Comparing within paddock yield variability of perennial ryegrass monocultures and perennial ryegrass, white clover and plantain mixtures using yield mapping

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Abstract
Diverse mixtures of pasture species have greater potential for exploiting niches within a paddock compared to monocultures resulting in less variability in pasture growth within the paddock. It is unknown if the variability occurs at a scale that is relevant in intensively managed dairy systems. This study assessed the variability in pasture biomass within 6 split paddocks sown to either perennial ryegrass monocultures (PRG) or perennial ryegrass, white clover and plantain mixtures (RCPM) on a dairy farm in north-west Tasmania. The biomass present in each area was mapped immediately prior to grazing in the spring of 2014 and autumn 2015 using a C-Dax pasture meter with a GPS console. Data was interpreted through the Manifold GIS software before being analysed in the R statistical package. There were no significant difference in pasture biomass between the PRG and RCPM treatments, with mean pasture biomass of 2997 and 3162 kg DM/ha respectively. The variation in pasture biomass within each area (as assessed by the co-efficient of variation) was greater in the PRG areas (16.6%) than in the RCPM areas (13.4%). The overall difference between the within plot standard deviation and coefficient of variation for the treatments was small at 65 kg DM/ha and 3.2% respectively. Diverse pastures have increased opportunities to exploit niches existing within dairy paddocks relating to soil diversity. This and other studies suggest that exploitation of niches only has a small impact upon within paddock yield variability.

Key words
Pasture mixtures, yield mapping, niche exploitation

Introduction
Diverse pasture mixtures containing grasses, legumes and forbs have been shown to out yield grass-legume binary pasture mixtures and grass monocultures by between 9 and 15% on dairy farms, in the temperate regions of New Zealand and Australia (Nobilly *et al*. 2013, Tharmaraj *et al*. 2008, 2014). If the yield advantage of diverse pasture mixtures are to be fully and consistently exploited we must understand the mechanisms promoting increased yield. It has been proposed that the exploitation of niches within the pasture is the primary driver of the increased yields (Pembleton *et al*. 2015). This means diverse pasture mixtures should have less within paddock variation for yield than less species diverse pastures.

Yield mapping allows for the effective and simple assessment of variability in yield within a field (Stafford et al. 1996). It has been used extensively to evaluate the within field variability in many crop production systems from cereal crops (Stafford *et al*. 1996) to orchards (Schueller *et al*. 1999). However, until recently these techniques have not been applied to intensively managed dairy pastures. The development of non-destructive, GPS enabled, rapid pasture biomass assessment tools (e.g. the C-Dax pasture meter) has made yield mapping of dairy pastures feasible (Dalley *et al*. 2014).

This study aimed to use yield mapping to evaluate variability in yield within diverse pastures comprised of perennial ryegrass (*Lolium perenne* L.), white clover (*Trifolium repens* L.) and plantain (*Plantago lanceolata* L.) when compared to perennial ryegrass monocultures on a dairy farm in North West Tasmania. It was hypothesised that the diverse pasture mixture would have lower within paddock variability than the monoculture pasture.

Methods
This study was undertaken within the six fields comprising part of the area grazed by the milking herd at the Tasmanian dairy research facility (TDRF) at Elliott (41.08◦S, 145.77◦E) in northwest Tasmania. This location has a winter dominant rainfall pattern and an annual rainfall of 1200mm. Long term average maximum and minimum temperatures for January are 19.4 and 10.3°C respectively while for July they are 10.4 and 4.3◦C respectively.

During April 2012, large plots (ranging between 0.40 and 0.72 ha in size) were sown in to fully prepared seedbeds with either 25 kg/ha of perennial ryegrass cv. Base (from here on referred to as PRG) or a mixture of 20kg/ha of perennial ryegrass cv. Base, 2kg/ha of white clover cv. Kopu 2 and 1kg/ha of plantain cv. Tonic (from here on referred to as RCPM). The plots were first grazed during late August to early September 2012. Following this initial grazing event, the plots were managed as part of the rotational grazing program utilised at TDRF (grazed between the 2nd and 3rd ryegrass leaf stage to a residual biomass of 1400kg DM/ha). Plots received an annual application of phosphorus, potassium and sulphur fertilizer (to replace nutrient removal) and 3 applications of nitrogen fertiliser per annum (40kg N/ha/application).

A GPS map of each treatment plot was obtained using a Trimble® CFX 750 ™ GPS control unit mounted to a vehicle. RangePoint™ RTX™ correction was used to improve the accuracy of the GPS locations. Waypoints were obtained around the perimeter of the treatments in each of the paddocks using a two metre offset from the GPS antenna. These waypoints were downloaded from the Trimble® CFX 750 ™ console into the Manifold GIS software package (Manifold Software Limited, Wanchai, Hong Kong) to create the maps for each treatment plot and georeferenced using the Universal Transverse Mercator (UTM) coordinate system.

During September 2014 and during March 2015, in the week prior to the planned grazing event, the pasture yield of each treatment plot was mapped using a C-Dax pasture meter integrated with a GPS console (C-Dax Ltd, Palmerston North, New Zealand). Each plot was mapped using 2 m intervals. Between 240 and 725 measurements were taken per plot. Data from the C-Dax pasture reader was downloaded into FarmKeeper software to produce an individual shape file (SHP) containing pasture yield data associated with corresponding GPS co-ordinates (point data) for each paddock. The mapping data was interpreted using Manifold GIS software before being analysed by the R statistical software package (R Core Team 2014). The mean biomass for each plot, along with the within plot standard deviation and coefficient of variation, was then subjected to an ANOVA as a randomised complete block design, using paddock as the blocks. To visually assess the variance in biomass between treatments the data was mapped using the 'fields' and 'RgoogleMaps' packages for R (Nychka et al. 2014, Loecher and Ropkins 2015).

Results

The total biomass of the PRG and RCPM treatment plots was similar in both the spring and autumn periods (Table 1). The biomass of the pastures ranged between 1659 and 3392 kg DM/ha and averaged 3080 kg DM/ha during spring (September –December) and 2305 kg DM/ha during autumn (March-May). The within plot variability, as assessed by the standard deviation and coefficient of variation in biomass, was greater in the PRG (monoculture) compared to the RCPM (diverse species) during spring. The overall difference between the within plot standard deviation and coefficient of variation for the treatments was small at 65 kg DM/ha and 3.2% respectively. In the autumn period there were no differences between the within plot standard deviation or coefficient of variation. A visual inspection of the yield maps (Figure 1) confirmed less variation in pasture biomass for the RCPM during the spring assessment and increased variation for the autumn assessment.

Table 1. The biomass as measured through yield mapping with a C-Dax pasture meter along with the standard deviation and coefficient of variation in biomass for each paddock in the study immediately prior to grazing in spring 2014 and Autumn 2015.

Paddock ID	Average biomass (kgDM/ha)		Standard deviation (kgDM/ha)		Coefficient of variation (%)	
	PRG	RCPM	PRG	RCPM	PRG	RCPM
			Spring 2014			
11	3043	3175	474	441	15.6	13.9
18	2879	3139	570	460	19.8	14.7
54	2500	3081	587	478	23.5	15.5
56	2788	2842	482	483	17.3	17.0
13	3380	3343	391	327	11.6	9.8
16	3392	3390	398	324	11.7	9.6
Mean	2997	3162	484	419	16.6	13.4
P value	NS	P<0.05	P<0.05			
			Autumn 2015			
11	2246	2176	280	615	12.4	28.3
18	2001	2086	459	438	22.9	21.0
54	1698	1659	241	264	14.2	15.9
56	1734	1687	225	186	13.0	11.0
13	3092	3139	494	529	16.0	16.9
16	3123	3009	586	476	18.8	15.8
Mean	2316	2293	381	418	16.2	18.1
P value	NS	NS	NS			

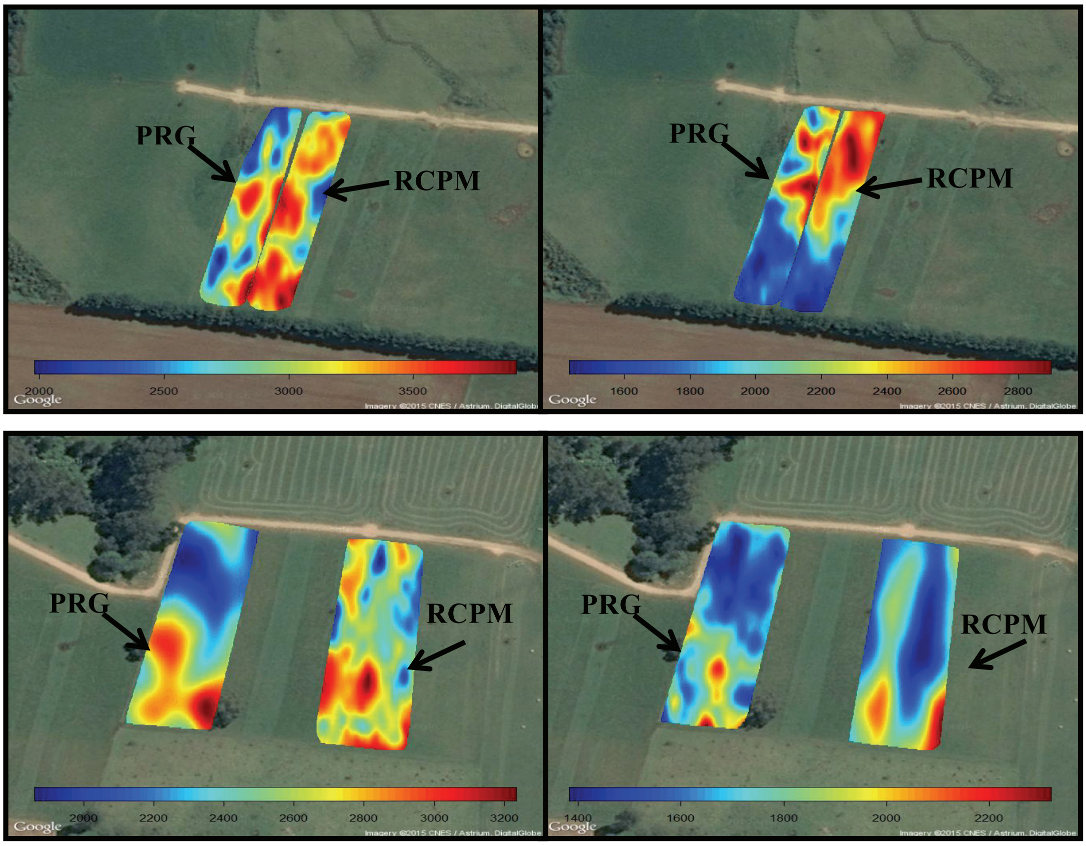

Figure 1. Yield maps of the perennial ryegrass monoculture (PRG) and perennial ryegrass, white clover and plantain mixture (RCPM) in paddock 18 (upper panels) and paddock 54 (lower panels) at the Tasmanian Dairy Research Facility prior to grazing in Spring 2014 (left panels) and Autumn 2015 (right panels).

Discussion

This study has highlighted that while diverse pasture mixtures can have less variability in pasture biomass compared to monoculture pastures; this variability is temporal in nature. This evidence confirms the hypothesis proposed by Pembleton *et al*. (2015) that the scale and levels of inputs applied to temperate dairy pastures means the niche exploitation achieved within these pastures occurring from increased species diversity is likely to occur temporally than spatially.

The decrease in variability in pasture biomass that occurred during spring was associated with fewer low yielding areas being present. While it was not clear from this study, a longer term analysis of the pastures has shown mixtures of perennial ryegrass, white clover and plantain have superior levels of forage production during spring compared to perennial ryegrass monocultures (K. G. Pembleton unpublished data). Low soil temperatures and/or water logging are some of the possible constraints to pasture production during spring at this location. Plantain has increased tolerance to water logging compared to perennial ryegrass (Banach *et al*. 2009). The cultivar of plantain used in this study, Tonic, is also noted for its high growth rates during the cooler months (Stewart 1996). These traits would have enabled plantain to exploit spatial differences in temperature and drainage during spring helping reduce the within paddock biomass variability.

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