Project Report:
Determination of field sampling methods for the assessment of curing levels in grasslands

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Abstract

Grasses cure on an annual or seasonal cycle by dying and drying out after flowering. The "degree of curing" refers to the percentage of dead grass, which significantly affects fire behaviour and fire danger models. The degree of curing is currently assessed visually or by satellite remote sensing using an index based on the reflective properties of grasses at different wavelengths. Unfortunately, both of these techniques have inherent problems, leading to inaccurate assessment of grassland fire danger levels and fire behaviour predictions. Inaccurate predictions are problematic because fire managers need reliable information to aid in decision-making to protect life and property. This Bushfire Cooperative Research Centre (CRC) project will develop improved methods for both assessing and predicting grassland curing for input into fire danger rating systems and fire behaviour models. Development of these methods relies on collection of curing data from grassland areas across Australia and New Zealand. Destructive sampling of grasses is the most accurate method of collecting this data, but is not practical to implement on a large scale. This report outlines results and recommendations from pilot studies carried out in Australia and New Zealand over the period from July to September 2005 in order to develop alternative methods to destructive field sampling. Methods investigated included height and cover assessment, fuel moisture analysis, tally methods using a levy rod, and analysis of digital imagery. The height and cover assessment and fuel moisture content approaches were the least suitable, and the simple levy rod approach is recommended for large-scale field sampling. It is also suggested that the analysis of digital imagery to determine live and dead (green and brown) components is advanced through further research.

Introduction

The degree of grassland curing (the proportion of cured and/or dead material in a grassland fuel complex) has a significant effect on fire behaviour in grasslands, particularly the ability for a fire to develop and its subsequent rate of spread. Both Australian and New Zealand fire behaviour models and fire danger rating systems require a degree of curing input. These models and systems provide an estimate of the ease of ignition, rate of spread and difficulty of suppression of grassfires. Outputs from fire danger rating systems are used by fire management agencies to determine the fire danger in a particular area and to aid in fire management activities such as determining fire season status, resource allocation and imposition of restrictions on activities. These decisions can have significant economic and social impacts on local communities. Similarly, predictions of rate of spread and headfire intensity based on grassland fire behaviour models assist in fire suppression decision-making, including critical decisions relating to firefighter and community safety. These decisions need to be based on accurate and scientifically sound information. The degree of curing is currently assessed visually or by satellite remote sensing using an index based on the reflective properties of grasses at different wavelengths. Unfortunately, both of these techniques have inherent problems, leading to inaccurate grassland fire danger levels and fire behaviour predictions.

This Bushfire Cooperative Research Centre (CRC) project aims to develop methods for assessing and predicting current and future levels of curing in grasslands. Research is focussing on two main areas, remote sensing applications and pasture (grass) growth modelling. Field data collection is required to provide data for development and validation of methodology. The methods also need to be applicable to a wide range of grassland types across Australia and New Zealand. An extensive field data collection program across both countries will commence in the summer of 2005/06. Previous field sampling has relied on the collection of destructive samples in the field, followed by tedious and labour-intensive sorting of samples in a laboratory. This method, although probably the most accurate, is not suitable for large-scale field data collection.

Pilot studies to develop alternative methods for collection of curing field data were carried out from July to September of 2005 in Australia and New Zealand. These pilot studies focussed on testing and comparing a number of alternative techniques to destructive sampling. The aim was to develop a method suitable for large-scale data collection by fire agency personnel, requiring minimal time and effort whilst still delivering accurate data to meet research needs.

This report is a summary of the pilot studies, and presents recommendations for a simple and effective method of collecting grass curing data in the field. It is hoped to implement this method across Australia and New Zealand during the summer of 2005/06.

Study sites

Sampling was carried out at seven sites, five located in Australia in the Australian Capital Territory (ACT) and coastal New South Wales, and two located near Christchurch in New Zealand (refer to Table 1). The sites ranged from native grasses in ungrazed areas, to improved pasture grasses in grazed areas. Full descriptions and photographs of sample sites are contained in Appendix A.

Table 1. Sample sites in Australia and New Zealand.

Sample site	Grass type	Location
Monaro Highway	Improved pasture	ACT, Australia
Fisher Parklands	Improved pasture	ACT, Australia
Majura Firing Range	Improved pasture	ACT, Australia
Umbigong Park	Native grasses	ACT, Australia
Milton	Improved pasture	Coastal New South Wales, Australia
Darfield	Improved pasture	Canterbury Plains, New Zealand
Godley Head	Native/retired pasture mix	Banks Peninsula, New Zealand

Methodology

Four methods were tested in the field and laboratory as alternatives to destructive sampling. These methods are discussed below in detail, and field methodologies and booking sheets are contained in Appendix B.

Destructive sampling

Destructive sampling was still carried out at each sample site to obtain an accurate curing assessment for the site. Each of the other methods was then compared against the curing estimate for the sample site obtained from the destructive sampling. Destructive sampling involved the removal of all above-ground material from within a sample frame. Initially, ten destructive samples of $1m^2$ were collected, along with a sample of $0.25m^2$, taken from within each $1m^2$ sample frame. These data were then used to establish the minimum number and size of samples required that would provide curing estimates within an acceptable margin of error. Findings are described in the results section, and it was decided that five samples from $0.25m^2$ frames would be sufficiently accurate. This destructive sampling was carried out at each of the sites, although only four samples were collected and sorted from Darfield and Godley Head due to time constraints. Following collection, samples were sorted into live and dead material in the laboratory and oven-dried and weighed. The average curing value of all samples from a site determined the curing value for that site.

Height and cover assessment

In the past, visual assessment has been found to be poorly correlated with destructive sample estimates (Dilley and Edwards 1998, Millie 1999). Visual assessment has been trialed for several years in New Zealand with very poor results. The correlation of curing estimates from visual assessment and destructive sampling over the summer of 2004-05 was of the order of 0.80, but that was only sufficient to estimate curing to within about $\pm$ 25% (and only within $\pm$ 30% if the Darfield and Majura Range sites were included). The height and cover method was an attempt to refine the visual assessment technique by dividing grassland fuels into vertical strata.

This technique involved estimating the average height and cover of the different strata present in grassland fuels within a $0.25m^2$ quadrat. Within the quadrat, an estimate of the height and cover of the standing tillers, sward and thatch (and cover of bare ground) was taken, along with a visual curing assessment for each stratum. The overall curing value for the quadrat was then obtained by weighting the volume assessment of the grass in each stratum. The volume of grass was estimated through multiplying height by cover.

Fuel moisture content

The fuel moisture content (FMC) of grass fuels has a significant impact on fire behaviour. Grass fuel with a higher FMC requires a larger energy input for the fuel to reach its ignition temperature. The FMC is significantly higher for live grass than for dead grass. It changes seasonally in live grass, and it changes in dead grass in response to temperature, relative humidity and rainfall. Previous studies have found correlations between overall grass FMC and the degree of curing (e.g. Parrott and Donald 1970, McArthur 1966, Barber 1990). Curing changes fairly slowly from day to day, but dead fuel moisture content changes diurnally, and after rain. The development and use of these correlations therefore depends on observations being taken when the grass has dried out, and under similar atmospheric conditions. The effect of dead fuel moisture content on the overall FMC of the grass will be particularly large when the curing is high, at a time when its determination is most critical for fire danger estimation. Another problem with this correlation method is that live fuel moisture is species dependent, so correlations developed in one grass type may not work elsewhere. To overcome these problems a method was developed in which the live and dead fuel moisture contents were estimated in addition to the combined FMC of the grass.

Five separate live and dead grass fuel moisture samples were collected from each site, as well as five combined (live and dead) fuel moisture samples. In some cases, the combined samples were the $0.25 m^2$ destructive samples collected from each site. These samples were oven-dried and weighed, and the curing was calculated using the following formula:

$$\text{Degree of curing } (\%) = ((\text{live FMC} - \text{combined FMC})/(\text{live FMC} - \text{dead FMC})) \times 100 \qquad (1)$$

An estimate of curing, C(%), was also calculated using the formula from Barber (1990)

$$C = -0.000006295(FMC)^3+0.0044(FMC)^2 -1.0721(FMC)+109.6758 \qquad (2)$$

where FMC is the combined fuel moisture content estimate (%).

Parrot and Donald (1970) give a curve relating curing to combined FMC based on about 30 data points. The equation of the curve isn't given, but it can be estimated from their Figure. A formula which fits the curve almost exactly is

$$C = 95 \exp(-0.0017052 (FMC)^{1.428})+10 \qquad (3)$$

A regression equation was also developed using the 2004-05 data from Australia and New Zealand for which the combined FMC was less than 300%. The formula is

$$C = 90 \exp(-0.0010439 (FMC)^{1.335})+10 \qquad (4)$$

Figure 1 shows a comparison of the three equations overlaid on the Australia-New Zealand data from the summer of 2004-05, and the data presented in this report (spring 2005). The variation of the data about the regression curve was quite large, and it can be seen that the spring data has larger curing values for the same FMC (due to the greater live and dead fuel FMC). However it was still thought worthwhile to calculate estimates of curing from this formula to see how well they compared with the estimates from Barber's formula. Parrott and Donald's relationship is similar to Barber's relationship up to an FMC of 100%, but then it dips below Barber's relationship, and flattens out, whereas Barber's relationship doesn't give predictions above an FMC of 350%.

Scott and Burgan (2005) give an algorithm for determining the percentage of dead fuel loading to be used in Rothermel's surface fire spread model (Rothermel 1972). It can also be used to estimate live fuel moisture content for a given degree of curing. It assumes a negative linear relationship between curing and live fuel moisture content. Figure 2 shows that the relationship is very poor for our limited set of data from spring 2005.

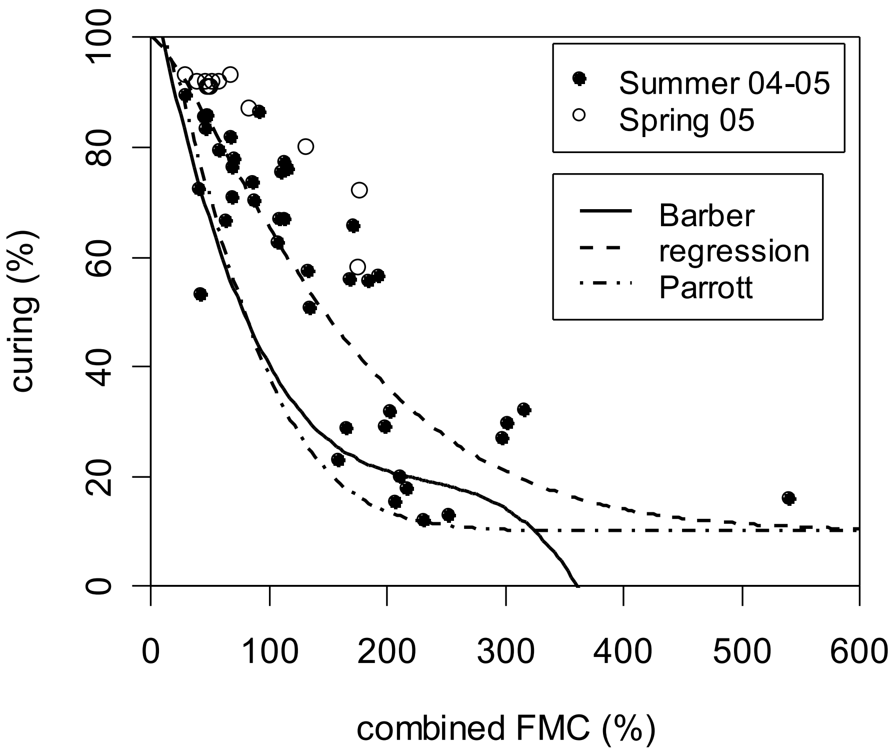

Figure 1. Barber's equation (2) and the regression equation (3) overlaid on the Australian-New Zealand data from summer 2004-05 and spring 2005.

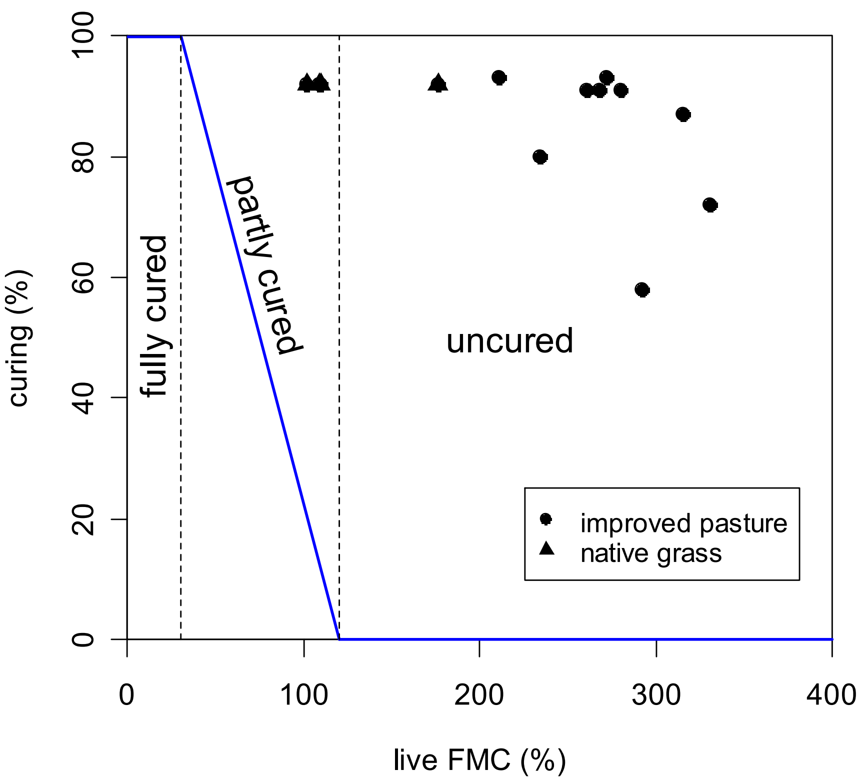

Figure 2. The relationship between curing and live fuel moisture in the data from spring 2005 overlaid with the relationship from Scott and Burgan (2005).

Levy rod assessment

The point quadrat method of pasture assessment relies on multiple pin point samples to be collected, thereby allowing any anomalies to be compensated for through mass repetition. It was introduced by Levy and Madden (1933) to quantify biomass in pastures. Variations of this method have been used with success in forest vegetation types to describe height and cover distribution (Sneeuwjagt 1971, McCaw 1998), but the method has not previously been used to quantify curing levels in grasslands. It has however been used to determine the percentage of each species in grassland (Levy 1933), which is a similar problem.

A single rod was used in preference to a frame of several rods (as described by Levy 1933) so that the variability due to large-scale spatial heterogeneity could best be captured (Goodall 1952). The levy rod used was a steel pole of 5mm diameter. The size was chosen to be as small a diameter as possible and yet retain rigidity. However the size of the rod does not appear to be of great significance when estimating the percentage of different vegetation types present in the pasture (Goodall 1952). The rod was driven into the ground at sample points along a transect. Touches of vegetation on the pole were then counted, and classified as dead or live (see Figure 3). These touches were then tallied and converted to a curing percentage.

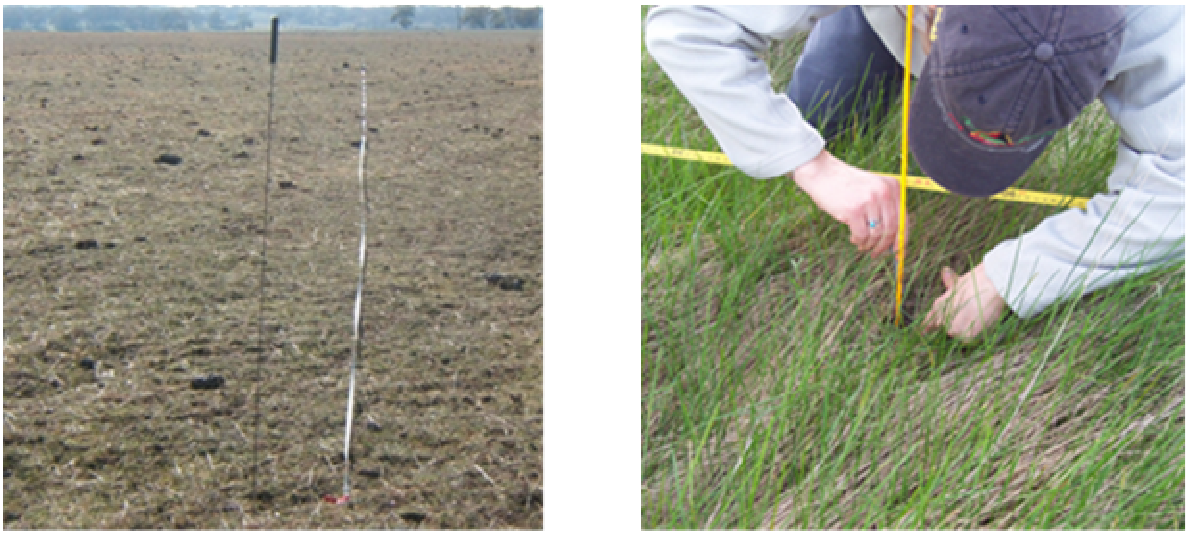

Figure 3. The levy rod assessment technique, showing the levy rod placed at the start of a transect (left), and counting of touches on the rod (right).

Three methods of using the levy rod were trialed during the field sampling. In all cases, points were selected systematically along transects across a grassland area. The first method was simply to count only the first touch on the pole (the highest touch), and note whether the grass in contact was dead or alive. The second method involved counting all the touches of grass on the pole and classifying each touch as dead or alive. Touches were counted and classified from the top of the pole downwards. The third method counted and classified the first touch in each stratum of grass fuel. Three strata were identified, as in the height/cover method: standing grass tillers, grass sward and thatch.

The results from the 3 methods are not independent after 1/09/2005, when the first touch in each stratum method was first used. From this date onwards all the touches at each sample point were tallied and classified (see the Levy rod booking sheet in Appendix 2), and the results of first touch, all touches and first touch in each stratum were calculated from the same sampling points. Prior to 1/09/2005 the results from the methods cannot always be regarded as completely independent as often the same transect was used, and the sample points for the first touch and all touches methods were often close together.

Digital image analysis

Digital imagery provides the possibility of quick and easy determination of curing levels. Using specialised software, it may be possible to obtain an estimate of the degree of curing through quantifying the proportions of green and dead material in the image. This technique has not been used for grass curing analysis, although has had application in other rangeland assessment research. To investigate the possibilities of this technique, digital images of destructive sample quadrats were taken in the field on several of the sampling occasions. Digital images were taken looking down at the quadrat, as well as side-on (profile). The profile image was taken on its own, and also with a black hardboard sheet behind the grass. This was to minimize reflectance and provide a reference background. Potential problems with this technique include reflectance and shadows from sunlight at different angles during the day.

In the laboratory, the destructive samples (from the 0.25m² sample quadrats) were spread out evenly onto a black background, and a digital image captured looking down at the sample (both with and without the use of a flash).

Analysis of these images is currently underway, and it is likely that this technique will require further and more thorough investigation and testing. This could form part of the research to be carried out by a postdoctoral fellow to work on remote sensing applications for grass curing.

Results

Destructive sampling

Table 2. Results from destructive sampling

Location	Date	Operator	Destructive Samples 0.25m²	Destructive Samples 0.75m²
Monaro Highway	8/08/2005	AF, FH	93 (1)§	91 (1)
	6/09/2005	AF, FH	91 [4]**	
Fisher Parklands	11/08/2005	AF, FH	87 (2)	86 (1)
Majura Range	6/09/2005	AF. FH	69 [6]	
Umbigong Park	30/08/2005	AF, FH	92 [3]	
Milton	12/09/2005	AF, FH	72 [6]	
Darfield	16/09/2005	SA, FT, TO	58 ((9))††	
Godley Head	17/09/2005	SA, TSO, TO	80 ((8))††	

Destructive sampling was used as a measure of curing against which the other methods could be compared, but the destructive sampling was kept to the minimum possible number required to keep within a reasonable margin of error. Firstly, quadrat sizes were compared. Quadrats of $0.25m^2$ were cut from within quadrats of $1m^2$. The curing of the remaining $0.75m^2$ areas was compared with the curing of the $0.25m^2$ quadrats. This was done using 10 samples of each size at the Monaro Highway and Fisher Parklands sites.

The margin of error gives a bound either side of the mean which we can be 95% sure covers the true average curing of the area (provided the sampling area is homogeneous). It depends on the number of samples taken and the inherent variability of the samples (which is likely to be greater

§ (ME) from 10 samples

** [ME] from 5 samples

†† ((ME)) from 4 samples

when the curing is around 50%). It can be reduced by increasing the number of samples taken. The margin of error (ME) for n samples is calculated from

$$\mathrm{ME} = \frac{t_{0.025,n-1} \times s}{\sqrt{n}} \tag{4}$$

where s is the sample standard deviation, and $t_{0.025,n-1}$ is the point on the t distribution with n-1 degrees of freedom that has 2.5% of the area to the right). This can be calculated in EXCEL using TINV(0.05,n-1). So, for example, if the mean curing is estimated as 90% with ME =2, we can be 95% sure that if we continued the destructive sampling a very large number of times the mean curing would lie between 88% and 92%.

The results from the destructive sampling are shown in Table 2. Both Monaro Highway and Fisher Parkland sets gave margins of error of 1-2% for both quadrat sizes (with mean curing of about 90%). From then on only the 0.25m^2 quadrat was used for destructive sampling. After 16/08/2005, only 5 samples were taken from each site. This resulted in an increase in the margin of error to 4% at Monaro Highway on 6/09/2005 (when the curing was about 90%), and 6% at the worst at Majura on the same date (when the curing was about 70%). Only 4 samples were taken at Darfield and Godley Head, and the margin of error was at worst 9% at Darfield when the curing was about 60%.

Height and Cover Estimates

Table 3. Results from height/cover method compared with destructive sampling (margin of error shown in brackets)

Location	Date	Operator	Height and Cover Estimates	Destructive Samples 0.25m^2
Monaro Highway	**8/08/2005**	**AF**	**76‡‡(5)§§**	**93 (1)**
	17/08/2005	**SA**	**88 (5)**	**91 [4]**
		FH	**81 (5)**	
Fisher Parklands	**11/08/2005**	**AF**	**53 (5)**	**87 (2)**
	18/08/2005	**AF**	**54 (6)**	
		FH	**74 (6)**	
		SA	**72 (4)**	
		RM	**28 (8)**	
		SF	**21 (6)**	
Umbigong Park	**30/08/2005**	**AF**	**82 (8)**	**92 [3]**
		FH	**85 (6)**	

Twenty curing assessments were made at 2m intervals along a transect line. The results are shown in Table 3. The assessments yielded fairly consistent margins of error for each operator of between 4% and 8% (curing), averaging 5.5%. This means that if the operator's estimate was C% that we can be 95% sure that if he assessed the whole paddock the average of his assessment would lie between C ± 5.5%. This assumes a spatially homogeneous paddock, i.e., no patchiness in the curing, and normally distributed data. In fact the assessment data is rather skewed to the left, so this margin of error is not quite correct.

‡‡ Figures marked in red are more that 10% curing away from the destructive sample mean.
§§ (ME) from 20 samples at 2m intervals

The height and cover assessment tended to always underestimate the actual curing. Using the trained operators in this method, AF and FH, the curing was underestimated by about 10% at Monaro Highway and Umbigong Park, and by over 20% at Fisher Parkland. Of even more concern was the variability between operators. At Fisher Parkland, where the destructive samples gave an estimate of 87% the previous week (and the season and weather suggested that the curing would have changed little in the week), the two trained operators' estimates ranged from 54% to 74%, and the three untrained operators recorded 21-72% curing. At Majura Range on 16/08/2005 (see Appendix A1), which is not included here as the destructive sampling had problems, the operator variation was 50-96%. The problems with the destructive sampling at Majura Range are discussed in Appendix A.

Using the median of the samples, rather than the mean, to account for the skewness did not change the estimates by more than about 1%. The large differences between these height and cover assessments and the destructive sample results, and the large variation between operators show that this method is unreliable. Accordingly, this method was abandoned after 30/08/2005.

Fuel Moisture Content (FMC) method

Table 4. Results from FMC methods compared with destructive sampling (margin of error shown in brackets).

Location	Date	Operator	Fuel Moisture Content Method	Barber's Estimate	2004-05 Australia-NZ estimate	Destructive Sample Results 0.25m2
Monaro Highway	8/08/2005	AF, FH	95	81	92	93 (1)
	17/08/2005	AF, FH, SA	79	56	78	
	6/09/2005	AF, FH	90% @ 1.45pm	66	84	91 [4]
		AF, FH	86% @ 3.00pm	67	85	
	8/09/2005	AF, FH	89	68	85	
Fisher Parklands	18/08/2005	AF, FH, SA	77	47	71	87 (2)
Umbigong Park	30/08/2005	AF, FH	81	69	86	92 [3]
	1/09/2005	AF	75% @ 10.30am	65	83	
		FH	70% @ 12.00am	62	81	
			84% @ 1.00pm	74	88	
Milton	12/09/2005	AF, FH	63	23	42	72 [6]
Darfield	16/09/2005	SA, FT,TD	45	23	42	58 ((9))
Godley Head	17/09/2005	SA,TO, TD	50	30	54	80 ((8))

The combined FMC estimated from five 0.25m^2 quadrats was used in Barber's correlation formula (equation 2) to provide an estimate of curing. The results are shown in Table 4. In all cases Barber's formula badly underestimated the curing. The formula was based on rough estimates of curing given in Figure 3 of McArthur (1966), and not on correlations from a large data set. Figure 3 of McArthur (1966) is based on curing in the ACT from Nov-Jan 1964/65 when the dead fuel moisture content was probably low, so the formula would tend to underestimate the curing in spring conditions. Parrott and Donald's relationship would give even greater underpredictions when the FMC was over 150%.

The formula developed from the Australia-NZ 2004-05 data (equation 3) provided better estimates of curing, although it too, consistently underestimated the curing, probably for the same reason. It performed particularly badly at Milton where the average dead fuel moisture content was 85% (free moisture was on the surface of the dead grass, so this result can be discounted). The problem at Darfield and Godley Head appears to be high combined FMC estimates, which also resulted in poor estimates for the FMC method discussed below. The reason for these is unknown, although it is possible that the Godley Head FMC samples had a higher value due to the higher moisture content of the thatch layer. Darfield had experienced recent rain, so it is possible that there was some free moisture present, although this would have been minimal. There is possibly potential to adjust the formula for season to take account of the higher live and dead fuel moisture in spring.

The FMC method was developed as a compromise, using destructive sampling and drying, but not sorting. Sorting was essentially done by selecting 5 live and 5 dead small grass samples separately from the combined samples. There were problems ensuring that the live fuel selected was of the same species as the live fuel in the combined samples. There were also problems in the amount of variability in the dead fuel moisture content, in particular because of the vertical profile change from tillers to sward to thatch. It added an extra degree of complexity to ensure that the dead fuel samples were representative of this vertical profile.

On 8/09/2005 an intensive trial was carried out at Monaro Highway to obtain a representative dead fuel moisture profile. Methods used were (a) the normal method of taking 5 samples, trying to get a representative sample by eye, (b) 5 samples using dead fuel within a quadrat, (c) 5 samples using a pipe, (d) 5 samples from each of the strata – tillers, upper sward, lower sward and thatch (weighted in the ratios 1:6:2:1). The pipe sampling was done as follows: A section of 90mm diameter PVC pipe was placed vertically down over the grass at a randomly chosen location. This was then hammered down into the ground. The grass around the outside of the pipe was then cut away. The pipe was then gently lifted up and the grass contained inside was cut off at ground level and the dead component placed in a sampling bag/tin. This method was used in an attempt to obtain a truly representative vertical sample of all strata. It was not very effective in very thick fuels or very sparse fuels. The method was repeated a number of times to get enough material for a sample.

The results are shown in Table 5. The combined FMC was 48%. Live fuel moisture measurements were taken using the normal method. The curing from destructive sampling on 6/09/2005 was 91%.

Table 5. Dead FMC from different sampling methods at Monaro Highway, 8/09/2005.

Method	Dead FMC	Curing Estimate
Normal	18	89
Quadrat	15	87
Pipe	22	90
Strata	22	90

It appears that in this situation the normal method was sufficiently accurate, and the curing estimate is not too sensitive to the dead fuel moisture content estimate.

It is hard to derive a margin of error for this method. It yielded several unacceptable results. At Umbigong Park the estimates ranged from 70-84% cured over 2-3 hours, when the destructive sample average was 92%. At Darfield the FMC estimate was 45% cured, when the destructive sample estimate was 58%. Worst of all at Godley Head the FMC estimate was 50% cured when the destructive sample estimate was 80%. This method probably cannot be modified enough to make it acceptable without further data collection over a season (or more).

Levy rod

Table 6. Results from Levy rod methods compared with destructive sampling (margin of error shown in brackets)

Location	Date	Operator	Number of first touches (single and stratum)	Number of all touches	Levi Rod 1st Touch	Levi Rod All Touches	Levi Rod 1st Touch in each Stratum	Destructive Samples 0.25m^2
Monaro Highway	8/08/2005	AF	60	20	88 (8)	89 (4)		93 (1)
	17/08/2005	SA	40	20	95 (7)	91 (4)		
		FH	40	20	98 (5)	89 (4)		
		Overall	80	40	96 (4)	90 (3)		
	6/09/2005	FH	30	30	77 (15)	88 (3)	87 (9)	91 [4]
		AF	30	30	84 (13)	89 (3)	91 (7)	
		Overall	60	60	80 (10)	88 (2)	89 (6)	
Fisher Parklands	11/08/2005	AF	60	20	60 (12)	81 (7)		87 (2)
	18/08/2005	AF	40	20	80 (12)	75 (7)		
		FH	40	20	78 (13)	77 (7)		
		SA	40	20	85 (11)	73 (8)		
		RM	40	20	75 (13)	82 (7)		
		Overall	160	80	79 (6)	76 (4)		
Majura Range	6/09/2005	FH	52	52	46 (5)	61 (5)	56 (10)	69 [6]
		AF	45	45	40 (14)	56 (6)	56 (11)	
		Overall	97	97	43 (10)	59 (4)	56 (6)	
Umbigong Park	30/08/2005	AF	60	20	95 (6)	94 (3)		92 [3]
		FH	60	20	98 (3)	92 (3)		
		Overall	120	40	97 (3)	93 (2)		
	1/09/2005	AF	20	20	95 (10)	92 (3)	95 (6)	
		FH	20	20	95 (10)	93 (3)	95 (7)	
		Overall	40	40	95 (7)	93 (2)	95 (5)	
Milton	12/09/2005	AF	30	30	33 (17)	81 (3)	66 (12)	72 [6]
		FH	30	30	44 (18)	81 (3)	72 (12)	
		Overall	60	60	39 (12)	81 (2)	69 (8)	
Darfield	16/09/2005	TD	20	20	25 (19)	54 (7)	63 (15)	58 ((9))
		SA	20	20	5 (10)	51 (7)	53 (15)	
		FT	20	20	25 (19)	50 (7)	63 (15)	
		Overall	60	60	18 (10)	52 (4)	59 (9)	
Godley Head	17/09/2005	TO	20	20	40 (21)	71 (4)	62 (14)	80 ((8))
		SA	20	20	40 (21)	72 (5)	62 (14)	
		TO	20	20	25 (19)	74 (5)	57 (15)	
		Overall	60	60	35 (12)	72 (3)	60 (8)	

Margin of error calculations for the first-touches were done assuming Bernoulli trials where for each sample point there are two possible outcomes, live or dead, with the same probability of a dead touch at each point. Then if the estimated percentage of dead fuel is C, the margin of error is approximately

$$\mathrm{ME} = 1.96 \times \sqrt{\frac{C(100-C)}{n}} \qquad (5)$$

where n is the number of sample points.

For the all-touches and first touch in each stratum methods a Bernoulli trial was assumed for each touch, so that *n* was the total number of touches. Although *n* was random in both cases, the ME in (5) can be used by regarding it as conditional on the number of touches. The method of calculating the margin of error for the all touches method was verified by simulating the method of estimating the curing using bootstrap sampling. For this the empirical distribution of the number of touches was used, with the probability of obtaining a dead touch set equal to the curing estimate divided by 100. The margins of error calculated in this way agree quite well with the margins of error calculated from the variation between transects (and observers) for the all touches method, but for the first touch by stratum method they give higher values.

First touch
The Levy rod method was first tried by recording the live/dead status of the first touch on the rod. The margin of error could be made reasonably low by using transects of 60 meters with samples at every meter, even when the curing was relatively low (i.e. the margin of error was 10% at Darfield when the destructive sample curing estimate was around 60%). However the method was badly biased, as it picked up tillers in preference to sward and sward in preference to thatch. The estimates highlighted red in Table 6 were unacceptably low compared with the destructive sampling estimates. The method worked reasonably well when the curing was above about 85% and the vertical profile of the curing was reasonably homogeneous, but on the whole it tended to be badly biased.

All touches
The all-touches method is obviously more precise, and less biased, but it is time consuming. In thick grass, moving the grass aside to see the touches can potentially lead to errors. Using 60 meter transects with samples every meter gave a margin of error of at most 7% at Fisher Parklands, and 4% at Darfield, where the curing was around 60%. Using 60 samples generally gave results within ± 10% of the destructive sample average. For practical application, 60 samples are probably too many. Using 20 samples at 1m apart gave at worst margins of error of 7% at Darfield and 8% at Fisher Parklands, which is still acceptable. In most situations, 20-30 samples spaced at 2-3 meters apart would probably give reasonable results.

First touch by stratum
This method was developed to reduce the bias of the first-touch method, and be less time consuming than the all-touches method. The margin of error was somewhere between those for the first touch and all-touches methods, e.g., at Darfield for 60 samples it was 9%. The method worked reasonably well, giving estimates within 10% curing of the destructive sample averages, with 2 exceptions shown in Table 6 at Majura Range and Godley Head. The Godley Head result can be attributed to the amount of dead thatch, so that the curing is underestimated because the thatch is under-represented in the sampling. It is more difficult to determine a reason for the poor result at Majura. This method is reasonably fast, mostly precise and accurate, but there are situations in which it doesn't work all that well.

The observers had problems in improved pastures where the tillers consisted of a casing of dead material around a live core. Recording these as dead fuel overestimated the curing (and vice versa). This appears to be a potential problem with the method. Possibly recording half of these touches as dead, and half live would be feasible.

Discussion and recommendations

Field data collection is important and provides data that will support the development of reliable operational tools for both assessing and predicting curing levels in grasslands. The field data will also allow validation of the models and systems developed. In order to collect a wide range of curing data from across Australia and New Zealand, it will be necessary to rely heavily upon support for data collection from fire management agencies. Operators from these agencies will have varying skill levels, and will mostly need to collect the field data with minimal supervision and training. It is therefore important that the data collection methods are simple and easy to follow, whilst at the same time providing accurate curing assessments for development and validation of systems within the research project. Destructive sampling has been shown to be far too time-consuming and logistically challenging in terms of sample collection, transportation and processing. An alternative technique suitable for field application by operational personnel needs to be developed.

Results from the techniques trialled during these pilot studies show that, apart from destructive sampling, two of the levy rod techniques yielded the most accurate assessments of curing. The height and cover methodology was the most inaccurate, which is perhaps not too surprising given that it is fairly well-known that visual field assessments of curing are unreliable. The height/cover methodology was supposed to improve its accuracy, but it introduced more error, probably in the estimate of cover. The fuel moisture content technique was too variable to be used reliably in the field, but modification of the formula developed to relate curing to FMC may still be potentially useful. Digital image analysis offers the possibility of quick and easy field assessment of curing, but requires further investigation and testing before an operational field sampling program using this technique can be implemented.

It is recommended that a levy rod method be implemented for the sampling program to commence in the summer of 2005/06 in Australia and New Zealand. The all touches levy rod method is the most accurate, but is possibly too time-consuming and therefore prone to error if poorly implemented. The first touch technique has a tendency to be biased, as only one stratum of the grass complex is generally recorded, and the others disregarded. The first touch by stratum method offers a possible compromise between the lengthy and involved all-touches method and the biased first touches method. Either of the all-touches or first touch by stratum methods is recommended for field use, dependant upon the nature of the grassland sample areas and operator experience and reliability. Care must be taken, however, to decide on an appropriate classification of tillers that consist of an outer coating of dead material around a live core. Total transect length should be from 40 to 60m (i.e., 40 to 60 data points), again dependant upon the sampling method, time available for sampling and operator experience and efficiency. The aim should be to complete sampling within 45 minutes of arrival at the sampling site. It is preferred if more than one transect is used, i.e. two transects at right angles to each other or 3 transects in a triangle. For example, for a total transect length of 60m it would be possible to have two transects of 30m at right angles to each other, or a triangle with sides of 20m each. This ensures greater representation of spatial variability in the sample area than just one single transect in a straight line. Goodall (1952) recommends using permanent points as a more precise method of recording changes in vegetation, but this may be impractical.

Destructive sampling, where practically possible, is still recommended periodically for sample sites. This would be useful at the start of the sampling season, as this would provide validation for the levy method and identify any factors influencing the accuracy of the levy rod observations. For example, if a thick thatch layer is present and skews the curing values, a correction factor can be applied to the levy observations. Periodic destructive sampling (once per month) is recommended throughout the sample period, to validate levy observations. This may only be practically possible at sample sites in the ACT and around Christchurch, i.e., where the seasonal project staff responsible for coordinating sampling will be based. It should be sufficient to take 5 destructive samples of 0.25m^2 size, but the margin of error should be calculated each time as a guide to whether extra samples are needed. At times when destructive sampling is carried out, the combined FMC can be determined and further development of a formula relating curing to FMC can be attempted. Should destructive sampling not be possible, it is recommended that at least 5 samples of each of dead, live and combined live and dead grass material is collected once per month to allow further investigation of fuel moisture and curing relationships.

The digital image analysis requires further investigation, and it is recommended that digital imagery be collected at sample sites throughout the sampling period. This method should, if possible, be investigated further by the postdoctoral fellow to be appointed for the remote sensing component of the project. At this stage, it is recommended that overview images of the sample location are taken at each sampling event, as well as a minimum of 5 downward-looking images at sampling points where levy rod observations are taken. These digital images will also provide a useful visual check of the results from levy rod assessment. There is also a further opportunity to explore the use of hand-held instruments, such as spectrometers, that measure reflectance of light at different wavelengths from vegetation. This is similar to the current NDVI curing index, which is derived from satellite imagery. This method could also possibly offer a quick field method to derive a curing estimate. The postdoctoral fellow in remote sensing should possess the necessary skills to research this technique.

Conclusion

These pilot studies have provided useful data for development of alternative methods to destructive sampling for assessing curing levels in grasslands. Destructive sampling, and the sorting of these samples, is time consuming, labour-intensive and can be logistically difficult in terms of transporting and processing samples. A simple tally method using a levy rod in the field is proposed as an alternative. This method is easy to carry out, and also fairly quick to complete in the field. These are important criteria for any field assessment program utilising in-kind support from fire agency personnel, as time and resources are often limited, particularly during the summer months. A further benefit of levy rod assessments is that much of the subjectivity associated with visual assessments is removed. Fuel moisture collection should continue to allow further validation and refinement of the grass curing and fuel moisture relationships. If possible, periodic destructive sampling should be undertaken to validate levy rod assessments.

Through these pilot studies, potential opportunities for further research have also been identified, such as the use of digital imagery for curing assessment in the field. This method requires further research and field testing, but does hold great potential as an extremely quick and easy method of fuel assessment.

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Appendix A – Sample sites

<u>Monaro Highway</u>

Improved pasture species dominated by *Phalaris* spp.

Photograph A.1. Monaro Highway sampling site.

Photograph A.2. Sample quadrat 0.25m² (horizontal profile).

Photograph A.3. Sample quadrat 0.25m² (vertical profile).

Table A.1. Data summary – Monaro Highway

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling 0.25m^2	Destructive Sampling 0.75m^2
8/08/2005	AF	88 (10)	89 (4)		95	76 (5)	93 (1)	91 (1)
17/08/2005	SA	95 (7)	91 (4)			88 (5)		
	FH	98 (5)	89 (4)		79	81 (5)		
6/09/2005	FH	77 (15)	88 (3)	87 (9)	90% @ 1.45pm		91 [4]	
	AF	84 (13)	89 (3)	91 (7)	86% @ 3.00pm			
8/09/2005	AF, FH				89			

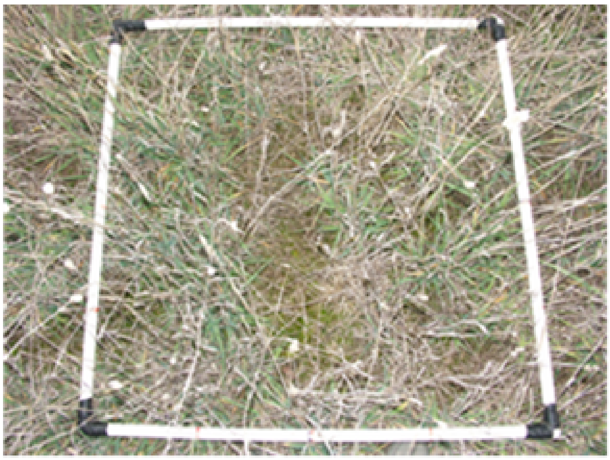
Results from the sampling conducted on 8/08/2005 showed reasonable agreement between the methods. Similar results were recorded on 17/08/2005. However, the fuel moisture content method gave somewhat lower estimates than the destructive sample results. This was most likely due to sampling live fuels that were unrepresentative of those live fuels collected in the destructive quadrats.

On the 6/09/2005 the sampling also yielded consistent results across the different sampling methods, with the exception of the Levy rod 1st touch method, which had a low estimate and large variability. The fuel moisture content method results on 6/09/05 proved far more consistent with the destructive samples, probably due to operators being more stringent in their collection techniques and only sampling live material representative of the live fuels found in the quadrats.

Fisher Parklands

Improved pasture species dominated by *Phalaris* spp..

Photograph A.4. Fisher Parklands Site.



Photograph A.5. Sample quadrat – $1m^2$ with $0.25m^2$ insert (horizontal profile).

Photograph A.6. Sample quadrat $0.25m^2$ (vertical profile).

Table A.2. Data summary – Fisher Parklands

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling 0.25m^2	Destructive Sampling 0.75m^2
11/08/2005	AF	60 (12)	81 (7)			53 (5)	87 (2)	86 (1)
18/08/2005	AF	80 (13)	75 (7)			54 (6)		
	FH	78 (12)	77 (7)		77	74 (6)		
	SA	85 (11)	75 (8)			72 (4)		
	RM	75 (13)	82 (7)			28 (8)		
	SF					21 (6)		

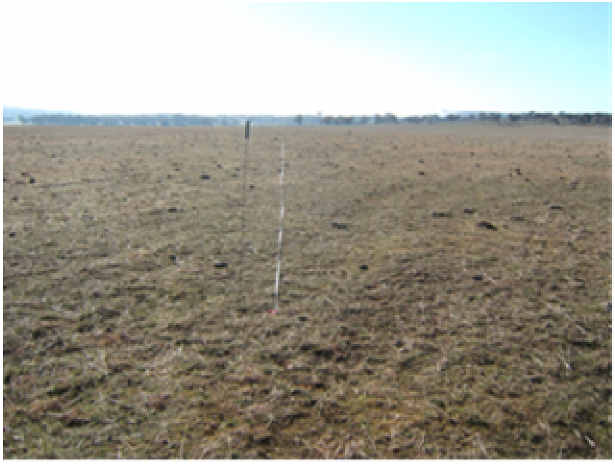
Although slightly lower than the destructive results, the Levy rod all-touches method was consistent for both sampling events. The low curing assessment from the Levy rod 1st touch on 11/08/2005 may be due to operator bias. This was remedied during future data collection by the operator closing his eyes whilst placing the rod, thereby avoiding subjective selection of sample areas.

The low curing assessment from the fuel moisture content method was most likely due to misrepresentation of the fuel strata in the dead grass samples. It was found that when samples were collected solely from the upper stratum, where the grass was drier, the curing assessment was skewed towards higher values. The opposite was found with the lower and typically wetter fuels from the lower strata. It is therefore important that representative and proportionally accurate moisture samples from the fuel strata are collected.

The height and cover assessments were all lower than the curing estimated from destructive sampling. There was also a large difference between estimates from different operators. Operators RM and SF were not experienced in using the method, but even the trained operators gave widely varying estimates.

Majura Firing Range

Improved pasture species, mostly native with some exotic grasses.
Inconsistent, patchy fuel loads. Rainfall event in between the sampling dates.



Photograph A.7. Majura Firing Range site.

Photograph A.8. Sample quadrat 1m² (horizontal profile).

Table A.3. Data summary – Majura Firing Range

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling $0.25m^2$	Destructive Sampling $0.75m^2$
16/08/2005	AF	60 (15)	55 (9)			57 (5)		
	BR	62 (15)	65 (8)			50 (5)		
	SA	69 (14)	72 (8)			96 (2)		
	FH	62 (15)			91		97 (1)	96 {10}***
6/09/2005	FH	46 (5)	61 (5)	56 (10)			69 [6]	
	AF	40 (14)	56 (6)	56 (11)				

*** {ME} from 2 samples

The first sampling event on 16/08/2005 produced relatively consistent results for the Levy rod 1st touch method between operators. This is to be expected, given the lack of tillers and the constant height of the live and dead fuel between sample points at this site. Similar results were obtained from the Levy rod all-touches and first touch by stratum methods. The height and cover assessment once again produced a large range of curing values between operators.

Reliability of curing results from the destructive samples was significantly reduced due to soil contamination of the samples when collected. The excess weight resulting from the soil being mixed with the dead grass raised the live:dead ratio in favour of the dead fuels, thereby raising the curing estimates significantly. This was particularly a problem with the sampling carried out on 16/08/2005, and these results were therefore disregarded in the analysis of the data, as presented in the results section of this report. The estimate of 69% on 6/09/05 was probably representative of the curing, but it may still be somewhat high.

Rainfall was received between the two sampling periods and the results support the field observations with the increased proportion of live fuels through new growth. On 6/09/05 the Levy rod first touch method produced very low results compared to the destructive sampling estimate, and was probably biased because the live fuel was growing near the ground underneath the old tillers. The other two Levy rod methods produced somewhat lower results than expected, and it is not clear whether there is a problem with the Levy rod method, a problem with the destructive samples, or it is simply a result of sampling variation.

Umbigong Park

Predominantly native pasture grasses (*Themeda* species).

Photograph A.9. Umbigong Park site.

Photograph A.10. Sample quadrat $1m^2$ (horizontal profile).

Photograph A.11. Sample quadrat $1m^2$ (vertical profile).

Table A.4. Data summary – Umbigong Park

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling 0.25m^2	Destructive Sampling 0.75m^2
30/08/2005	AF	95 (6)	94 (3)		81	82 (8)	92 [3]	
	FH	98 (3)	92 (3)			85 (6)		
1/09/2005	AF	95 (10)	92 (3)	95 (6)	75% @ 10.30am			
	FH	95 (10)	93 (3)	95 (7)	70% @ 12.00am			
					84% @ 1.00pm			

Results from each method are consistent between the two sampling events.

The Levy rod 1st touch over-predicted curing due to the taller dead tillers and seed heads making first contact with the rod. The Levy rod all touches results matched the actual curing values. This is most likely because the dead material in the tillers of the native grasses at this site do not form a sheath around the live fuel, as is the case with improved pasture species. Although slightly high, the Levy rod 1st touch by stratum is consistently accurate between operators and compared to the destructive samples.

The differences between the fuel moisture content and destructive samples is unexplained, as the fuel moisture samples were collected from representative species and included a proportional representation of the fuel strata in the destructive quadrats.

Although the curing values from the height and cover assessments are close between operators, differences with the actual curing from destructive samples are still considerable.

Milton

Improved pasture species (Kaikoura).
Coastal site with recent rainfall events.

No photographs available.

Table A.5. Data summary - Milton

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling $0.25m^2$	Destructive Sampling $0.75m^2$
12/09/2005	AF	33 (17)	81 (3)	66 (12)	63		72 [6]	
	FH	43 (18)	83 (3)	71 (12)				

The Levy rod 1st touch method under-estimated curing due to the high amount of dead fuel in lower strata present from the last season's curing cycle, as well as emerging new growth. The Levy rod all-touches method over-predicted curing due to the improved pasture species present at this site. The outer tillers were encased in a dead sheath with live fuel underneath, but were recorded as dead. As a result the all touch method tends to over-predict the curing of the site. The Levy rod 1st touch per stratum results are the most accurate, and the average falls within 5% of the actual curing, possibly because of a combination of over and under prediction for the reasons given above.

The difference between the fuel moisture content and the destructive sample is unexplained, as the fuel moisture samples were collected from representative species and included a proportional representation of the fuel strata in the destructive quadrats.

Darfield

Improved pasture species, predominantly rye grass (*Lolium perenne*) and goose grass (*Bromus mollis*)

Photograph A.12. Darfield site.

Photograph A.13. Sample quadrat 1m² (horizontal profile).

Table A.6. Data summary – Darfield

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling $0.25m^2$	Destructive Sampling $0.75m^2$
16/09/2005	TO	25 (19)	54 (7)	63 (15)	45		58 ((9))	
	SA	5 (10)	51 (7)	53 (15)				
	FT	25 (19)	50 (7)	63 (15)				

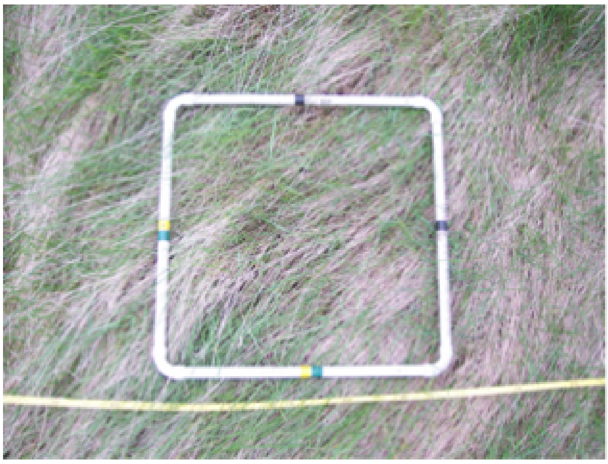
The Levy rod 1st touch method underestimated curing significantly. This is most likely because the first touch was in many cases new growth of either tillers or sward, and not the dead material from the last season and the winter that was present in the lower strata, particularly as thatch. The values from the Levy rod all touches method were close to the actual (destructive) curing value for the site, as expected. The Levy rod first touch by stratum method also closely matched the destructive value.

The difference between the fuel moisture content and the destructive sample is unexplained, as the fuel moisture samples were collected from representative species and included a proportional representation of the fuel strata in the destructive quadrats. It is possible that some residual moisture from rainfall in the days prior to sampling was present, but this is not certain.

Godley Head

Retired pasture grass and native mix, predominantly perennial rye grass and clover. Some weeds present.

Photograph A.14. Godley Head site.



Photograph A.15. Sample quadrat $1m^2$ (horizontal profile).

Photograph A.16. Sample quadrat $1m^2$ (vertical profile).

Table A.7. Data summary – Godley Head

Date	Operator	Levy Rod 1st Touch	Levy Rod All Touches	Levy Rod 1st Touch by Stratum	Fuel Moisture Content Method	Height/ Cover	Destructive Sampling $0.25m^2$	Destructive Sampling $0.75m^2$
17/09/2005	TS0	40 (21)	71 (4)	62 (14)	50		80 ((8))	
	SA	40 (21)	72 (5)	62 (14)				
	TS0	25 (19)	74 (5)	57 (15)				

The Levy Rod all touches method gave estimates closest to the destructive sampling results. The other two Levy rod methods yielded curing estimates very different to the average from the destructive sampling quadrats. This could be due to the nature of the grass fuel complex at this site. It is an ungrazed area containing a significant proportion of perennial grasses, and as a result has a significant layer of dead thatch accumulated over many seasons. The average thatch depth was estimated to be 5cm, and was a dense layer. The thatch layer was not easily visible without separating the grasses, and for this reason a cursory visual assessment of the site estimated the curing to be around 60%. The grasses were mostly in a spring new growth phase, so the first touches favoured the live material. The thatch layer was also very difficult to tally accurately, due to the density of the layer and the errors introduced when trying to separate the matted thatch material. The all touches method slightly underestimated the curing due to a lower tally of dead thatch than was actually the case, but gave an acceptable estimate nonetheless. The 1st touch by stratum method badly underestimated the curing due to only one dead count for thatch (when there was a very thick layer present) and significant live counts for the grass sward stratum. Weighting the thatch layer when using this method may improve the accuracy of estimates when sampling in grassland fuel complexes with significant thatch layers, and it is recommended that the all touches method be used for these types of grasslands.

The difference between the fuel moisture content and the destructive sample may be due to bias in sampling. The dead fuel moisture content would have had to be around 100% to obtain a curing estimate of 80%. The average dead fuel moisture was in fact 30%. It is possible that dead FMC sampling favoured grass tillers and sward, and that a representative proportion of thatch (at higher FMC due to dampness and less exposure to drying) was not collected. However, this is not certain and would require further field sampling to confirm or reject this.

Appendix B – Sample methodology

Destructive sampling Methodology

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species composition. Sites on level terrain are preferred. Allow enough area to fit two 20 m transects at right angles to each other.
2. Five destructive samples need to be collected from each site.
3. Use the random number chart to assign the transect, and which point along the transect the sample will be collected from. Place the $0.25m^2$ quadrat down at the designated point along the transect, and secure with tent pegs or similar (this stops the frame from moving during sampling).
4. Cut around the edges of the frame to ensure only the fuel bound by the quadrat is sampled. Cut down to the ground level, as low as possible without collecting soil or stones.
5. Place all above-ground material into a large tin and seal. Alternately place into a large, robust plastic zip-lock bag. Label all bags with the location, date, axis and plot number.
6. Repeat this method for all five samples.
7. In the laboratory, separate each sample into live and dead material. Place this live and dead sorted material into separate, pre-weighed labelled bags[1]. Leaving the bags open, place into the oven and dry at 105ºC for 24 hours.
8. Weigh and record sample weights.
9. Grass curing percentage is then determined by the following equation:

$$\text{Curing} = (\text{Net weight of dead sample/Total net sample weight}) \times 100$$

Important:

- Upon allocation of suitable sampling sites, a destructive sample size validation program is to be carried out to ensure that five samples from $0.25m^2$ quadrats produce an accurate curing assessment representative of the larger area.
- Samples should be weighed immediately after being removed from the oven. The samples will rapidly re-absorb the moisture from the atmosphere.
- White sorting trays are recommended for the separation of live and dead material. This process should be carried out in a calm (still air) environment, such as a laboratory.

Equipment:

- Tape measure
- Sampling quadrat ($0.25m^2$)
- $1m^2$ quadrat for sample size validation
- Tent pegs
- Cutters/shears
- Tins and / or zip-lock bags.
- Marking pens
- Sorting trays

Destructive sampling booking sheet

[1] Individual bags can be pre-weighed after oven drying at 105°C for 24 hours. If the same type of bag is being used for all samples, oven-dry a minimum of 10 bags at 105°C for 24 hours and use the average of the ten bags as the standard bag weight for all curing weights.

Destructive Sample Size Validation Program

Assessors:
Location: ________________________ **Date:** ____________________

Kestrel:
Temperature: __________
RH: __________

Transect Location (m)	$0.25m^2$ ODW Live Grass (g)	Live Grass Bag weight (g)	Net Live Grass (g)	$0.25m^2$ ODW Dead Grass (g)	Dead Grass Bag weight (g)	Net Dead Grass (g)	$0.25m^2$ ODW Combined (g)	$0.25m^2$ Curing (%)

Height/Cover Methodology

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species composition. Sites on level terrain are preferred. Allow enough area to fit a 40 metre transect. This distance may be simply paced out whilst sampling.
2. Assess and record visual estimate of grass curing based on Victorian CFA Grassland Curing Guide 1999.
3. Assess and record pasture type, fuel condition and curing phase.
4. At 2m intervals, place the $0.25m^2$ quadrat and secure with tent pegs.
5. Visually divide the vertical profile of the grass into the required strata (as per the booking sheet), and assess the average height, percentage ground cover and degree of curing for each stratum.

Important:

- The booking sheet is not restricted to the use of only three strata. As many strata can be used as deemed necessary by the operator to accurately assess the site.
- The number of strata used may vary amongst operators at any given site and remain valid as long as the fuel in each stratum is assessed only once, and independently of the remaining grass profile.
- It is recommended that the sides of the quadrat be divided into 10% intervals (using a marker, or tape) to allow easier assessment of the percentage ground cover.

Equipment:

- CFA guide
- Tape measure
- $0.25m^2$ quadrat
- Tent pegs
- Clipboard
- Ruler
- Marking pen or tape

Height/cover field booking sheet

bushfire CRC

Grass Curing Project - Height and Cover Methodology Field Data Sheet

Assessors:	Date:
Location:	Transect Line Bearing (o):
GPS Location: North/Lat:	East/Long:

Visual estimation of grass curing along transect based on Victorian CFA Grassland Curing Guide 1999 (circle one).

0 10 20 30 40 50-60 70-80 90 100

Is the assessment transect representative of the broader landscape level of curing?

Yes No.

Pasture Type (circle one)

Cultivation Native Grass Improved pasture

Fuel Condition (circle one)

Ungrazed Grazed Eaten Out

Curing Phase (circle one)

Flowering Curing Fully Cured Growth Phase

	Strata 1 - Tillers and Seed Heads				Strata 2 - Thatch and Litter					Strata 3 - Grass Sward				Strata 4 - Non Grass Sward (ie thistle, herbs and forbs)				Plot Summary	Total Volume
	Type	Height (cm)	Cover (%)	% Cured	Type	Height (cm)	Cover (%)	% Cured	% Bare Soil	Type	Height (cm)	Cover (%)	% Cured	Type	Height (cm)	Cover (%)	% Cured	% Cured	
Plot 1	Grass				Litter					Grass				Herb/B-leaf					
Plot 2	Grass				Litter					Grass				Herb/B-leaf					
Plot 3	Grass				Litter					Grass				Herb/B-leaf					
Plot 4	Grass				Litter					Grass				Herb/B-leaf					
Plot 5	Grass				Litter					Grass				Herb/B-leaf					
Plot 6	Grass				Litter					Grass				Herb/B-leaf					
Plot 7	Grass				Litter					Grass				Herb/B-leaf					
Plot 8	Grass				Litter					Grass				Herb/B-leaf					
Plot 9	Grass				Litter					Grass				Herb/B-leaf					
Plot 10	Grass				Litter					Grass				Herb/B-leaf					
Average																			
Notes:																			

Fuel Moisture Content Methodology.

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species. Sites on level terrain are preferred.
2. Assess and record visual estimate of grass curing based on Victorian CFA Grassland Curing Guide 1999.
3. Assess and record pasture type, fuel condition and curing phase.
4. Collect 5 live grass fuel moisture samples. Place sample in air tight, clean, dry and pre-weighed tin. Tape lid. Record the container number on the sampling sheet.
5. Collect 5 combined destructive samples ($0.25m^2$ quadrats), as per the methodology for destructive sampling. Place in a large tin if available (2 litre), or robust large plastic zip-lock bag. Record the container number on the sampling sheet. Alternatively, collect 5 combined fuel moisture samples in tins as used for live and dead samples.
6. Collect 5 small dead grass fuel moisture samples. Place sample in air tight, clean, dry and pre weighed tin. Tape lid. Record the container number on the sampling sheet.
7. Weigh all samples ASAP and record wet weights on sampling sheet. Ensure that all tape is removed from the tin lids prior to weighing. The recorded weight is to include container and lid.
8. Oven-dry samples for 24 hours at $105^{o}C$ with the lids off. Combined samples (from $0.25m^2$ destructive sampling) should be transferred to large paper bags or tray for drying[1]. Remember to account for this change of weight when carrying out the fuel moisture calculations.
9. After oven drying weigh all samples and record oven dry weight (ODW).
10. Calculate FMC and curing for large sample using the spreadsheet.

Important

- When collecting FMC samples, it is imperative that the appropriate grass species for the area are represented in the sample. This is especially important if the FMC samples are to be compared against the destructive sample results.
- Ensure that the vertical profile of the grass is represented in the samples. Due to the higher strata commonly being drier through greater exposure, and the lower strata wetter via screening from the overstorey, a proportionate mix is required for accuracy.

Equipment:

- Sampling quadrat ($0.25m^2$)
- Small sampling tins x 10
- Large sampling tins or zip-lock x 5
- Tape
- Cutters/shears

[1] If using the destructive samples as the combined fuel moisture sample, simply combine the oven-dried weight of the sorted live and dead material to obtain the oven-dry weight of the combined sample. Remember to take account of different bag weights in calculations.

Fuel moisture content booking sheet

Grass Curing Project - Fuel Moisture Content Sorting Data Sheet

Assessors: Date:

Location:

Visual estimation of grass curing along transect based on Victorian CFA Grassland Curing Guide 1999 (circle one).

0 10 20 30 40 50-60 70-80 90 100

Pasture Type (circle one)

Cultivation Native Grass Improved pasture

Fuel Condition (circle one)

Ungrazed Grazed Eaten Out

Growth Phase (circle one)

Flowering Curing Fully Cured New Growth

	Container Number	Container weight (g)	Pre Oven Sample Weight (incl container) (g)	Pre oven sample weight (excl container) (g)	ODW Weight (incl container) (g)	ODW of Sample (24hrs @105°C) (g)	FMC (%)
Live Fuel FMC Sample #1							
Live Fuel FMC Sample #2							
Live Fuel FMC Sample #3							
Live Fuel FMC Sample #4							
Live Fuel FMC Sample #5							
Dead Fuel FMC Sample #1							
Dead Fuel FMC Sample #2							
Dead Fuel FMC Sample #3							
Dead Fuel FMC Sample #4							
Dead Fuel FMC Sample #5							
Large Combined Fuel Sample #1 (0.25m2)							
Large Combined Fuel Sample #2 (0.25m2)							
Large Combined Fuel Sample #3 (0.25m2)							
Large Combined Fuel Sample #4 (0.25m2)							
Large Combined Fuel Sample #5 (0.25m2)							

Anderson and Hines FMC Method 2005

Live Fuel Sample Average FMC (%)	
Dead Fuel Sample Average FMC (%)	
Combined Fuel Sample Average FMC (%)	
% Curing of Large Sample	

Simon Millie's FMC Formula 1999

% Curing of Large Sample	

Barber's FMC Formula 1990

% Curing of Large Sample	

Results from sorted and oven dried destructive sample (results cut and pasted from Destructive Sample Size Validation.

Levy Rod All Touches Methodology:

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species. Sites on level terrain are preferred. Allow enough area to fit a 40 metre transect. This distance may be simply paced out whilst sampling.
2. At the first metre mark strike the levy rod vertically into the earth.
3. Record all contacts made with the rod starting from the highest contact to the lowest. Record the contacts as live or dead.
4. Move to the next metre interval and repeat the process, continuing for the length of the transect.
5. Grass curing is then determined through the following formula:
   Degree of Curing (%) = (Total dead touches/Total Touches) x 100

Important

- It is important that the levy rod is as close to perpendicular with the earth as possible to ensure an accurate representation of the vertical profile of the grass.
- When driving the levy rod into the ground at the sample points, the operator should not directly look at the area to be sampled. This eliminates operator bias.

Equipment:

- Levy rod: A steel rod 1.3 metres in height, 3.5mm – 5mm in diameter, with the tip fashioned into a point. A handle may be mounted to allow ease in operational use.
- Booking sheets

Levy Rod 1st Touch per Stratum Methodology:

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species. Sites on level terrain are preferred. Allow enough area to fit a 40 metre transect. This distance may be simply paced out whilst sampling.
2. At the first metre mark strike the levy rod vertically into the earth.
3. Record the first contact made with the rod over each of the following three strata: tillers, grass sward and thatch. Record the contacts as live or dead.
4. Move to the following metre interval and repeat the process, continuing for the length of the transect.
5. Grass curing is then determined through the following formula:
   Degree of Curing (%) = (Total dead touches/Total touches) X 100

Important

- It is important that the levy rod is as close to perpendicular with the earth as possible to ensure an accurate representation of the vertical profile of the grass.
- When driving the levy rod into the ground at the sample points, the operator should not directly look at the area to be sampled. This eliminates operator bias.
- The number of strata is not in all cases restricted to the three listed above. It is rather determined by the grass types present. If more than three vertical strata are identified, it is essential that each defined stratum is only counted once.

Equipment:

- Levy rod: A steel rod 1.3 metres in height, 3.5mm – 5mm in diameter, with the tip fashioned into a point. A handle may be mounted to allow ease in operational use.
- Booking sheets

Levy Rod 1st Touch Methodology:

1. Select a site that is representative of the overall area with respect to slope, aspect and grass species. Sites on level terrain are preferred. Allow enough area to fit a 40 metre transect. This distance may be simply paced out whilst sampling.
2. At the first metre mark strike the levy rod vertically into the earth.
3. Record the first contact made with the rod (the highest touch) as live or dead.
4. Move to the following metre interval and repeat the process, continuing for the length of the transect.
5. Grass curing is then determined through the following formula:
   Degree of Curing (%) = (Total dead touches/Total touches) X 100

Important

- It is important that the levy rod is as close to perpendicular with the earth as possible to ensure an accurate representation of the vertical profile of the grass.
- When driving the levy rod into the ground at the sample points, the operator should not directly look at the area to be sampled. This eliminates operator bias.

Equipment:

- Levy rod: A steel rod 1.3 metres in height, 3.5mm – 5mm in diameter, with the tip fashioned into a point. A handle may be mounted to allow ease in operational use.
- Booking sheets

Levy Rod booking sheet

Assessors: ______________________ **Date:** ______________
Location: ______________________

T = Tillers, S = Sward, Th = Thatch

Transect Location (m)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Touch No. 1	Strata (T/S/Th)																					Touch No. 1
	Live or Dead																					
Touch No. 2	Strata (T/S/Th)																					Touch No. 2
	Live or Dead																					
Touch No. 3	Strata (T/S/Th)																					Touch No. 3
	Live or Dead																					
Touch No. 4	Strata (T/S/Th)																					Touch No. 4
	Live or Dead																					
Touch No. 5	Strata (T/S/Th)																					Touch No. 5
	Live or Dead																					
Touch No. 6	Strata (T/S/Th)																					Touch No. 6
	Live or Dead																					
Touch No. 7	Strata (T/S/Th)																					Touch No. 7
	Live or Dead																					
Touch No. 8	Strata (T/S/Th)																					Touch No. 8
	Live or Dead																					
Touch No. 9	Strata (T/S/Th)																					Touch No. 9
	Live or Dead																					
Touch No. 10	Strata (T/S/Th)																					Touch No. 10
	Live or Dead																					
Touch No. 11	Strata (T/S/Th)																					Touch No. 11
	Live or Dead																					
Touch No. 12	Strata (T/S/Th)																					Touch No. 12
	Live or Dead																					
Touch No. 13	Strata (T/S/Th)																					Touch No. 13
	Live or Dead																					
Touch No. 14	Strata (T/S/Th)																					Touch No. 14
	Live or Dead																					
Touch No. 15	Strata (T/S/Th)																					Touch No. 15
	Live or Dead																					
Touch No. 16	Strata (T/S/Th)																					Touch No. 16
	Live or Dead																					
Touch No. 17	Strata (T/S/Th)																					Touch No. 17
	Live or Dead																					
Touch No. 18	Strata (T/S/Th)																					Touch No. 18
	Live or Dead																					
Touch No. 19	Strata (T/S/Th)																					Touch No. 19
	Live or Dead																					
Touch No. 20	Strata (T/S/Th)																					Touch No. 20
	Live or Dead																					

Transect Location (m)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Touch No. 21	Strata (T/S/Th)																					Touch No. 21
	Live or Dead																					
Touch No. 22	Strata (T/S/Th)																					Touch No. 22
	Live or Dead																					
Touch No. 23	Strata (T/S/Th)																					Touch No. 23
	Live or Dead																					
Touch No. 24	Strata (T/S/Th)																					Touch No. 24
	Live or Dead																					
Touch No. 25	Strata (T/S/Th)																					Touch No. 25
	Live or Dead																					
Touch No. 26	Strata (T/S/Th)																					Touch No. 26
	Live or Dead																					
Touch No. 27	Strata (T/S/Th)																					Touch No. 27
	Live or Dead																					
Touch No. 28	Strata (T/S/Th)																					Touch No. 28
	Live or Dead																					
Touch No. 29	Strata (T/S/Th)																					Touch No. 29
	Live or Dead																					
Touch No. 30	Strata (T/S/Th)																					Touch No. 30
	Live or Dead																					
Touch No. 31	Strata (T/S/Th)																					Touch No. 31
	Live or Dead																					
Touch No. 32	Strata (T/S/Th)																					Touch No. 32
	Live or Dead																					
Touch No. 33	Strata (T/S/Th)																					Touch No. 33
	Live or Dead																					
Touch No. 34	Strata (T/S/Th)																					Touch No. 34
	Live or Dead																					
Touch No. 35	Strata (T/S/Th)																					Touch No. 35
	Live or Dead																					
Touch No. 36	Strata (T/S/Th)																					Touch No. 36
	Live or Dead																					
Touch No. 37	Strata (T/S/Th)																					Touch No. 37
	Live or Dead																					
Touch No. 38	Strata (T/S/Th)																					Touch No. 38
	Live or Dead																					
Touch No. 39	Strata (T/S/Th)																					Touch No. 39
	Live or Dead																					
Touch No. 40	Strata (T/S/Th)																					Touch No. 40
	Live or Dead																					

	Totals
All Touches Live	
All Touches Dead	
First Touches Live	
First Touches Dead	
First Touch each Strata Live	
First Touch each Strata Dead	

Digital Image Methodology:

In the field:

Select a site that is representative of the overall area with respect to slope, aspect and grass species. Sites on level terrain are preferred. Imagery should be combined with destructive sample quadrats.

At each quadrat, take photographs as described below with a digital camera. Use a sheet/board identifying the site, date and plot number and include this in the photographs.

a. A downward-looking digital photograph of the $1m^2$ quadrat.
b. A profile (side-on) photograph of the grass from the ground surface to the tops of the tillers. Flatten the grass in front of the profile to obtain a “clean” face of grass at the profile. A hardboard sheet weighted down with bricks may be necessary for this. Take photographs with the sun behind the camera, i.e., shining onto the grass profile.
c. A profile (side-on) photograph, as described above, but with a sheet of black cardboard/hardboard behind the grass profile. This is to provide a uniform background for image analysis.

Important

- Images should be taken in full sunlight during the middle of the day (1200-1400), to minimise the effect of shadows.

In the laboratory:

1. Prior to sorting and drying destructive samples, spread the sample out on a black background.
2. Use a sheet/board identifying the site, date and plot number and include this in the photograph.
3. Take two digital photographs of the grass from directly above, one with and the other without the flash.
4. Record the image number on the booking sheet for future reference.

Important

- The grass should be spread as thinly as possible over the black background.

Equipment:

- Sampling quadrat ($0.25m^2$)
- Digital camera
- Notebook
- Booking sheets
- Hardboard sheet (and bricks) for flattening grass in the field
- Hardboard sheet painted black (matt finish)

Digital imagery record sheet

bushfire CRC

Grass Curing Project - Digital Imagery Field Data Sheet

Assessors:	Date:
Location:	Transect Line Bearing (o):
GPS Location: North/Lat:	East/Long:
Start time:	Finish time:

Visual estimation of grass curing along transect based on Victorian CFA Grassland Curing Guide 1999 (circle one).

0 10 20 30 40 50-60 70-80 90 100

Is the assessment transect representative of the broader landscape level of curing?

Yes No.

Pasture Type (circle one)

Cultivation Native Grass Improved pasture

Fuel Condition (circle one)

Ungrazed Grazed Eaten Out

Curing Phase (circle one)

Flowering Curing Fully Cured Growth Phase

	Downward-looking photograph Photograph number	**Profile photograph (without background)** Photograph number	**Profile photograph (with background)** Photograph number	**Laboratory photograph on background** Photograph number
Plot 1				
Plot 2				
Plot 3				
Plot 4				
Plot 5				
Plot 6				
Plot 7				
Plot 8				
Plot 9				