Estimating on-farm methane emissions for sheep production on the Northern Tablelands: establishment of demonstration site

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Abstract: A 36-hectare demonstration site at Armidale on the Northern Tablelands of New South Wales has been established to give livestock producers a practical insight into the magnitude of carbon fluxes, especially methane (CH_4), associated with crossbred lamb production. The site contains soil and topographical diversity typical of the region (pH 4.8–5.1 (1:5 $CaCl_2$); soil organic carbon 1.2–3.8%; cation exchange capacity 3–41 meq/100g). The replicated study over two years will compare animal productivity and emissions of low stocking rate enterprises on a low fertility (hill) section of the site (3.7 DSE/ha) with those of high soil fertility enterprises on the more fertile alluvial flats (6.7 DSE/ha). An EM38 soil map and seven soil samples were used to characterise the soil diversity within the two landscapes and to block each landscape into three classes (A, B, C), with three paddocks/class. Monthly pasture (green and dead DM availability) and regular production data (liveweight gain, fat score, fecundity, wool and lamb carcass weights at slaughter) will be collected. These measures will be used in decision support tools to estimate total on-farm CH_4 emissions, emission per unit product, and to conduct a life cycle analysis of the contrasting enterprises. It is intended to use the site as a regional reference point for effective integration of farm carbon, productivity and economic understandings.

Keywords: greenhouse gas, high fertility, low fertility, pasture production.

Introduction

Agricultural emissions (methane (CH_4) and nitrous oxide (N_2O)) comprise 16% of Australia's total emissions, and livestock emissions (enteric fermentation and manure management) contribute 69% of agricultural emissions (Department of Climate Change and Energy Efficiency 2010). While there is no intention to directly include agricultural emissions in a future national emissions trading system, downstream penalisation on agricultural commodities is feasible and, more favourably, there may be opportunity for mitigation of agricultural emissions to provide a carbon offset market (Australian Farm Institute 2010).Therefore an increasing need exists to provide information to livestock producers including estimates of on-farm emissions and opportunities for on-farm emissions mitigation.

In collaboration with Meat and Livestock Australia and the Australian Government's Climate Change Research Program, the national "Reducing Livestock Emissions Program" has established four sites across Australia to demonstrate potential mitigation strategies for enteric emissions. These are: sites for beef and dairy emission mitigation in northern Queensland and Victoria respectively, and sites in Western Australia and in Armidale on the Northern Tablelands of New South Wales for sheep production. This paper discusses the establishment of the demonstration site for sheep production on the Northern Tablelands of New South Wales. It is anticipated that field days on the Northern Tablelands will equip producers with the knowledge, tools and strategies to manage and understand their on-farm sheep production emissions. The site will also provide training for undergraduate and postgraduate students in measurements of animal production, soil properties, and the use of whole-farm system models.

The objectives of this study are to:

1. Demonstrate to New England graziers the magnitude of sources and sinks of greenhouse gas emissions in a sheep grazing enterprise;
2. Demonstrate the contrasting production of greenhouse gases from low fertility and high fertility sheep grazing systems;
3. Demonstrate methods for predicting and measuring on-farm CH_4 production so producers can assess potential opportunities and liabilities in a carbon economy;
4. Develop an inventory of CH_4 production from grazing systems;
5. Train agricultural scientists in understanding farm carbon, pasture management and sheep growth and production.

This paper describes the establishment of the demonstration site and initial results.

Methods

Plant, soil and topographical features of the site

The 36-hectare demonstration site 'Trevenna', is located at the University of

New England on the Northern Tablelands of New South Wales (latitude 30° 30′ S, and longitude 151° 40′ E). The Northern Tablelands has a summer-dominant rainfall and an elevation of 1000 plus metres. The existing pasture was dominated by summer growing natives such as red grass (*Bothriochloa macra*), yearlong natives (*Austrodanthonia spp.*, *Microlaena stipoides and Poa spp.)* and introduced cool season species such as Ryegrass (*Lolium spp*.), Broomes (*Bromus spp*.) and Paspalum (*Paspalum spp*.). There were also some legume species present such as Subterranean (*Trifolium subterraneum*) and White (*Trifolium repens*) clover.

The site has two distinct topographic landscapes (tougher hill country and fertile creek flats) that are being used to differentiate grazing systems into low and high fertility systems appropriate for the topography. An electromagnetic induction soil survey was conducted of the hills and flats on the 'Trevenna' on-farm emissions site. The derived apparent electrical conductivity (eC_a) maps were used to stratify the 'Trevenna' landscape into basic soil zones on the basis that spatial variability in eC_a was a surrogated indicator of soil textural differences (Corwin and Lesch 2005). Soil samples to a depth of 100 mm were taken at seven marked sites varying in eC_a (see Figure 1). All soil samples were analysed for $pH_{(Ca)}$, organic carbon, phosphorus, sulphur and exchangeable cations. Additional soil samples across all the paddocks were taken at the beginning of the demonstration and were air-dried and stored for future analysis. Fertiliser was applied to the flats during May 2010 at the rate of 20kg/ha of phosphorus and 25 kg/ha of sulphur, 70 kg/ha of nitrogen and 5 kg/ha of white clover seed.

Botanical composition, using the Botanal technique (Tothill et al. 1978) and herbage mass will be assessed each season in pre-located sites. In addition pasture samples investigating quantity and quality are taken at entry and exit of sheep from each paddock using the median quadrat technique as outlined in the appendix of the PROGRAZE manual (NSW Department of Primary Industries 2007). Scans of pasture quadrats are taken before the quadrat is cut to determine green and dead biomass using a Crop Circle (Holland Scientific equipment model ACS210). The image analysis data from the Crop Circle scans will be correlated with the actual total and green biomass to assist in calibrating the Crop Circle scans. Each paddock is also scanned along transects either north/south or east/west using Crop Circle equipment attached to a quad bike.

Water holding capacity measurements and N_2O will also be measured during the trial. A soil density calibration to provide a measure of plant available water (PAW) capacity for the hills and the flats will be undertaken and the data (bulk density, saturated water capacity (mm/mm), drained upper limit (mm/mm) @ 1 bar pressure, lower limit (mm/mm) @ 15 bar pressure, clay and sand percentages) will be used as inputs into the whole-farm decision support systems.

Selection of appropriate long-term stocking densities

Stocking density (DSE/ha) was determined using PRO Plus™ (McPhee et al. 2000), a whole-farm fodder budgeting decision support tool. Prior to commencement: the planning period, the area (ha) of each paddock, the estimated pasture growth rates (kg DM/ha/day) and intake (kg DM/ha) for each month and pasture biomass (kg DM/ha) at the beginning of the planning period, stock numbers and anticipated movement of stock between paddocks were entered into PRO Plus. Intake of supplementary feed (300g of grain and 300g of hay) and fodder quality were taken into consideration from September to mid-October. A fodder budget was calculated and used to modify stock numbers so that the livestock demand on pasture availability in early spring was met. The DSE/ha for individual paddocks on the two different landscapes and the overall DSE/ha for the hills and flats are reported.

Animal measurement and allocation

Three hundred and nine Merino ewes from the UNE Merino research flock were group-mated to four Border Leicester rams over 38 days at a ratio of ~1 ram to 77 ewes. All ewes were pregnancy tested 75 days post-joining using ultrasound, weighed and condition scored by palpitation. From these, 168 ewes carrying single lambs were selected for the trial (starting LW = 40.91kg± 4.00kg) and allocated to experimental groups; 48 to graze on the hills split into three flocks (n=16 per plot) grazing across three paddocks to create a blocking effect across the hills, and 96 to graze on the flats split into three flocks (n=32 per plot) grazing across three paddocks, again to create a blocking effect across the flats, and 24 ewes were kept as replacements. The allocation of ewes to flocks used stratified randomisation based on liveweight. Ewes were moved to their initial allocated paddocks eight days prior to the commencement of lambing on September 10 2010. Staple and tensile strength and fibre diameter samples will be taken at shearing. Four ewes on the hills and four ewes on the flats have a GPS tracking device attached so that future research on the movement of ewes and lambs can be evaluated.

Estimating methane

Methane will be estimated using the whole-farm decision support tools AusFarm (Horizon Agriculture 2010; Freer et al. 1997; Moore et al. 1997) and EcoMod (Johnson et al. 2003). Relevant data collected from the trial will be used as inputs to the models. FarmGas (FarmGas Calculator 2010) and OVERSEER (OVERSEER 2010;Wheeler et al. 2006) will also be used to compare the on-farm outputs.

Experimental design

The experimental design is based on the plant soil and topographical features of the site; two landscapes (hills and flats) where each landscape is divided into three land classes (A, B, and C) each with three paddocks within each land class. In total 18 paddocks: nine on the hills and nine on the flats. Three flocks allocated to each of the landscapes with a rotation across the three land classes i.e. each flock rotationally grazes three allocated paddocks and hence rotationally grazes each land class (A, B, and C). The experimental design is not replicated within landscape, but the paddock subdivisions across the land classes are used as blocking effects to account for the variation across the landscapes. Replication of the experiment will occur across two years. Class and paddock were randomised before allocating flocks. Genstat version 13 (2010) was used to tabulate means and standard deviations and a two-way analysis of variance was performed to access differences between flocks.

Results

Soil characteristics and available pasture

Distribution of the two landscapes (hills, flats) and the within landscape classification (A, B, C) is shown in Figure 1. The profile of the apparent electrical conductivity (mS/m) of the soils is shown and the EM38 soil map assisted in determining the classifications (A, B, C). The chemical properties of soil samples taken at the start of the study are shown in Table 1. All assay analyses were conducted by a laboratory accredited under the National Association of Testing Authorities.

Soil pH was above critical levels of 4.7–4.8 in Ca and no lime was required on this site (see Table 1). The cation exchange capacity (CEC) reflected the soil texture closely, with sites located on the hills having basalt influence, higher clay contents and higher CEC. The more alluvial flat country had low CEC associated with its coarser soil texture. This is confirmed by the soil carbon concentrations being <1% lower on the flats where the coarser texture limits accumulation of carbon sequestration. Soil P was uniformly high (Colwell >35 mg/kg) across the demonstration site, posing no limitation to the establishment and persistence of legume pastures. The Phosphorus Buffer Index (PBI) of both hill and flat country indicates that starter basal P applications will remain highly available throughout the life of the demonstration. In contrast, the low CEC and lighter textured soils have sulphur levels (KCl_{40}-S) < 8 mg/kg and hence sulphur application (25kg/ha) was essential to maintain persistent legumes in the swards.

Figure 2 illustrates the Normalised Difference Vegetation Index (NDVI). The quantity of pasture available is represented as an NDVI in all of the paddocks for the hills and flats and paddocks HA2, HB3, HC3, FA3, FB3, and FC3 illustrate the lower quantities of pasture available after ewes and lambs have grazed on the paddocks for the first 39 days of the trial.

Selection of long-term stocking densities

The simulated results, at the end of the month from June 2010 to March 2011, of pasture availability (kg DM/ha) for ewes grazing in paddocks HA2 and FA3 on the hills and flats, respectively, are shown in Figures 3 and 4. The paddock stocking densities were 5.4 and 9.3 DSE/ha for HA2 and FA3, respectively and the landscape averages on 18 ha were 3.7 and 6.7 DSE/ha, for hills and flats, respectively.

Animals

The live weights and condition scores of six flocks are shown in Table 1. There was no difference in ewe liveweight or condition score at the start of the study (P>0.05). Since all ewes entered the trial carrying a single lamb, no testing of treatment effects on the number of lambs has been made in year 1.

Discussion

The establishment of the 'Trevenna' UNE on-farm methane emissions for sheep production demonstration site has been assisted through the use of EM38 maps as illustrated in Figure 1. The EM38 soil map (Figure 1) clearly defines the two different landscapes (hills and flats) and the apparent electrical conductivity (Figure 1) assisted in ascertaining where the demarcations were for the different land classes (A, B, C) within the landscapes. The EM38 soil map also assisted in determining the location of fencing for the paddocks. The Cicerone project, a producer-led research/adoption group, conducted on the Northern Tablelands of New South Wales also used EM38 mapping for the layout of their paddocks after optimising the distribution of land according to soil, fertiliser and topography (Scott 2003).

The fodder budgets (Figures 3 and 4) were valuable for determining the stocking rate densities. The 3.7 and 6.7 DSE/ha on the hills and flats respectively are close to the average DSE/ha for the region. Pasture availability at lambing was a critical window and hence supplementary feeding during this period assisted in maintaining the ewes with a condition score that ranged from 2 to 4 across the 144 ewes.

Measuring the quantity and quality of pastures is an extremely important component of this project. Determining the amount of green and dead feed available to livestock is essential for estimating on-farm CH_4 emissions. Figure 2 illustrates the changes in pasture availability as indicated by the NDVI. Actual green and dead biomass (kg DM/ha) will be used to calibrate the NDVI values shown in Figure 2.

The pasture biomass, and data collected during this project (e.g., liveweight, fleece weight, rainfall and water capacity) will be used to simulate sheep production on the Northern Tablelands. The decision support tools AusFarm and EcoMod and the inventory models FarmGas and OVERSEER will be used to estimate CH_4. At the end of the second year a detailed analysis will be conducted to determine the differences between landscapes of CH_4 produced (g)/kg of sheep meat and wool produced. A simulation study using 50 years of weather data will be conducted to analyse long-range forecasts of climate change. A life-cycle analysis will also be conducted at the conclusion of the project.

The results of estimating CH_4 from the decision support tools and the inventory models need to be treated with caution. Baseline estimates of CH_4 using open-path Fourier-transform infrared spectrometer technology and measuring CH_4 production in chambers will assist in interpreting the results from the decision support tools. Further research is required in building mathematical models to improve the prediction of CH_4 production.

Conclusions

The information gathered from this type of demonstration will be important in the decisions made by regional graziers, advisers and policy developers. Producers will have on–ground local and relevant information that will help in long-term understanding of the principles and practicalities of their farm systems. The analyses from the different models will be useful in estimating CH_4, and carbon cycling on a relevant albeit, small-scale demonstration site. By using multiple farm system models, greater (or lesser) confidence in the estimates can be conveyed to producers, advisers and policy makers. An increased understanding of the usefulness of models and their generated outputs will be helpful to those using the models, as well as providing a greater knowledge of the input drivers.

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Appendix

Table 1. Results from soil sample analysis taken across seven sites at the Trevenna on-farm methane emissions demonstration site. Sampling sites are identified on the site map provided in Figure 1.

Soil parameter	Sampling site						
	1	2	3	4	5	6	7
pH (1:5 CaCl2)	5.4	5.2	5.6	4.7	4.9	4.8	5.1
Organic Carbon (%)	3.8	3.7	2.6	1.3	2.0	2.9	1.2
SulphateSulphur (KCl40) (mg/kg)	6.2	5.5	2.8	5.1	4.1	7.8	2.6
Phosphorus (Colwell) (mg/kg)	85	51	100	71	69	91	130
Phosphorus Buffer Index	190	150	200	61	53	140	35
Cation Exch. Cap. (CEC) (meq/100g)	29.4	13.7	41.0	4.61	8.56	11.6	3.11

Table 2. Live weights (LW) and condition scores (CS) of pregnant ewes with single lambs for each flock

Flock	No	LW (kg)	CS
1	16	40.35	2.88
		(3.29)	(0.50)
2	16	40.89	2.91
		(4.00)	(0.55)
3	16	40.42	2.97
		(4.11)	(0.50)
4	32	40.90	2.91
		(4.16)	(0.50)
5	32	41.13	2.92
		(3.69)	(0.49)
6	32	40.82	2.95
		(4.11)	(0.53)

Figure 1. Paddock layout and size of paddocks for the hills (H) (low fertility) and flats (F) (high fertility) landscape and their classes (A,B, and C) within the landscapes at the Trevenna on-farm methane emissions demonstration site, Armidale, the soil GPS satellite classification and sample sites

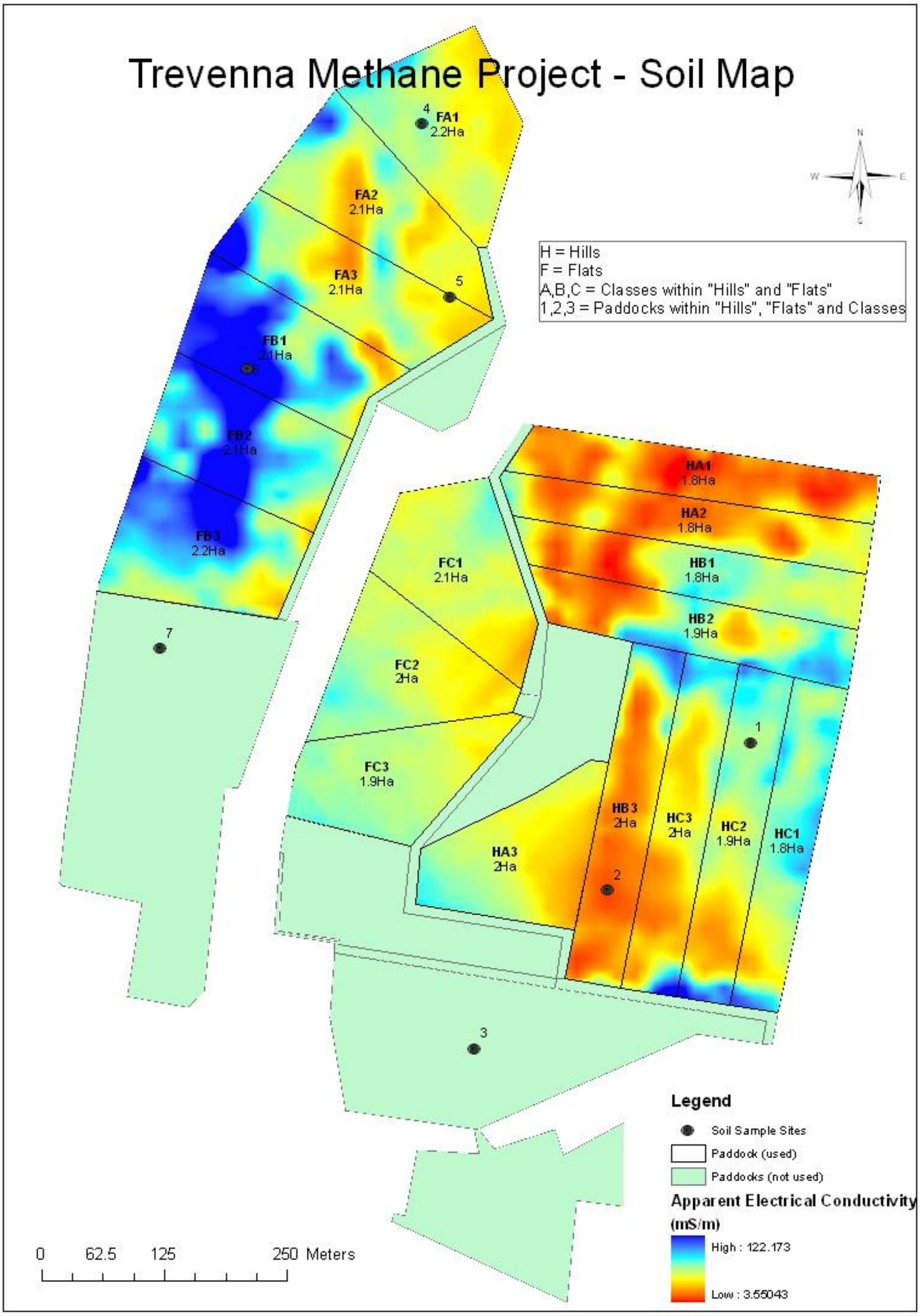

Figure 2. Normalized Difference Vegetation Index (NDVI) of Trevenna paddocks taken on the 18th October 2010 for the hills (H) (low fertility) and flats (F) (high fertility) landscape and their classes (A, B, and C) within the landscapes at the Trevenna on-farm methane emissions demonstration site, Armidale

Note: the lower the NDVI index the lower the pasture biomass available

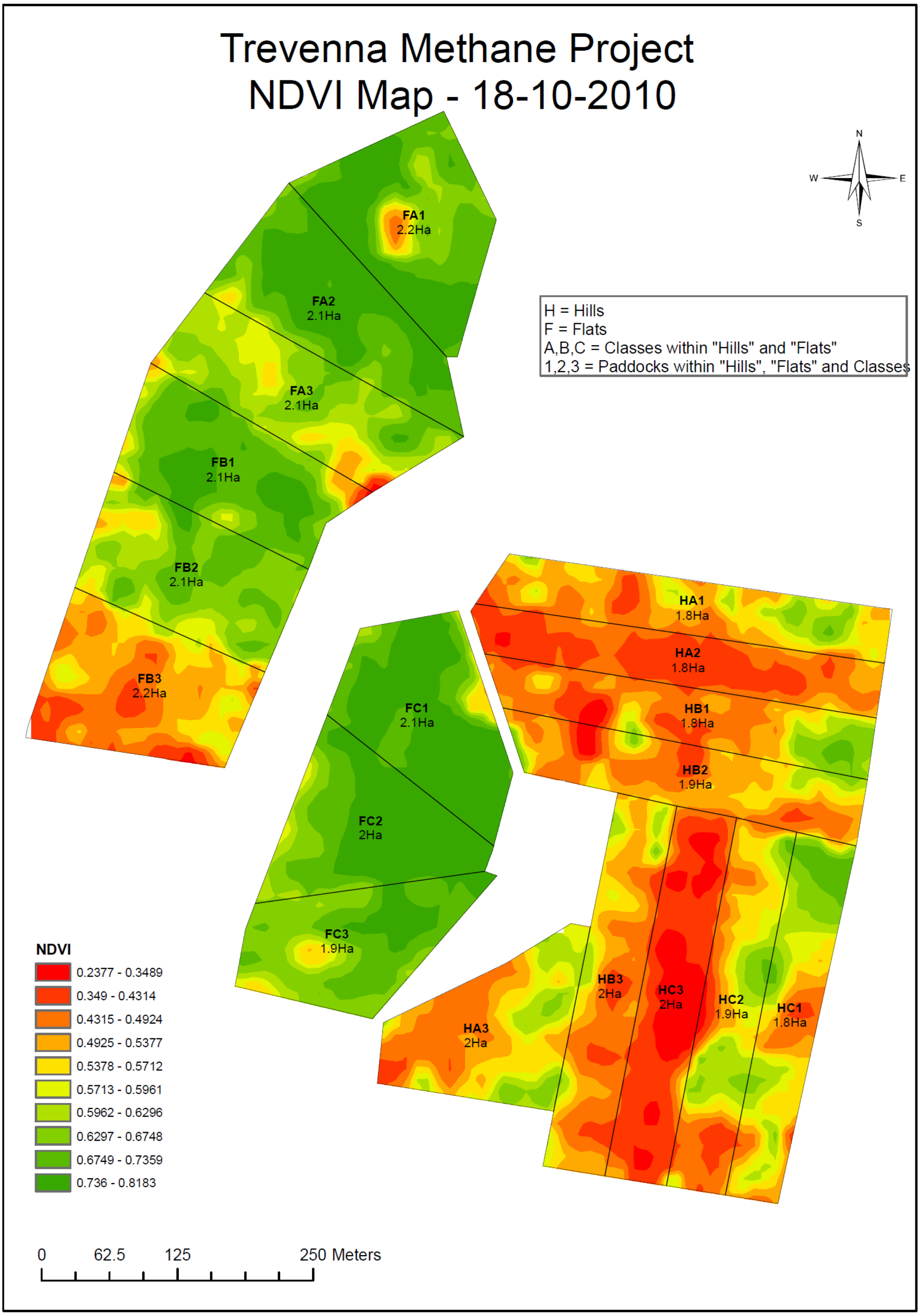

Figure 3. Pasture growth rate (kg DM/ha/day), intake (kg DM/ha/day) and green pasture biomass available (kg DM/ha) for each month (value at end of month; values in parenthesis are days ewes grazed in paddock) on the hills (H) (low fertility) landscape for class A paddock 2

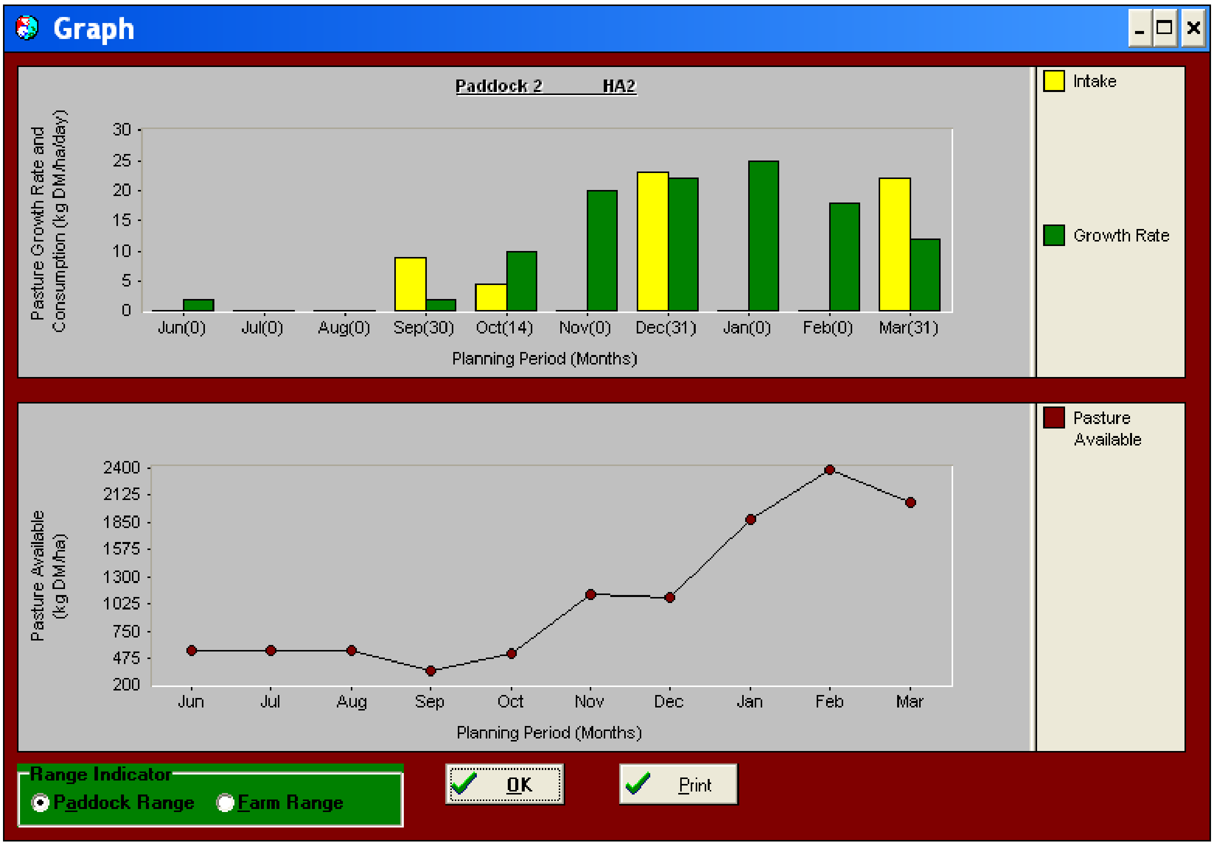

Figure 4. Pasture growth rate (kg DM/ha/day), intake (kg DM/ha/day) and green pasture biomass available (kg DM/ha) for each month (value at end of month; values in parenthesis are days ewes grazed in paddock) on the flats (F) (high fertility) landscape for class A paddock 3