Cropping intensity and crop choice influence long-term mineral N cycling and balance within north-eastern farming systems

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Abstract
Modifying farming systems in the northern grain region (NGR) can change soil nitrogen (N) mineralisation and its availability to crops. Variation of cropping intensity, based on soil moisture planting triggers at seven locations in the NGR impacted plant N uptake, exported grain N and soil mineral N dynamics pre- and post-crop. Increasing the cropping intensity resulted in 88% more fertiliser N application compared with the *Baseline* system and 144% more than the *Lower intensity* system. This was due to lower N mineralisation during shorter fallow periods of the *Higher intensity* system (81 kg N/ha) compared to the *Baseline* system (173 kg N/ha). The research showed that, if grain cropping opportunities are increased by decreasing planting soil water triggers, a greater emphasis on N budgeting and N supply is needed to ensure that all crops receive adequate N and NGR farming systems perform well.

Keywords
Farming systems, soil, cropping intensity, nitrogen,

Introduction

Soil fertility and nutrient budgeting is crucial for Australia's producers to improve the performance of their grain crops. While advances in agronomy and improved performance of individual crops have helped grain growers to maintain their profitability, current farming systems are underperforming; only 30% of the crop sequences in the northern grains region achieve 75% of their water limited yield potential (Hochman et al. 2014). Growers are facing challenges from declining soil fertility, increasing herbicide resistance, and increasing soil-borne pathogens in their farming systems. Changes will be needed to meet these challenges and to maintain the productivity and profitability of these farming systems. Consequently, Queensland Department of Agriculture and Fisheries (DAF), New South Wales Department of Primary Industries (NSW DPI) and CSIRO are collaborating to conduct an extensive field-based farming systems research program, focused on examining how key farming system decisions can influence the productivity, profitability and efficiency of resource use. One of the central aspects of this research is to examine how farming systems compared in terms of their requirements for nutrient inputs and their long-term impacts on soil N status and cycling.

Methods

Research site locations

In 2014 the Northern Farming Systems Initiative implemented long-term farming systems research trials at seven sites throughout Queensland and northern New South Wales: Pampas, Emerald, Billa Billa, Mungindi *(Queensland)*, Spring Ridge, Narrabri and Trangie (red & grey soils) *(NSW)*. Research sites were selected to represent a range of climatic conditions, soil types, nutritional status and paddock history. Each site was comprehensively soil tested at the beginning of the project (Table 1).

Table 1. Site soil description and N availability at the initiation of experiments in 2015.

Site	Mineral N (kg/ha)	% Clay		Organic Carbon (%)		pH ($CaCl_2$)	
	0 – 90 cm	*0–10 cm*	*10–30 cm*	*0–10 cm*	*10–30 cm*	*0–10 cm*	*10–30 cm*
Billa Billa	366	34	44	1.20	0.70	6.4	7.6
Pampas	200	57	59	1.25	1.11	6.5	7.2
Spring Ridge	199	58	60	1.09	0.66	6.2	7.4
Emerald	99	56	58	0.76	0.50	6.8	7.2
Narrabri	145	50	53	0.83	0.55	7.5	8.1
Mungindi	61	57	57	0.69	0.47	7.6	7.8
Trangie (grey)	106	49	50	1.48	0.70	7.6	7.7
Trangie (red)	19	19	28	1.02	0.43	5.3	6.0

Farming system descriptions

This paper compares the following farming systems across all experimental sites:

1. *Baseline* (grower's practice) - zero tillage farming system with crops sown when moderate plant available water is reached, i.e. 60% of plant available water-holding capacity (PAWC) – this equates to approximately one crop per year over the long-term. These crops have nitrogen fertiliser applied to achieve 50th yield percentile as determined by the PAW prior to planting and based on APSIM yield simulations for each site.
2. *Lower crop intensity* – a conservative rotation where fallows are maintained until greater than 80% of PAWC has accumulated before crops are sown. Selected crops are high in grain value to take advantage of high soil moisture. The same nutrient management as the *Baseline* system is applied.
3. *Higher crop intensity* - aims to minimise the fallow periods within the system by sowing on a lower PAW trigger (30% full profile). Over the long-term this system will produce three crops every two years.

Sampling methodology

For six years, soil mineral nitrogen (nitrate and ammonium), both pre-sowing and post-harvest was measured for each crop planted. Soil sampling occurred at six depth layers (0–10 cm, 10–30 cm, 30–60 cm, 60–90 cm, 90–120 cm, 120–150 cm). Mineral N per hectare (ha) was calculated with the following equation – Σ (nitrate + ammonia above 3 ppm x bulk density (BD) × layer depth) to 90cm depth. Harvested grain was milled and analysed for N concentration and multiplied by harvest grain dry weight to calculate exported N (kg/ha) from the system. Mineralisation N was calculated as the change of mineral N between sampling dates or planted crops (as stated).

N application strategy

The application rate of N fertiliser was determined following the crop requirement of the APSIM estimated grain yield minus the measured mineral N prior to sowing.

Results

Cropping intensity requires modifying N fertiliser budgets

Increasing cropping intensity led to a decrease in mineral N accumulation across five of the six regional sites. The adoption of sowing with lower soil water planting triggers came at a cost to the mineralisation of soil organic N from within the Higher intensity system.

After six-years, the average cropping N requirements of the *Lower intensity* system across all trial sites were 60% lower than that required for the *Higher intensity* system – 56 kg N/ha compared to 139 kg N/ha (Table 2). The Narrabri site (145 kg N/ha of plant available N in April 2015) where two crops were sown in the *Lower intensity* system and five in the *Higher intensity* system, had the highest difference between the two systems (197 kg N/ha) in terms of applied N fertiliser. In contrast, Billa Billa which started with 366 kg N/ha of mineral N in 2015, did not require additional fertiliser N for the *higher intensity* system.

The application of more fertiliser N at Pampas and Narrabri within the *Higher intensity* systems increased the system N use over the *Lower intensity* system – ranging from 171 kg N/ha (Pampas) to 182 kg N/ha (Narrabri). N use was not markedly different in Billa Billa and Spring Ridge did not increase N use in the *Higher intensity* system, mainly due to a number of poor performing crops and a major loss of mineral N during 2019 from localised flooding.

Along with the greater system N use of the *Higher intensity* systems, data showed N accumulated during fallow periods averaged 81 kg N/ha between 2015 and 2020, resulting in an overall system deficit of 119 kg N/ha since 2015. In contrast, the *Lower intensity* systems which had 471 more days in fallow compared to the *Higher intensity*, mineralised 169 kg N/ha during fallows over the same 6-year period, providing an additional 88kg N/ha.

Table 2. Effect of crop intensity on system N dynamics over six years at Pampas, Billa Bill (Qld), Narrabri and Spring ridge (NSW): N fertiliser input, system N export, fallow mineralisation (change of mineral N between planted crops), system N use (applied N and change in mineral N) and system N balance (the difference between grain N exported and N inputs)

Site *System*	**N fertiliser applied** *kg N/ha*	**System N export** *kg N/ha*	**Fallow mineralisation N** *kg N/ha*	**System N use** *kg N/ha*	**System N balance** *kg N/ha*
PAMPAS					
Baseline	56	336	245	353	-280
Higher intensity	135	382	170	439	-247
Lower intensity	59	199	228	268	-140
BILLA BILLA					
Baseline	12	285	310	443	-273
Higher intensity	13	219	225	324	-206
Lower intensity	8	207	250	343	-199
NARRABRI					
Baseline	128	190	137	231	-62
Higher intensity	271	219	51	266	52
Lower intensity	74	89	231	84	-15
SPRING RIDGE					
Baseline	138	277	-143	96	-139
Higher intensity	138	216	-122	33	-78
Lower intensity	80	159	-33	82	-79

Crop influence on mineral N in the subsequent fallow

There were also large differences in soil mineral N levels and subsequent mineralisation during fallow depending on crops grown. The greatest mineral N increase in subsequent fallows occurred after canola. This aligned well with high biomass (10 t dm/ha) and high N use (change of mineral N during the crop and applied N fertiliser; 171 kg N/ha) by canola crops (Table 3). We observed that, across all sites and crops successful and/or higher yielding crops which had higher N use and accumulated greater biomass generally have a legacy of higher N accumulation due to mineralisation during subsequent fallow periods.

The fallow periods following legumes increased mineral N on average by 15 kg N/ha more than what was observed for wheat. Interestingly, fababean with a fallow mineralisation of 65 kg N/ha had the lowest increase in fallow mineral N compared to the other legumes grown (chickpea-83 kg N/ha, fieldpea-81 kg N/ha and mungbean-77 kg N/ha). This can be explained by the higher amount of N exported in the fababean crop compared to the other legume crops (95 to 156 kg N/ha more) (Table 3).

Table 3. Effect of crops on soil mineral N extraction, N export and subsequent fallow mineral N accumulation across farming systems sites (2015–2020)

Crop	*n*	Crop biomass (t dm/ha)	Change in mineral N over crop (kg N/ha)	Applied N fertiliser (kg/ha)	Crop N export (kg N/ha)	Fallow min N Δ (kg N/ha)	*s.e.*
barley	12	5.6	10	34	48	32	*2.0*
canola	9	10.1	-104	66	88	109	*6.8*
chickpea	40	5.3	-51	4	65	83	*5.2*
cotton	10	5.6	-30	26	34	61	*3.8*
durum	5	8.7	-50	30	93	59	*3.6*
fababean	7	11.2	-159	7	188	65	*4.0*
fieldpea	7	5.3	-46	6	79	81	*5.0*
maize	5	8.1	-6	68	68	-5	*0.3*
mungbean	15	3.0	-29	4	32	77	*4.8*
sorghum	43	8.8	-51	26	61	65	*4.0*
sunflower	4	4.8	-23	1	32	36	*2.2*
wheat	79	8.8	-64	29	68	62	*3.8*

Conclusion

Modifications to cropping systems outlined in this study influenced the N cycling and use of individual crops and the long-term system use. Cropping intensity (percentage of time crops was in the ground) had the highest impact on fertiliser N use, as N cycling during fallow periods were limited in shorter fallow periods. Whereas longer fallows had higher mineralisation, resulting in less fertiliser N input. A negative of this trend is that the lower intensity systems utilised higher N from background soil N sources. This trend reduced fertiliser N application but may result in a long term drop of organic sources which would decrease the potential of mineralisation in future years. Monitoring of all sites will continue to answer this hypothesis.

The choice of crop choice affected N mineralisation during the following fallow period, with some crops (like canola, chickpea and fieldpea) providing increased mineral N to subsequent crops. This was a result of high crop N use correlating with soil mineralisation activity during the following fallow period.

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