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Proceedings of the National Workshop on the use of ^{137}Cs to Measure Erosion

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Soil Conservation Service of New South Wales
Sydney September 20-21, 1988

OVERVIEW OF THE NATIONAL WORKSHOP ON THE USE OF CAESIUM-137 TO MEASURE EROSION

The National Soil Conservation Program provided funds for a workshop to discuss the use of Caesium-137 to measure erosion.

The Workshop was held in Sydney on 20th and 21st September, 1988 and was attended by 12 persons vitally concerned with the use and development of Cs^{137} techniques of measuring erosion. In addition written contributions were solicited from a further 12 workers in this field.

A brief report of the Workshop, with related papers, is attached. From this it can be seen that the first day was one of in-depth discussion. This allowed all points of contention to be laid on the table and discussed at length (as necessary) with a view to achieving consensus at the end of the workshop.

These discussions were most fruitful and were appreciated by all participants as they were able, for the first time, to discuss in person in a round-table setting any differences to a point of agreement.

The overall outcome of the Workshop was a view that:

. it is inappropriate at this time to conduct a comprehensive national assessment of soil erosion using the Caesium-137 technique, BUT

. it is appropriate to conduct a reconnaissance survey which would (i) establish/confirm reference levels of Cs^{137} deposition across Australia (ii) establish, at a statistically viable level, the capability to confirm at least large differences in Cs^{137} concentration, and (iii) build up a more comprehensive picture of Cs^{137} and its association with soil movement in the Australian landscape.

The workshop further decided that a reconnaissance survey using some 120 agroclimatic/land use/toposequence sites across Australia would meet these requirements. Such a survey would be carried out over a 2 year period and would require purchase of four additional Cs^{137} detectors to analyze the proposed 4,200 samples.

Depending on the method of financing staffing for sample preparation and processing, the total cost of the program including 4 detectors would be $432,000 (using fully trained professional staff) or $352,000 (using studentships) over 2 years.

It was considered that collection of samples is a State responsibility. A maximum of 35 samples would be collected at each of the 120 toposequence sites (grazed and cultivation paired) Australia-wide and each set of these samples would take 2 people three days to collect. Some additional time would be involved in site selection and related tasks. The overall time involvement from the States in sample collection would be 720 working days or approximately 3 person-working years (spread over 2 calendar years). This would be shared by the States and Territories with the actual burden an each depending upon final sample site selection.

The workshop participants were strongly of the view that such a reconnaissance survey was a program which could be funded by the National Soil Conservation Program.

G.M. CUNNINGHAM
WORKSHOP CHAIRMAN

Introduction

There is a superficial enigma about land degradation. On one hand, almost unanimously, environmental scientists propose that land degradation is progressively reducing the real productivity of our nation's soil resources. On the other hand, agricultural yields are consistently increasing. [Although even in the matter of yields, long term trends for decline in quality have been recognised by some.]

The reasons for this apparent discrepancy include the effects of; improved management; weed, pest and disease control; improved varietal potential; fertilizer use and technology etc. Therefore the true cost of degradation is both masked by these improvements and hidden from us by our general inability to measure irreversible degradation.

Assessments of irreversible degradation are both subjective and/or probabilistic. Such assessments are difficult to interpret.

Results of worldwide investigations of the destruction of ^{137}Cs in soils have led to the possibility that Caesium-137 may be useful for either or both sediment tracing and quantitative erosion assessment. (Erosion is a major component of irreversible land degradation).

The Federal Soil Conservation Advisory Committee was keen to obtain an objective review of the current status of the use of the Caesium-137 technique for the above purposes. The National Soil Conservation Program therefore provided financial support for a National workshop for this purpose. This report contains the proceedings of that workshop.

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<u>Contributors</u>

While it was not possible to assemble a large number of people from diverse locations for this workshop, it was well recognised that the opinions of as many people as possible associated with the caesium technique should be sought.

In addition to non-specific requests to colleagues of all people contacted, contributions to the workshop were therefore solicited from the following:

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<u>Program</u>

The purpose of the workshop was to determine the feasibility of a national assessment of soil erosion using Caesium 137.

Workshop Chairman G.M. Cunningham

Day 1 <u>Session 1</u>	<u>Precision of Measurement and Interpretation of Data</u>
Part (a) Overview: 800-1000	Evan Thomas . statistical techniques to aid sampling within and between catchments . statistical techniques to aid processing of data
Part (b) Overview: 1030-1230	Greg Elliott . interpretation of Caesium values/concentration/distribution within soil profiles
<u>Session 2</u> 1330-1530, 1600-1630	<u>Recent and projected application of the ^{137}Cs technique to estimate land degradation</u>
Overview:	Bob Loughran . land use effects . soil type effects . climate effects

	Session 3	Prerequisites for a National Degradation Assessment Program and
	1630-1730	Procedures for a National Degradation Assessment Program
	Overview:	B.L. Campbell . equipment availability (including hardware) . staff resource requirements for sample preparation. . efficiency of output of results
Day 2	Session 3 (cont) 800-1030 1030-1230 1330-1630	. selection of sample sites . sampling programs . constraints in interpretation
	Session 4	Recommendations

WORKSHOP PROCEEDINGS

1. Session 1

a) Statistical Techniques to aid Sampling and Date Processing

In this session of the workshop statistical prerequisites to the design and running of a national survey were established.

The workshop participants agreed that a national survey would be possible if the following factors could be defined, in terms which would permit the reproduction of mappable units;

element	-	unit of measurement (although the measurement may include a group of elements)
population	-	the group of elements about which we may make inferences
sampling units	-	the collection of non-overlapping elements
frame	-	list of sampling units
sample	-	collection of sampling units drawn from the frame

The workshop participants further agreed that stratified random sampling (as opposed to systematic, simple random sampling or cluster sampling) would be the preferred method of sampling.

A hypothetical case for a sampling strategy was presented to the workshop. After discussion, the variables in sampling were established; (i.e. the main factors affecting variations in soil loss).

These were:

. climatic zone (rainfall)
. slope
. slope length
. management

The workshop participants agreed that, given the ability to map the variables, a presentation of results in tabular and spatially variable form should be possible. Tha meeting established that the first need for quantitative data was to understand how many data points in a very small area (<<1ha) would represent a large "uniform" area.

The participants noted that: sampling would need to be based on geographically/geomorphologically identifiable factors; manual sampling would be required and; samplers would need to agree on uniform standards of site selection.

The participants discussed at some length the "bounds" of these large uniform areas and the necessity to establish an understanding of the Caesium-137 'numbers which have validity at policy level'. Several "bounds" were suggested which seemed practical to adopt. However the bounds were not defined in detail although recognisable land types such as those listed below were generally agreed upon as being the typres of units that could be used in a National Survey.

i) Darling Downs soils with slopes >1%
ii) Cotton soils on bottom lands in parts of Arkansas
iii) Sections within slopes
iv) Units within CSIRO Land Systems and
v) Landform elements

The total number of measurements necessary within these areas could easily be determined by applying pre-set statistical standards. Variations in management effects are factors which could not easily be mapped but general results could be presented for geomorphic units, even if all management possibilities were not encompassed during sampling.

The number of data points required is something which can only be determined by an actual sampling exercise in a mapping unit of defined bounds.

The participants recognised the magnitude of the task of sampling every combination of slope, slope length, landuse, etc, in Australia but the effects of these compounding factors can be overcome by;

i) modelling slopes and
ii) applying USLE-type statistical correlations to areas of interest to obtain "ball park" figures which at least define the order of magnitude of soil loss.

<u>b) Interpretation of caesium-137 concentrations and distributions within soil profiles</u>

The aim of this session was to address the distribution and total of Caesium-137 levels in a soil profile in a manner compatible with the requirements of the first session. Simply stated we need to investigate the interpretation of caesium-137 activities in order to;

i) make quantitative estimates of soil loss
ii) make efficient allocation of resources to repair erosion damage [Although it is possible that the prevention of erosion damage is in itself a more economically desirable activities.]
iii) create a benchmark for measurement of future changes in erosion status, and,
iv) validate perceived land-use effects

This session featured discussion on the mapping and mappability of landform elements and on the number of observations necessary to be made within landform unit boundaries. Further discussion was had the definition of degradation. It was necessary to reiterate that the workshop, concerned 'sheet' erosion by water. Nevertheless, with respect to a national survey, several useful constraints were articulated at this time;

i) a national survey would probably not include central Australia
ii) there is a need to develop an understanding of ^{137}Cs adsorption processes in water repellant soils and
iii) areas of wind erosion would require special consideration with respect to understanding Caesium-137 adsorption, redistribution and the quantitative interpretation of soil loss.

The results of a comparative study of measured soil loss and residual soil Caesium-137 content were presented to the meeting. It was proposed that in appropriate circumstances (i.e. where sheet erosion and very minor rill erosion had occurred in continuously uniformly managed areas) the average net soil erosion rate could be estimated from the regression of soil loss on measured relative caesium-137 deficit. A minority of participants only appeared to accept this regression as a useful basis for quantitative estimation of soil loss.

The merits of the proportional loss model of Kachinoski and de Jong were then discussed. The model was consistent with soil loss measured at Pokolbin and with plot results obtained at the University of Guelph, Canada. These results indicate that for cultivated soils in which the Caesium-137 content can be estimated for the early 1970's, the proportional model may be used to estimate soil loss.

Steve Perrens noted that Caesium-137 and soil loss correlations had been developed from essentially limited data. He proposed that this data base could be expanded by making additional Caesium-137 measurements on areas where information on different management practices was available (even if the number of available sites was also limited). In this way management (and conservation) practices could be built into an empirically based model for the extrapolation of all data. Later discussion also identified the possibility of building slope and slope length factors into a multiple regression model of Caesium-137 redistribution.

The session saw purist and pragmatic views expressed. The pragmatic view being that there was a need to obtain real Caesium-137 values for;

i) their own value
ii) interpretation with current knowledge or
iii) re-interpretation in the light of future advances in understanding

The purist view required measurement of sufficient factors to understand why the caesium-137 activity is as it is.

The criticisms of the purist view were that;

i) it is probably impossible to obtain sufficiently detailed management records to enable an understanding of prior soil conditions and
ii) ground cover estimates would be impossible to obtain

The extreme episodicity of erosion events in Australia was seen to further complicate the process of developing a model for explaining a particular caesium-137 concentration value.

Session 2

Applications of the ^{137}Cs Technique

Bob Loughran presented a unified scale slope model with six (6) units. A large range of case studies in Australia fitted this model. Significantly, independently derived data also fitted the model.

Individual case studies were also presented. These studies well illustrated the effects of landuse, slope length and geomorphology. They also well illustrated the quantitative differences in ^{137}Cs activities which have been consistently measured between areas of different landuse.

Opinions of participants were somewhat at variance about the issue of variability of erosion on slope facets compared with the pre-existing variability of deposition of caesium-137. Possible reasons for variability of actual incorporation of caesium-137 into a soil profile were discussed;

i) spatial variability in deposition and
ii) redistribution of caesium in runoff generated by variable infiltration behaviour and by saturated flow.

There was agreement among participants that a single element of a slope model could form the basis of both comparison between elements and establishment of base levels of caesium-137 values for comparison with future values. The comment was made that case studies were not considered as good a basis for representation as a statistically valid selection of representative sites overall.

Discussion was developed on the variability of Caesium-137 concentration in reference input sites. Data was presented from randomly selected core sites which indicated a variation of 33 per cent in Caesium-137 activity on an areal basis. This data was inconsistent with the large amount of data from 1000cm2 sampling grids which indicates that errors are close to 5 per cent. The large area grid samplings were used to illustrate the trends of both latitude and longitude effects on soil Caesium-137 content. The participants suggested that an advance in science in understanding the variation would be to measure the Caesium-137 activity in adjacent grids samples rather than in core samples which are known to produce variation. The consensus of the meeting was that (input) site variability was not as much as may have been thought, field practioners of the technique expressed the view that one could be very confident about reference levels.

The following points of agreement were made during these sessions;

1. It was agreed that homogeneous units of management/land use could be described, and ascribed boundaries.

2. It was agreed that statements about spatial distribution of Caesium-137 within land system units could be made (eg. 50-70% Caesium-137 deficit on wheat lands on red-brown earths in northern New South Wales)

3. It was agreed that agroclimatic zones could be described and identified on maps.

4. It was agreed that Caesium-137 is rapidly (possibly even at a microsecond scale) adsorbed into soil minerals and is stable within soils.

5. It was agreed that reference input sites have a uniform profile shape which exhibits rapidly decreasing levels of activity with depth.

6. It was agreed that samples from within geomorphic units could sensibly be bulked to overcome the problem of variation within units (which are probably due to variation in erosion) bearing in mind the constraint of counting time availability.

7. The majority of participants agreed that meaningful differences in Caesium-137 activity value in soils could be explained by relative differences in soil movement (some exceptional circumstances were noted: non wetting soil effects, hot fire effects and cracking soil effects in certain circumstances).

8. The participants agreed that there was no need to separate soil on the basis of texture or pH as a variable within geomorphic units. [The possibility of effects within alpine humus soils and saline soils was noted].

The following topics were identified as those requiring clarification or as those needing resolution by data collection;

1. Dynamics of Caesium-137 adsorption in non-wetting soils and the subsequent evenness of labelling.

2. Role of dust accessions in adding Caesium-137 to soil profiles.

3. Testing Caesium-137 soil loss models by sampling opportunistic field occurrences where total sediment can be independently estimated (comparative profiles, reservoir storages etc.).

4. Assessment of reference input levels of Caesium-137 in central Queensland.

5. Expansion of the quantitative soil loss - Caesium loss relationship with artificial labelling experiments.

6. Effect of enrichment in eroded sediment of ^{137}Cs.

7. Caesium volatilisation during bush fires.

8. Caesium adsorption in a saline soil.

Session 3

(a) Measurement of Caesium - 137

During this session the availability and suitability of detector systems was discussed. Off-specification detectors, multiple purchase discounts, the superseding of multi channel analyzers and module purchases were discussed. A detection unit was estimated to cost $35,000. The requirements for super cooling of drifted detectors and hyperpure detectors were noted. The advantage in reduced counting time of high efficiency detectors (relative to NaI crystals) was noted. The point that accurate counting of low activity samples was necessary in some situation was made (i.e. soil interfaces).

The accuracy of counting systems was considered very acceptable. The availability of standards from the International Atomic Energy Agency and the United States Bureau of Standards at about $200/100g was noted. Standards may be diluted.

(b) Toward a national degradation assessment

It was the consensus of the participants that it was inappropriate at this time to conduct a comprehensive National assessment of the soil erosion component of land degradation using ^{137}Cs technique. This was principally because of the unresolved issued concerning the initial uniformity of deposition of Caesium-137 and/or the immediate redistribution in runoff driven by variable infiltration rates in soil on a slope facet (i.e. movement of Caesium-137 without soil erosion). However this participants did agree that a reconnaissance study was required in order to;

1. establish/confirm an understanding of reference levels of Cs137 deposition.

2. establish, at a statistically viable level, the ability to confirm at least large differences in Caesium-137 concentration.

3. build up a more comprehensive picture of ^{137}Cs and soil movement in the Australian landscape.

Independent means of confirming the second objective were proposed:

1. consistence with a geomorphic model (eg. by multitude regression or 9 unit land model)

2. consistence with a process model (Rose)

3. statistically acceptable differences

THE PROPOSED RECONNAISSANCE SURVEY

- The sampling strategy for the reconnaissance study was agreed to be:

  20 Agroclimatological Zones (McBratney)
  x 2 Land Uses (grazing, cultivation)
  x 3 Replicates (closely related to toposequence)
  ___
  120

- At each toposequence the samples to be collected will be:

A maximum of 20 each at equal vertical intervals down the slope in paired grazed and cultivated sites plus a maximum of 10 incremental depositional samples, with an overall maximum of 35 samples per site (grazed and cultivated paired).

- If we assume 600 sampled can be counted per detector per year we require about 7 detector-years of work. Over a 2 year period of date collection, 4 detectors would be required.

Collection of samples could be a State responsibility. This would involve about 3 days for 2 people for each toposequence plus time to select sites, supervise ancillary data collection and perform calculations.

Preparation and processing of samples would be performed by staff employed by grant monies either as studentships/scholarships or as temporary employees. Ancillary soil tests would include: XRD, Bulk density, particle size analyses, settling velocity characteristic, organic carbon, shear vane, drop cone etc. Consumables would need to be paid for by grant money. Ancillary tests could explain variations in Caesium-137 concentrations which occur within landforms and with land use variables.

COSTS:

4 Detectors @ $40,000		$160,000
4 anc. staff @ $30,000 for 2 years (1)		$240,000
or studentships 8 @ $20,000 (2)		$160,000
Soil Tests (provisional figure)		$ 15,000
XRD - selected samples		$ 7,000
Co-ordinator's Travel/Report Expenses etc.		$ 10,000
	Total	$432,000 (1)
	or	$352,000 (2)

OTHER CONSIDERATIONS

1. A co-ordinator would be essential to ensure that site selection was based on common criteria. In particular, soil group and management guidelines would been to be firmly defined and adhered to, so as not to create disparities between Caesium concentrations between zones.

2. Detector operators should be trained to ensure common standards and techniques are used.

3. Detectors must be located near soil test facilities to ensure efficient use of temporary staff or both soil testing and detecting activities need to be located at centres where specialised support is available.

4. Depending on the level of funds available, less detectors may need to be purchased and some measurements made on existing detectors under contract if capacity is available. For example an alternative cost for 600 samples is $15,000 by contract from ANSTO.

5. A catalogue of Caesium-137 research in Australia should be established so that administrators can start to see the applications and results.

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CS-137 ACTIVITY AS AN INDEX OF SOIL MOVEMENT UNDER A GRAZED NATIVE PASTURE AT NARAYEN, QUEENSLAND

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The Black Speargrass Lands of eastern Queensland contain some of the most productive pastures in northern Australia (Mott *et al.*, 1981). They occur extensively on coarse textured duplex soils and are considered stable under stocking rates of one beast to 3-15 hectares. With introduced legumes and tree killing much higher stocking rates can be achieved.

In a long term grazing trial on a Yellow Podzolic at the CSIRO Narayen Research Station, a number of treatments involving the native grasses *Heteropogon contortus* and *Bothriochloa* spp., the legume *Sirato*, introduced grasses, annual burning, and a range of stocking rates were applied. The following four treatments were selected for study.

- Code N - native pasture stocked at 1 beast per 2.4 ha;
- Code BnN - native pasture bunt annually and stocked at 1 beast per 2.3 ha;
- Code SpN - native pasture with supplementary feeding stocked at 1 beast per 1.5 ha; and
- Code NS - native pasture with *Siratro* stocked at 1 beast per 1.3 ha.

A visual inspection of these four grazing systems showed that the annual burning treatment BnN resulted in a crust-like surface on the sandy loam A horizon with evidence of soil movement. This was not present in the other three treatments.

Surface soil samples were taken from the BnN paddock during October 1985 for measurement of Cs-137 activity. The results are shown in Table 1.

Table 1. Cs-137 activity in BnN paddock at Narayen, October 1985.

Sample position	Depth (cm)	Specific activity (Bq kg^{-1})	Aerial activity (Bq m^{-2})
Flat hilltop (0 m)	0-10	7.7 ± 0.6*	951
Hilltop in lane (10 m)	0-5	10.4 ± 0.6	633
Slope (20 m)	0-10	5.6 ± 0.6	496
Slope (60 m)	0-10	3.0 ± 0.6	758
Slope (300 m)	0-8	5.3 ± 0.3	636
Bottom (500 m)	0-10	13.5 ± 0.4	2 446
	10-15	3.6 ± 0.3	
	15-20	0.8 ± 0.3	

* counting errors

Here it is seen that Cs-137 activity was lower on the slope than the hilltop, and highest at the foot of the slope. The results support a hypothesis of soil movement downslope. With this encouraging data, further samples were taken from all four treatments in August 1986, together with measurements of sorptivity calculated from time to ponding under a drip infiltrometer (Bridge and Ross, 1985). These later results are presented in Table 2.

Table 2. Cs-137 activity at Narayen, August-September 1986

Treatment code	Sample position	Depth (cm)	Specific activity (Bq kg^{-1})	Aerial activity (Bq m^{-2})	Sorptivity (mm $h^{-1/2}$)
	Slope (50 m)	0-10	7.7 ± 0.3	955	
BnN		10-20	1.6 ± 0.3		14.7 a
	Slope (150 m)	0-10	7.0 ± 0.3	832	
		10-20	0.6 ± 0.2		
	Slope (250 m)	0-10	5.5 ± 0.3	570	
	Slope (350 m)	0-10	1.5 ± 0.3	163	
	Top (50 m)	0-10	2.9 ± 0.3	278	
N	Middle (200 m)	0-10	8.5 ± 0.3	992	28.9 b
	Bottom (350 m)	0-10	9.0 ± 0.3	770	
		10-20	0.6 ± 0.3		
	Top (50 m)	0-10	3.3 ± 0.3	303	
SpN	Bottom (200 m)	0-10	4.0 ± 0.3	422	14.4 a
	Top (50 m)	0-10	4.8 ± 0.3	551	
NS	Bottom (350 m)	0-10	5.6 ± 0.2	553	

This second sampling in the BnN treatment showed a fairly uniform downslope Cs-137 activity. Any accumulation of activity must only occur right at the bottom of the paddock, that is, at the 500 m distance. The limited measurement in the other paddocks showed no discernable trends with slope and variability between paddocks. Sorptivity was lowest on the BnN paddock, being significantly lower than that on the unburnt N paddock which had a similar stocking rate. Plant cover on the BnN paddock over the period May 1973 to April 1984 was 82% (S.D. = 13%) compared with 93% (S.D. = 7%) for the other treatments. From these results it is surmised that annual burning reduced plant cover, exposed the soil surface to raindrop action so that a surface crust developed, reduced infiltration and resulted in greater runoff and soil movement.

The combined 1985 and 1986 Cs-137 measurements for the 0-10 cm soil depth are presented in Figure 1, together with the paddock slope profile. The trend for lower activities in the region of maximum slope and the high activity at the bottom of the slope is apparent. However, the variability is considerable and this makes quantitative assessment difficult. Soil movement in a grazed native pasture may be localised and variable, particularly if slopes are not smooth. Large numbers of samples would be needed and this imposes counting problems. The present study used a Li-drifted Ge 12% detector which allowed only one sample per day to be counted. A newer 28% detector will allow two samples per day to be counted, but this is still slow. Any field investigation of this nature would require a great deal of counting time if enough samples are taken to overcome variability. This is a major problem with the Cs-137 technique.

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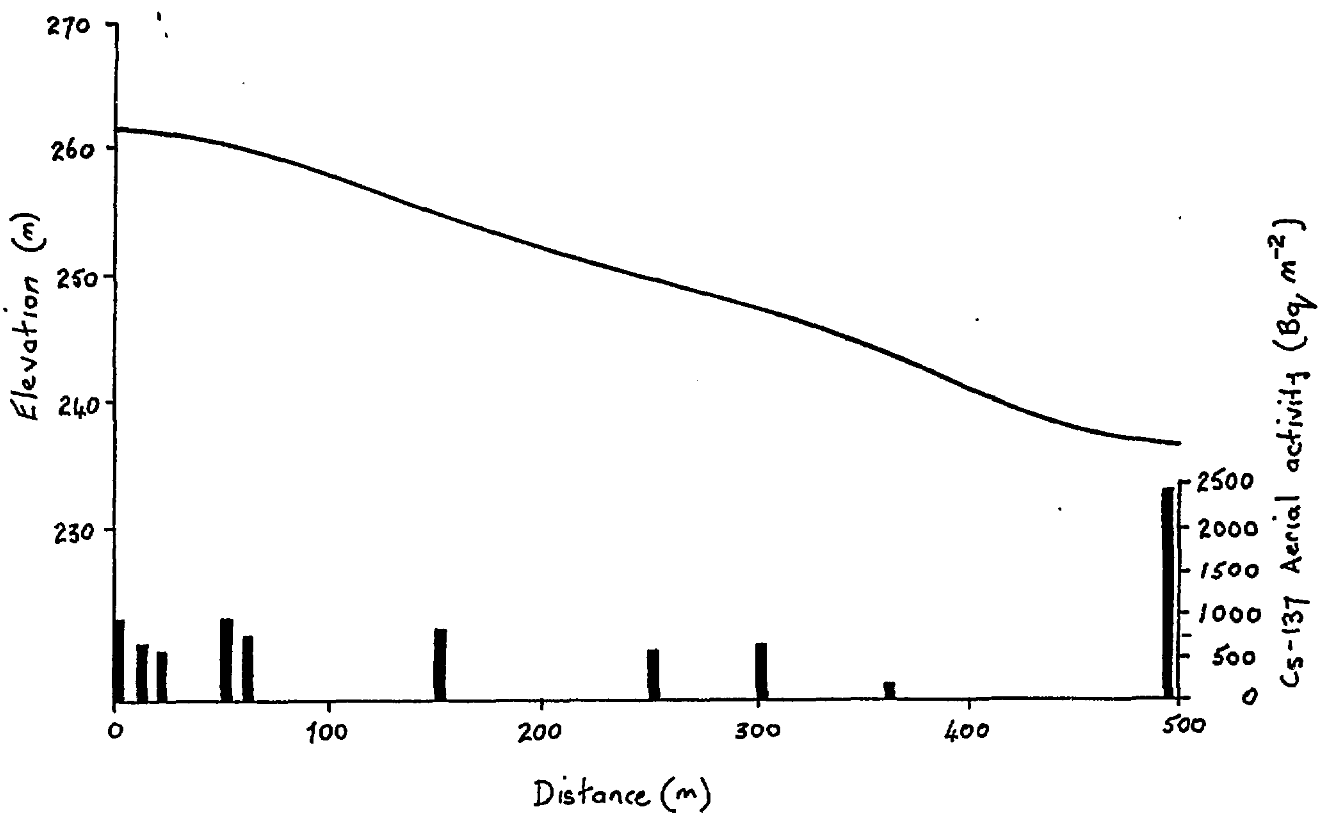

Figure 1. Cs-137 activity down hillslope in BnN treatment.

CAESIUM-137 WORKSHOP, SYDNEY, 1988

USING CS-137 TO ASSESS SHEET EROSION IN WESTERN AUSTRALIA

D.J. McFarlane, R.J. Loughran and B.L. Campbell

ABSTRACT

The Cs-137 technique represents the only feasible method whereby sheet erosion is likely to be measured in Western Australia given the expense of building, equiping and monitoring stream gauging stations and the difficulties in detecting small but significant changes in soils level on sites subject to wind erosion. A pilot study in 1987 used a stratified sampling technique to assess sheet erosion on representative hillslopes.

There are possible problems in using the Cs-137 technique in Western Australia due to poor labelling of non-wetting soils, due to poor retention by very sandy soils, due to the selective removal of dust particles and due to wind erosion adding Cs-137 to input sites. Lateritic gravel stones may also need to be crushed and added to the samples for analysis. Some of these problems may be better understood when the results of the pilot survey have been analysed.

BACKGROUND

There have been very few measurements of soil loss due to sheet erosion in Western Australia. Therefore it is not known whether sheet erosion is an important form of land degradation (relative to other forms), whether it is worse in areas with erosive winter rain or in areas with erosive summer rain, or whether wind erosion is more important than water erosion.

In late 1987, soil samples were taken from ten hillslopes in the agricultural areas in south western Australia and from three sheep stations in the Murchison pastoral area. The samples are being analysed for Cs-137. The project will give some indication of the amount of soil loss throughout the agricultural and Murchison pastoral areas. This paper outlines the sampling procedure that was used and some possible problems with using the Cs-137 method in Western Australia.

SAMPLING PROCEDURE

In the agricultural areas, a stratified sampling approach was adopted. Going from west to east, there is a progressive decrease in rainfall amount, winter rainfall erosivity and the length of the growing season. Vegetables are grown in the west, which changes to sheep grazing, to mixed farming and to predominently cereal growing by the eastern wheatbelt. Slopes decrease while slope lengths increase towards the east.

Five strata were selected to sample different rainfall-landuse-landforms (Figure 1). The strata were horticultural (Donnybrook), grazing (Darkan), western agricultural (Gabalong and Northam), central agricultural (Kellerberrin) and eastern agricultural (Bodallin). Soils from the Narrogin area have previously been analysed for Cs-137.

The hillslopes were selected if they had a similar slope, slope length and management history to the surrounding district. Where possible the hillslope was within a single paddock to lessen discontinuities down the transect. In four areas two hillslopes were sampled resulting in ten hillslopes being assessed. At Northam and at Kellerberrin a lateritic hillslope (soils formed on truncated parts of the laterite profile) and an exposed rock hillslope (young soils formed from exposed granite) were sampled to determine which hillslope had the higher soil loss.

A transect was surveyed on each hillslope and sample sites selected at regular or representative positions. Either two or three replicate cores were taken at each sample site. Input levels of Cs-137 were determined from nearby undisturbed sites. A questionnaire is being filled out for each hillslope (Table 1).

In the pastoral areas exclosures on Belele, Bullardy and Barnong Stations (Figure 1), which have been in use since the early 1950's, were used as Cs-137 input sites while samples were collected from paddocks which had different stocking rates.

POSSIBLE PROBLEMS WITH THE SURVEY

1. The selection of the hillslopes is currently subjective and it is not known whether they are representative. It is hoped to construct digital terrain models of well surveyed areas (i.e. 1:20,000 or smaller) to determine the range of slope angles and slope lengths in an area. It will then be possible to determine the representativness of different hillslopes.

2. Most of the soils in the agricultural areas have very sandy topsoils. Tests will need to be carried out to determine whether Cs-137 is retained by these soils.

3. It is not certain that the Cs-137 technique will work in areas with non-wetting soils which prevent raindrops making contact with soil particles. Non-wetting soils occur over about 5 million hectares of the W.A. agricultural area and are common on lateritic hillslopes prone to water erosion and on sandplains prone to wind erosion. On the hillslopes, Cs-137 may be carried to the bottom of the slope in the runoff, resulting in soil losses being overestimated. On the non-wetting sandplains, infiltration occurs in local depressions which could result in uneven labelling of the soil profile.

4. Wind erosion is a major problem in Western Australia due to the sandy soils and the long dry summer. Dust particles are known to be selectively removed by the wind (as they are by water) and they are also thought to be enriched in Cs-137 relative to other soil fractions. This could result in soil losses being overestimated.

It is also possible that Cs-137 input sites in wooded areas will have received some Cs-137 enriched dust, also resulting in erosion being overestimated. To detect wind additions, the distribution of Cs-137 in the soil profile profile may need to be examined.

5. Cs-137 has been found attached to lateritic gravel stones which requires that the stones be ground and included in the sample.

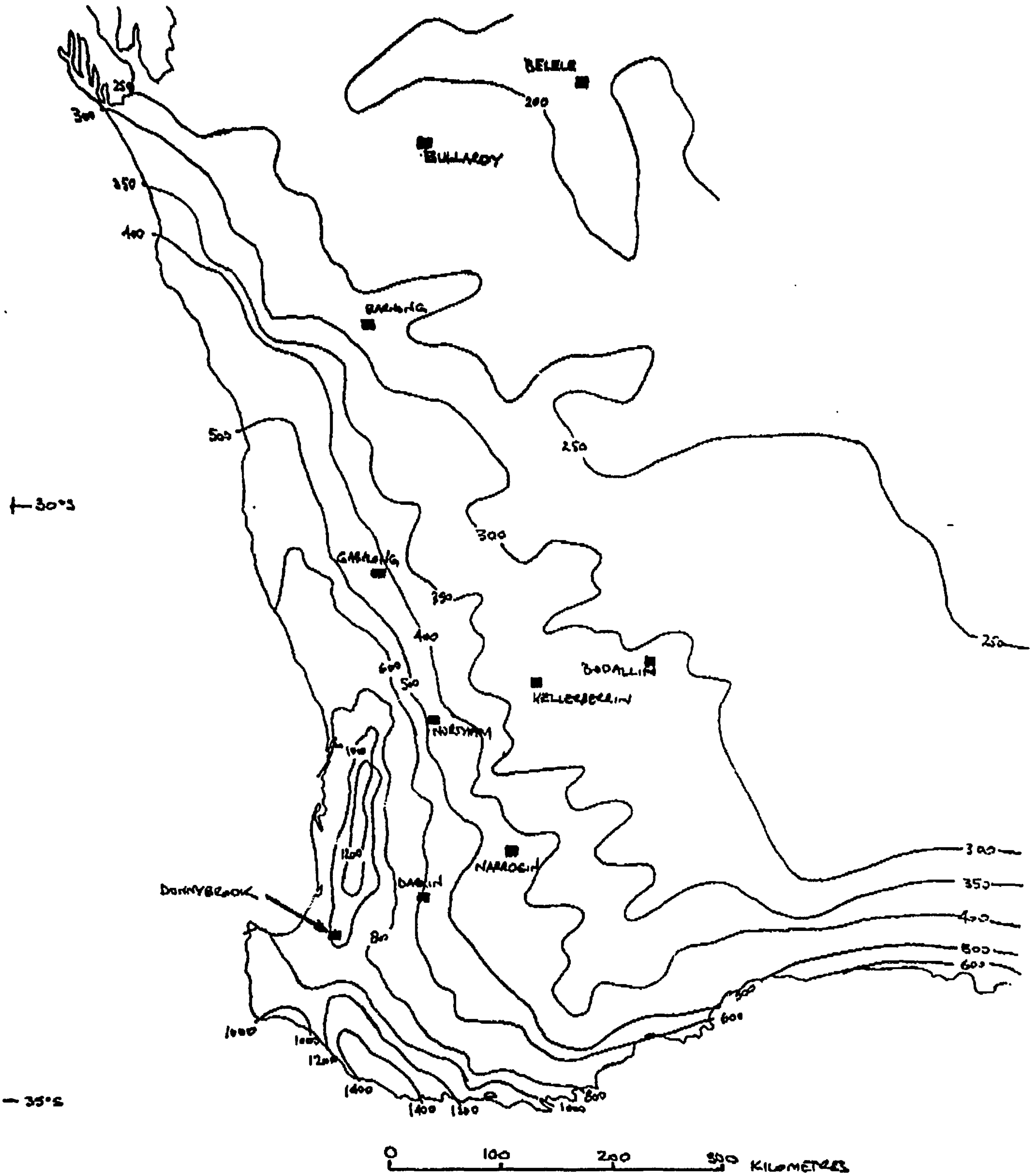

FIGURE 1 : LOCATION OF CAESIUM-137 SAMPLING SITES

TABLE 1: SURVEY OF CAESIUM-137 SAMPLE SITES

To be accompanied by a surveyed hillslope transect and soil description sheet

SITE:

OWNER:

AMG:

BRIEF DESCRIPTION OF SITE:

Average slope (%): Slope length (m):

Complete hillslope sampled ?

Sampled section in one paddock ?

Is sampled section (across slope) concave, flat or convex ?

AVERAGE ANNUAL RAINFALL (mm):

AVERAGE ANNUAL RAINFALL EROSIVITY (metric units):

TEN YEAR RETURN PERIOD RAINFALL EROSIVITY (metric units):

DATE OF CLEARING:

LAND USE SINCE 1954:

Maximum depth of cultivation (cm):

MAJOR EROSION EVENTS SINCE 1954:
Water erosion

Wind erosion

SUMMARY OF SOILS ON HILLSLOPE:

VARIABILITY OF CAESIUM-137 IN SOILS

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and
V Norris, University of New England

1.0 INTRODUCTION

The advantages of using ^{137}Cs over other methods of erosion measurement, is that ^{137}Cs activity in the soil provides objective information on soil movement since fallout began in 1954. Also, it is applicable to areas ranging in size from as small as localised rills and interfluves to as large as whole catchments.

The basis of estimating erosion and deposition rates in a locality rests on comparing the residual ^{137}Cs at an uneroded site to that at sites where erosion or deposition has occurred. The accuracy of estimation of the rates of erosion or deposition at the site of interest is dependent on the accuracy with which the "reference" level of ^{137}Cs activity can be measured at the uneroded site. Little information is available concerning sampling designs for making these assessments or the effect of spatial variability on the accuracy of erosion estimates.

Buchhuber et al, (1987) noted that any erosion estimate based on the spatial pattern of fallout ^{137}Cs implies that its spatial variability is also known for a soil unaffected by erosion. Buchhuber et al, sampled 100 points along the diagonals of a flat, cultivated field, 100 x 150 metres. Their results showed a random deivation of 26%.

Fredericks (1987) in a study near Inverell, NSW, found that the ^{137}Cs concentrations from six uncultivated ridge-top samples within a 10 metre radius showed a coefficient of variation of 38%. Six samples from a similar sized cultivated area showed a coefficient of variation of 19%.

2.0 METHODS

A study was undertaken to assess the variability of ^{137}Cs in a red-brown earth, located 10 kilometres north-east of North Star, northern NSW, in gently undulating dryland farming country. Two sites were studied; one cultivated wheat and one virgin sclerophyll forest. Sampling at each site included detailed sampling at 2 cm vertical sample interval and replicated coarse sampling within a 10 m radius using a 15 cm sample interval.

All samples were oven dried at 110°C for at least 48 hours and ground to pass through a 2 mm sieve. Caesium-137 was determined by gamma-spectroscopy using a Ge-Li detector and multi-channel analyser. Total activity was calculated as an areal concentration (Bg m^{-2}) corrected to 1985.

3.0 RESULTS AND DISCUSSION

Table 1 shows the results for the two sets of 15 individual coarse samples taken at the virgin site and an interfluve site on the cultivated area.

It can be seen from Table 1 that there is great variability among the 15 samples at both sites. In order to check these results, a total of 13 of these samples were re-analysed but were found to give ^{137} Cs activity levels the same as those from the original analysis.

In order to test whether the samples in each group fitted a normal distribution, the data tested for its fit to a normal distribution. The analysis showed that at the virgin site, the activities of the samples are a good fit to a normal distribution. There are, therefore, no clear "outliers" which should be given special scrutiny in case they should be removed from the analysis. The data for the cultivated soil differs slightly from a normal distribution and has an unusually large number of samples with similar levels of activity. This is to be expected because of the mixing caused by ploughing. The probability plot shows no evidence, however, of any result which should be considered an "outlier".

TABLE 1

^{137}Cs ACTIVITY MEASUREMENTS FOR THE
15 BULK CORE SAMPLES AT EACH SITE

Sample Site	Increment Depth (cm)	Mean ^{137}Cs Activity ($Bq\ m^{-2}$)	Coefficient of Variation Among the Samples (CV) %
Virgin	0 - 15	679	35
	15 - 30	118	46
	0 - 30	798	33
Cultivated Inverfluve	0 - 15	434	23
	15 - 30	100	65
	0 - 30	534	26

Because of the magnitude of this variation, a total of 22 samples at the interfluve site and 34 at the virgin site, would have been needed to give a mean total activity to 30 cm depth with an error of less than 10% with a 90% confidence (Hakanson, 1984). The time required for sampling, preparation and analysis of such large numbers of samples is a severe limitation of the widespread use of the technique for measurement of erosion rates.

4.0 CONCLUSIONS

The requirement for taking and analysing large numbers of samples in order to obtain sufficient confidence in estimates of erosion rate poses a serious limitation on the widespread use of ^{137}Cs measurement for this purpose.

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