and 2014 at the Glenroy and Kia-Ora trial sites

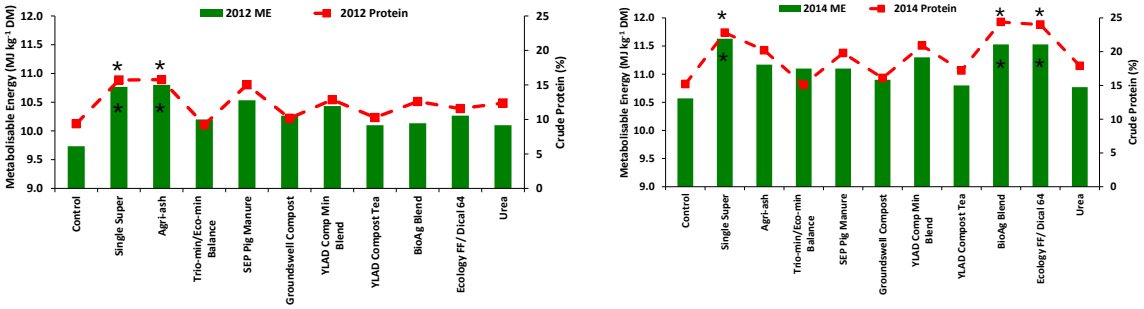
Year	Product Used	Rate of product and nutrient[1] applied at each site (kg ha^{-1})		
		Glenroy		Kia-Ora
		All Nutrient +N	All Nutrient -N	All Nutrient -N
2013	Single super	490 (44 kg ha^{-1} P; 54 kg ha^{-1} S)	490 (44 kg ha^{-1} P; 54 kg ha^{-1} S)	510 (45 kg ha^{-1} P; 56 kg ha^{-1} S)
	Potassium sulphate	Nil	Nil	100 (42 kg ha^{-1} K)
	Lime	2020	2020	2020
	Urea	109 (50 kg ha^{-1} N)	Nil	Nil
	Sodium molybdate	0.107 (0.05 kg ha^{-1} Mo)	0.107 (0.05 kg ha^{-1} Mo)	0.107 (0.05 kg ha^{-1} Mo)
	Boric Acid	1.75 (0.31 kg ha^{-1} B)	1.75 (0.31 kg ha^{-1} B)	1.75 (0.31 kg ha^{-1} B)
	Copper Sulphate	1.75 (0.44 kg ha^{-1} Cu)	1.75 (0.44 kg ha^{-1} Cu)	1.75 (0.44 kg ha^{-1} Cu)
	Zinc sulphate	3.5 (1.23 kg ha^{-1} Zn)	3.5 (1.23 kg ha^{-1} Zn)	3.5 (1.23 kg ha^{-1} Zn)
2014	Single super	800 (71 kg ha^{-1} P; 88 kg ha^{-1} S)	800 (71 kg ha^{-1} P; 88 kg ha^{-1} S)	Nil
	Triple super	Nil	Nil	340 (70 kg ha^{-1} P; 3 kg ha^{-1} S)
	Potassium sulphate	Nil	Nil	120 (50 kg ha^{-1} K)
	Lime	Nil	Nil	1000
	Urea	109 (50 kg ha^{-1} N)	Nil	Nil

[1] Notations for nutrients include P = Phosphorus; S = Sulphur; K = Potassium; N = Nitrogen; Mo = Molybdenum; Cu = Copper; B = Boron; Zn = Zinc.

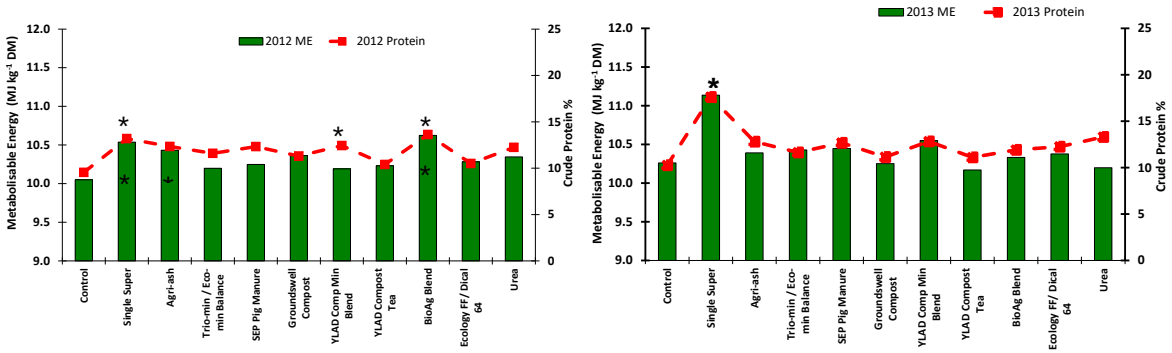
a) Glenroy



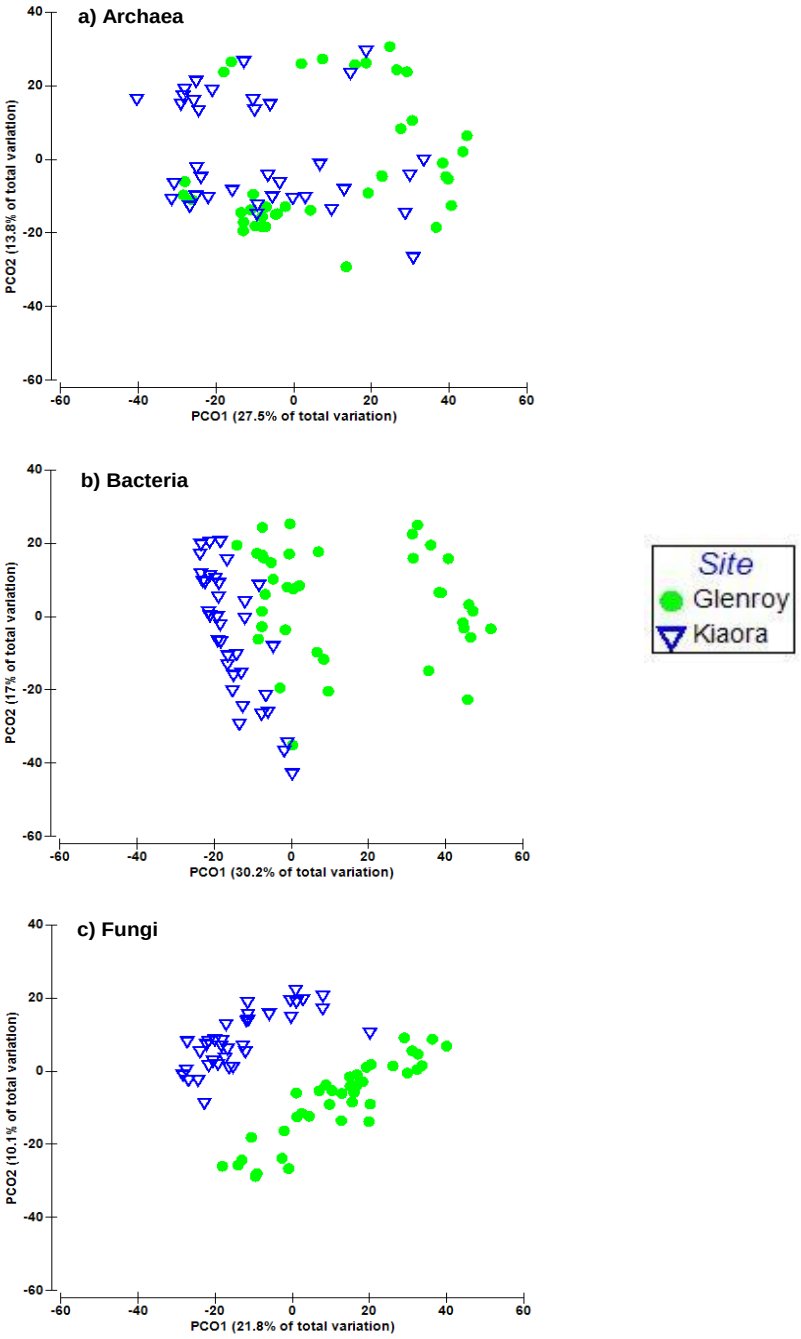
b) Kia Ora



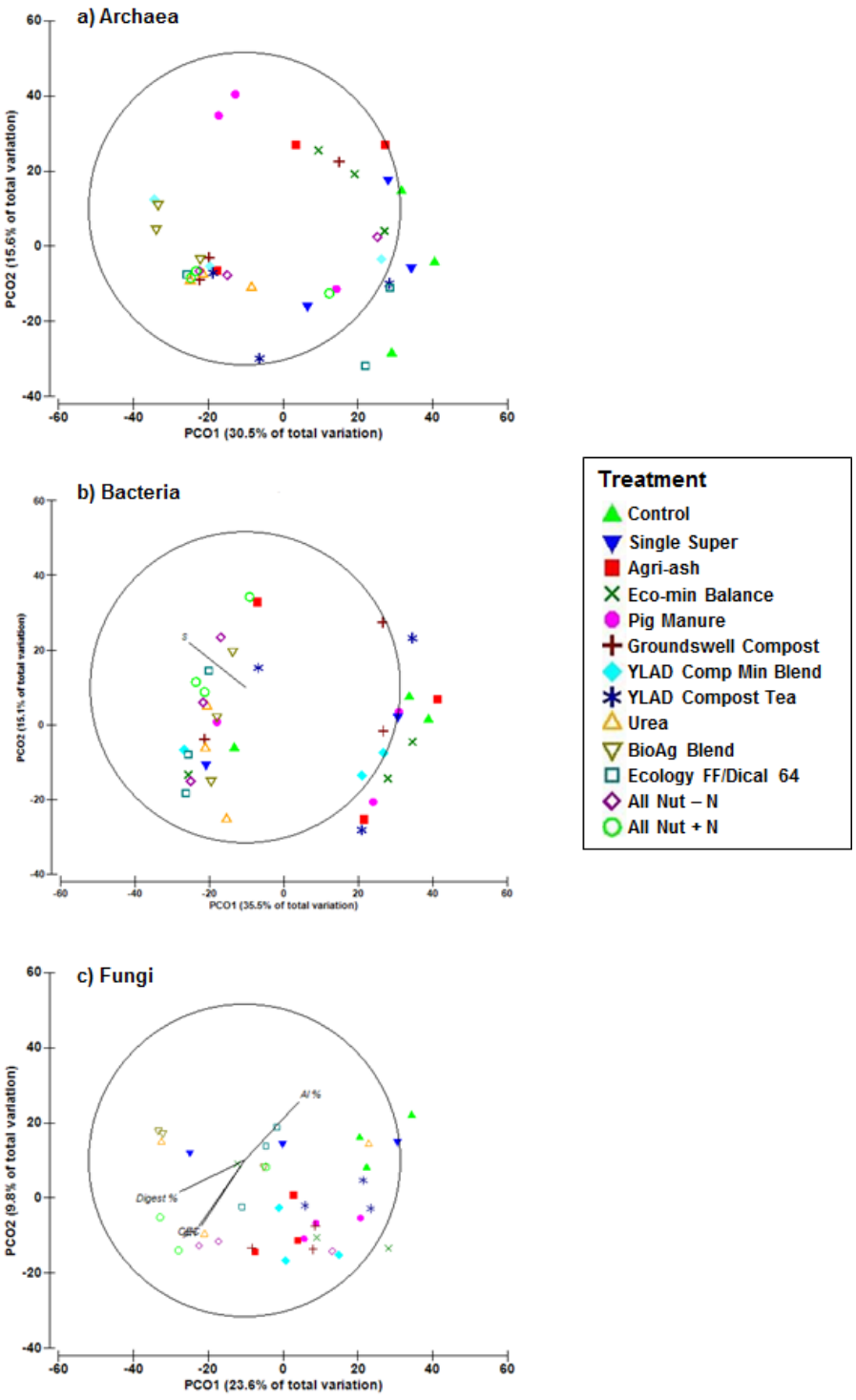
c) Te Kooti



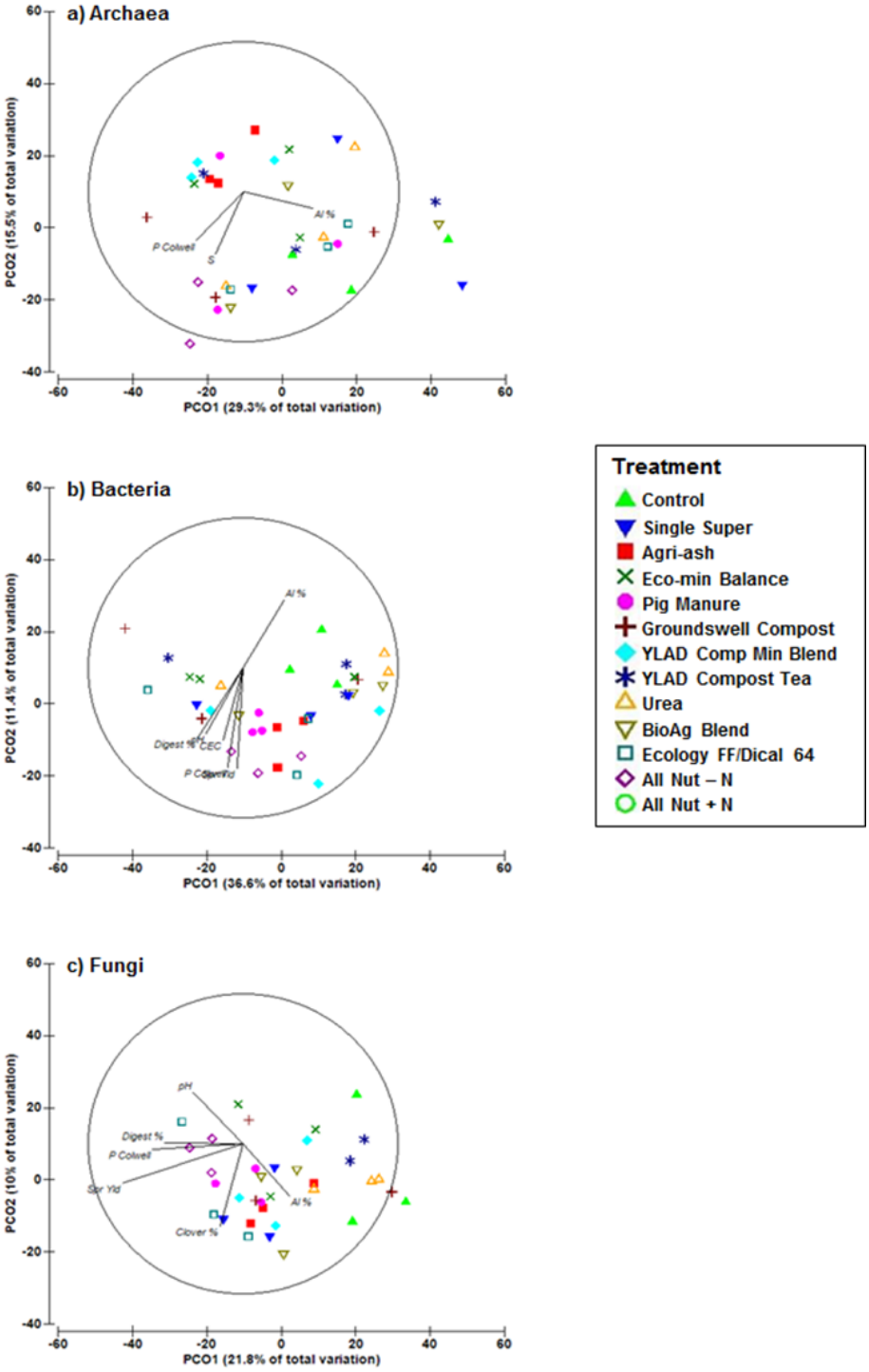
Supplementary Figure S1. Estimates of pasture quality as indicated by metabolizable energy (ME; MJ kg^{-1} DM) and crude protein content (%) in pasture grown under eleven fertilizer treatments including a nil fertilizer control and superphosphate treatment at the a) Glenroy site in 2012 and 2014; b) Kia-Ora site in 2012 and 2014 and c) Te Kooti site in 2012 and 2013. Within each panel (for both ME and CP) data points marked with asterisk (*) indicates a significant difference (P<0.05) compared to the nil fertilized control.



Supplementary Figure S2a: Structure of a) archaeal, b) bacterial and c) fungal communities across treatments for 2 field trial sites Glenroy, Binalong and Kia-Ora, Bookham in NSW. Community structure was assessed on a T-RFLP data set using principal component analysis ordination (PCO) performed on Bray-Curtis similarity resemblance matrix of archaeal 16S rRNA (a), bacterial 16S rRNA (b) and fungal 18S ITS (c). Statistical result for a) Archaea F = 6.99, $P<0.001$; b) Bacteria F= 18.51, $P<0.001$ and c) Fungi F= 14.80, $P<0.001$.



Supplementary Figure S2b: Structure of a) archaeal, b) bacterial and c) fungal communities across the Glenroy field trial site, Binalong NSW for 13 fertilizer treatments. Community structure was assessed on a T-RFLP data set using principal coordinate analysis ordination (PCO) performed on Bray-Curtis similarity resemblance matrix of archaeal 16S rRNA (a), bacterial 16S rRNA (b) and fungal 18S ITS (c). Vectors show Pearson Correlation Coefficients with site and soil factors with R value of 0.430 used (*P*<0.01). Statistical result for a) Archaea F= 1.336, *P*<0.049; b) Bacteria F=1.487, *P*<0.024; c) Fungi F=1.522, *P*<0.001. The ellipse indicates a 95% Confidence Interval.



Supplementary Figure S2c: Structure of a) archaeal, b) bacterial and c) fungal communities across the Kia-Ora field trial site, Bookham NSW for 13 fertilizer treatments. Community structure was assessed on a T-RFLP data set using principal coordinate analysis ordination (PCO) performed on Bray-Curtis similarity resemblance matrix of archaeal 16S rRNA (a), bacterial 16S rRNA (b) and fungal 18S ITS (c). Vectors show Pearson Correlation Coefficients with site and soil factors with R value of 0.430 used (P<0.01). Statistical result for a) Archaea F=1.144, P<0.217; b) Bacteria F=1.125, P<0.264; c) Fungi F=1.547, P<0.002. The ellipse indicates a 95% Confidence Interval.

1. Community structure assessed by T-RFLP: Results

i) Combined sites: Kia-Ora and Glenroy

Principal Coordinate Analyses (PCO) of the T-RFLP dataset for both Kia-Ora and Glenroy sites for each of the kingdoms, archaea, bacteria and fungi was conducted to determine the effects of site and treatment on community structure (Fig S2a). In all cases the spatial variation in community structure was visualized using the first two ordinates that explained a significant percentage of the total cumulative variation present i.e. for archaea two ordinates explained 41.3 % of the total variation; for bacteria two ordinates explained 47.2 % of the total variation and for fungi two ordinates explained 31.9 % of the total variation. Archaea, bacteria and fungi clearly separated according to site. A PERMANOVA analysis was run to explore any statistical differences. An effect of site on archaea, bacteria and fungi was found to be statistically significant at $P<0.001$ level for each kingdom.

ii) Analysis of treatments at the Glenroy trial site

A PCO of the T-RFLP dataset for the Glenroy site (Fig S2b) for each of the kingdoms, archaea, bacteria and fungi was conducted where the first two ordinates were plotted for each kingdom to explain a significant percentage of the total cumulative variation present i.e. for archaea two ordinates explained 46.1 % of the total variation; for bacteria two ordinates explained 50.6 % of the total variation and for fungi two ordinates explained 33.4 % of the total variation. A PERMANOVA analysis was run to explore any statistical differences. There was an effect of treatment found on the spatial community structure of archaea ($P<0.05$), bacteria ($P<0.05$) and fungi ($P<0.001$) at the Glenroy site. However, post hoc PERMANOVA pairwise testing found no significant differences when comparing the control or superphosphate to all other treatments.

The PCO for each kingdom at Glenroy was also statistically analysed to determine any correlation to other measured soil and pasture variables under each treatment. Soil chemical variables include soil pH, aluminum percent (Al %), Phosphorus (P) Colwell (mg kg^{-1}), Sulphur KCl40 (S) (mg kg^{-1}), Cation Exchange Capacity (CEC) (cmol+ kg^{-1}) and total carbon percentage. Pasture variables that have also been measured and used to test for any correlation include winter/spring herbage yield (kg ha-1 dry matter), digestibility percentage (%) and clover percentage (%). A two-tailed probability test ($P<0.01$) is presented to highlight correlations present. For archaea there was no correlation between spatial structure and any soil or pasture variables measured. However, S was shown to be correlated to bacterial structure and pH, Al %, CEC and digestibility % were found to be correlated to the fungal structure at Glenroy.

iii) ***Analysis of treatments at the Kia-Ora trial site***

A PCO of the T-RFLP dataset for the Kia-Ora site (Fig S2c) for each of the kingdoms, archaea, bacteria and fungi was conducted where the first two ordinates were plotted for each kingdom to explain a significant percentage of the total cumulative variation present i.e. for archaea two ordinates explained 44.8 % of the total variation; for bacteria two ordinates explained 48 % of the total variation and for fungi two ordinates explained 31.8% of the total variation. A PERMANOVA analysis of the Kia-Ora dataset found there was no effect of treatment on the spatial structure of archaea or bacteria while there was an effect on the spatial structure of fungi (P<0.01). However, similar to results obtained for the Glenroy site, post hoc PERMANOVA pairwise testing for fungi found no significant differences when comparing the control or superphosphate to all other treatments.

Similar to Glenroy a PCO for each kingdom at Kia-Ora was statistically analysed to determine any correlation to other measured soil and pasture variables under each treatment using a two-tailed probability test (P<0.01). Archaeal community structure was correlated Al %, P Colwell and S while bacterial structure was correlated to pH, Al %, P Colwell, CEC, winter/spring yield and digestibility %. The Fungal structure was correlated with pH, Al %, P Colwell, winter/spring yield, digestibility % and clover %.

2. Community structure assessed by T-RFLP: Methods

i) Treatments

In 2013 two additional treatments were established at the Glenroy site and one additional treatment established at the Kia-Ora site that were replicated three times. The two additional treatments at Glenroy were ‘All Nutrients plus N’ and ‘All Nutrients minus N’ and were set up in spare plots already present in each replicate. At the Kia-Ora site the additional treatment included ‘All Nutrients minus N’ only. These plots were set up adjacent to the main trial plots and were established as a separate agronomic experiment in the fifth year with All Nutrients, with the exception of N, to ensure that plant growth was not being limited by any individual elements, and as such were also available to investigate soil microbial diversity. Note at the Glenroy site, N acted at the variable between the two ‘All Nutrient’ treatments. Soil test results were used to guide the quantities of nutrients applied to these plots (Richard Simpson, CSIRO, personnel communication). In autumn 2014 the ‘All Nutrient’ treatments were again fertilized based on the soil test results to ensure that plant growth would not be limited.

ii) Soil sampling and processing

Soil samples were collected in spring 2014 from all treatment plots at the Glenroy and Kia-Ora trial sites including the additional 'All Nutrient' plots. Fifteen soil cores (2.5 cm diameter and 0-10 cm depth) taken from each 2 m by 10 m plot were combined and stored on ice while in the field. Approximately 1 kg soil collected per sample. Samples were then transported to the laboratory thoroughly mixed and passed through a 5 mm sieve. Each sample was then split 4 ways; one sample (~50 g) stored at -20 °C, one sample (~15 g) stored at -80 °C, 500 g sample sent to an external laboratory for chemical analysis and the remaining soil sample air dried and archived. Moisture content was determined on all samples by gravimetric analysis of soil samples prior to and after oven drying for 24 hours at 105 °C. Percent moisture content was determined on soil wet-dry weight difference by the following calculation: Percent moisture content = 100 – (dry soil weight/wet soil weight) x 100.

iii) DNA extraction

Soil DNA was extracted from approximately 0.25 g of representative soil from each sample which had been stored at -80 °C using MoBio Power Soil DNA Isolation kit following manufacturer's instructions (MoBio Laboratories Inc. www.mobio.com). Briefly, soil samples were suspended and vortexed in Solution C1 for 5 s in PowerBead Tubes. Samples were then completely homogenized using a Qiagen Tissue Lyser II for 2 min. Tubes were then centrifuged for 1 minute and the supernatant transferred to a clean 2 ml collection tube. Solution C2 was added to the supernatant, mixture vortexed for 5 s and incubated at 4 °C for 5 min. In this step non-DNA organic and inorganic material is precipitated from the sample. Tubes were then centrifuged and the supernatant removed and placed in a clean 2 ml collection tube. The process was repeated with Solution C3 to remove additional non-DNA organic and inorganic material. Tubes were then centrifuged and the supernatant transferred to a clean 2 ml collection tube for DNA collection using Solution C4, which provides a high concentration salt solution to allow binding of DNA to a Spin Filter within the extraction tube. Solution C5 was then added to further clean the DNA bound to the membrane. The Spin Filter was then placed in a clean 2 ml collection tube to elute DNA form the filter using Solution C6. The collection tube was then centrifuged for 1 min to release DNA from the filter. The DNA in each sample tube was then of uniform concentration and sufficient purity for further application.

iv) PCR Amplification

Polymerase Chain Reaction (PCR) amplifications of the 16S rRNA gene in archaea, 16S rRNA gene in bacteria and 18S ITS (Internal Transcribe Spacer) gene in fungi were performed using published primers. Forward and reverse primer sequences used for PCR amplification of archaea and bacteria 16S rRNA genes and the fungi 18S ITS region (for the bacterial primers, M, W and K refers to nucleotide redundancy provided by A/C, A/T or G/T, respectively.

Kingdom	Primer Name	Primer sequences	Size (bp)
Archaea	AR3F AR927R	5' TTCCGGTTGATCCTGCCGGA 5' CCCGCCAATTCCTTTAAGTTTC	~ 924
Bacteria	27F 519R	5' AGAGTTTGATCMTGGCTCAG 5' GWATTACCGCGGCKGCTG	~492
Fungi	ITS1F ITS4	5' CTTGGTCATTTAGAGGAAGTAA 5' TCCTCCGCTTATTGATATGC	~ 500

PCR was conducted using either an Applied Biosystems GeneAmp PCR System 9700 Thermal Cycler or a BioRad S1000 Thermal Cycler. PCR cycle conditions were set at single cycle of 94 °C for 2 min, followed by multiple cycles at 94 °C for 30 s, 53 °C for 30 s, 72 °C for 30 s, with final single cycle of 72 °C for 10 mins. The number of cycles varied across microbial kingdoms with archaea being run for 35 cycles and bacteria and fungi each run for 30 cycles. Each PCR reaction (50ul) contained 1 µl of undiluted DNA template (from above), 10 µl of 5x MyTaq™ Buffer (BIOLINE www.bioline.com), 1 µl of each primer (from10 µM solution), 1.25 units of MyTaq™ DNA Polymerase and H_2O added to the final volume of 50 µl. For archaea and fungi, the reaction also contained 1 µl 100x BSA. PCR products were analysed by Agarose gel electrophoresis (2% gels) and visualized by SYBR® Safe DNA Gel Stain (Invitrogen) to confirm the presence of correctly sized PCR products for each gene. These assessments indicated that bacteria and fungi PCR products were satisfactorily amplified, whereas amplification of the archaea was relatively weak. PCR products for archaea, bacteria and fungi were purified using Agencourt® AMPure® XP (Beckman Coulter, Lane Cove, New South Wales, Australia) following the manufacturer's instructions. Subsequently, the original archaea PCR products were re-amplified using the purified archaea PCR product as a template, whereby 1 µl of a 1 in 100 dilution was used as a template. Purified PCR products were quantified using either NanoDrop UV-Vis Spectrophotometer (Thermo Scientific, Scoresby, Victoria, Australia) or the PicoGreen Assay kit (Quant-iT™ PicoGreen® dsDNA Assay Kit, Life Technologies Scoresby, Victoria, Australia), with the latter being considered to be more reliable. DNA concentration was determined using 5 µl of PCR product, 95 µl of 1 x TE buffer and 100 µl of the kit supplied Picogreen solution. Samples were assayed in black 96-well plates suitable for fluorescence spectrophotometry, by comparison with known standard DNA concentrations using a plate reader (Wallac Victor 1420 multilabel counter, Perkin Elmer, Waltham, MA, USA) to quantify the amount of DNA present.

iv) T-RFLP Analyses

Terminal restriction fragment length polymorphism (T-RFLP) was performed on all samples to differentiate microbial community composition and diversity in soils across the different fertilizer treatments at both sites. 25 ng of PCR product for each sample were digested using *Hin*F1 restriction enzyme. For 30 µl digestion reaction, 3 µl of 10 x NEBuffer4 (Bio Labs) and 1 unit HinF1 restriction enzyme were used. Each reaction was made up to 30 µl using sterile H_2O. All samples were then

incubated for 3 hours at 37 ˚C. To clean the digestion reaction, the product was precipitated with 100 µl of 75% isopropanol at 4 ˚C for 30 min. DNA restriction fragments were recovered by centrifugation at 5700 rpm (Allegra™ 25R Centrifuge, Beckman Coulter) for 30 min. The supernatant was carefully removed and samples allowed to dry for 10 min at 65 ˚C. Restriction fragments were then suspended in 9.7 µl of Hidi Formamide (GeneScan 600™) and 0.3 µl Liz 600 (GeneScan 600™) was added to each sample before being analysed by ABI 3130xl Fragment Analyzer, Capillary Electrophoresis (Applied Biosystems), according to manufactures protocol. GeneMapper® Software 5 (Applied Biosystems, 2012) was initially used to collect and filter the T-RFLP data for archaea, bacteria 16S rRNA gene and 18S ITS fungi gene data sets. A custom R script (R Development Core Team, 2014) was subsequently used to remove spurious baseline peaks. In all cases T-RFLP profiles were processed by removing peaks smaller than 50 bp and larger than 500 bp and according to a minimum relative peak fluorescence intensity of 0.09, a window size of 1.5 base pairs and a shift size of less than 0.15 base pairs. Fragment lengths were assigned according to the Interactive Binner R script using a sliding window approach (Ramette 2009). TREX Software© 2008 (http://trex.biohpc.org/) was then used to process the raw data to generate operational taxonomy units (OTUs) for archaea, bacteria and fungi. Archaeal data samples (Terminal Restriction Fragments; TRFs) were processed to remove samples with a bin size <1, total peak height <111 and total peak area <1178. Bacterial TRFs were similarly processed with < 1 bin size, total peak height <17 and total peak area <69, and fungal data samples with <1 bin size, total peak height <148 and total peak area <560. Resultant data tables were then analysed statistically.

v) Statistical Analysis

Operational taxonomy units (OTU) data tables for archaea, bacteria and fungi for T-RFLP data were analysed using PRIMER (Version 6.1.15) and PERMANOVA+ (Version 1.0.5) software from PRIMER-E (Plymouth, UK). A square-root transformation was first conducted on the T-RFLP raw data as it best explained the variation present when viewing the data using two Principal Coordinates (PCO). PCO plots were used to assess the spatial structure of archaea, bacteria and fungi communities across sites and according to fertilizer treatments. Differences were assessed using PERMANOVA statistical analyses (Main test and a Pair-wise Treatment test) on the transformed data using Bray Curtis resemblance matrices with 999 permutations to assess fertilizer treatment effects and site by treatment effect (site by treatment effect only performed on T-RFLP data) on the archaeal, bacterial and fungal communities.