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SOIL MOVEMENT IN A GRASSLAND ECOSYSTEM AS MEASURED BY BETA PARTICLE ATTENUATION

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TABLE OF CONTENTS

ABSTRACT

This report covers progress made on a soil movement study being conducted at the Pawnee Site. A method involving beta attenuation was developed and employed. From initial investigation, this method gives sensitive measurements of both erosion and deposition of soil and litter over a period of a few weeks. Data recorded on 265 field plots are summarized in tables. Future plans include continuing observation on field plots and laboratory studies to solve minor problems with the beta attenuation method as well as those associated with a proposed cesium tag concept.

INTRODUCTION

The objective of this research has been to develop and put into practice a method for measuring soil movement in a grassland ecosystem.

Initial efforts involved fallout cesium-137 as a soil particle tag. By relating the depth to which this isotope occurred in the soil profile to the duration the nuclide has been in the environment, it was anticipated that an estimate of soil accumulation could be obtained. Problems have been encountered in the application of this concept and at the present time, laboratory studies are being conducted in an attempt to overcome these problems.

In conjunction with our objective, we have developed and employed a method of measuring soil movement by beta attenuation. Initial investigations indicate that this method allows the detection of both soil erosion and accumulation, over a period of a few weeks, and in amounts considerably less than one millimeter in depth.

METHODS AND MATERIALS

The basic principle involved in the beta attenuation method is illustrated in Fig. 1. As soil, or litter, measured in milligrams per square centimeter is deposited over a buried radioactive source, a decrease in count rate is observed using a portable GM (Geiger-Mueller) survey meter; removal of material yields an increased count rate. Field data, in counts per minute, can then be related to the calibration curve (Fig. 1), and soil fluctuations can be determined. Fig. 1 is the graphical presentation of data taken using machined aluminum absorbers in the laboratory; however, identical results were obtained using a variety of soils and litter. In

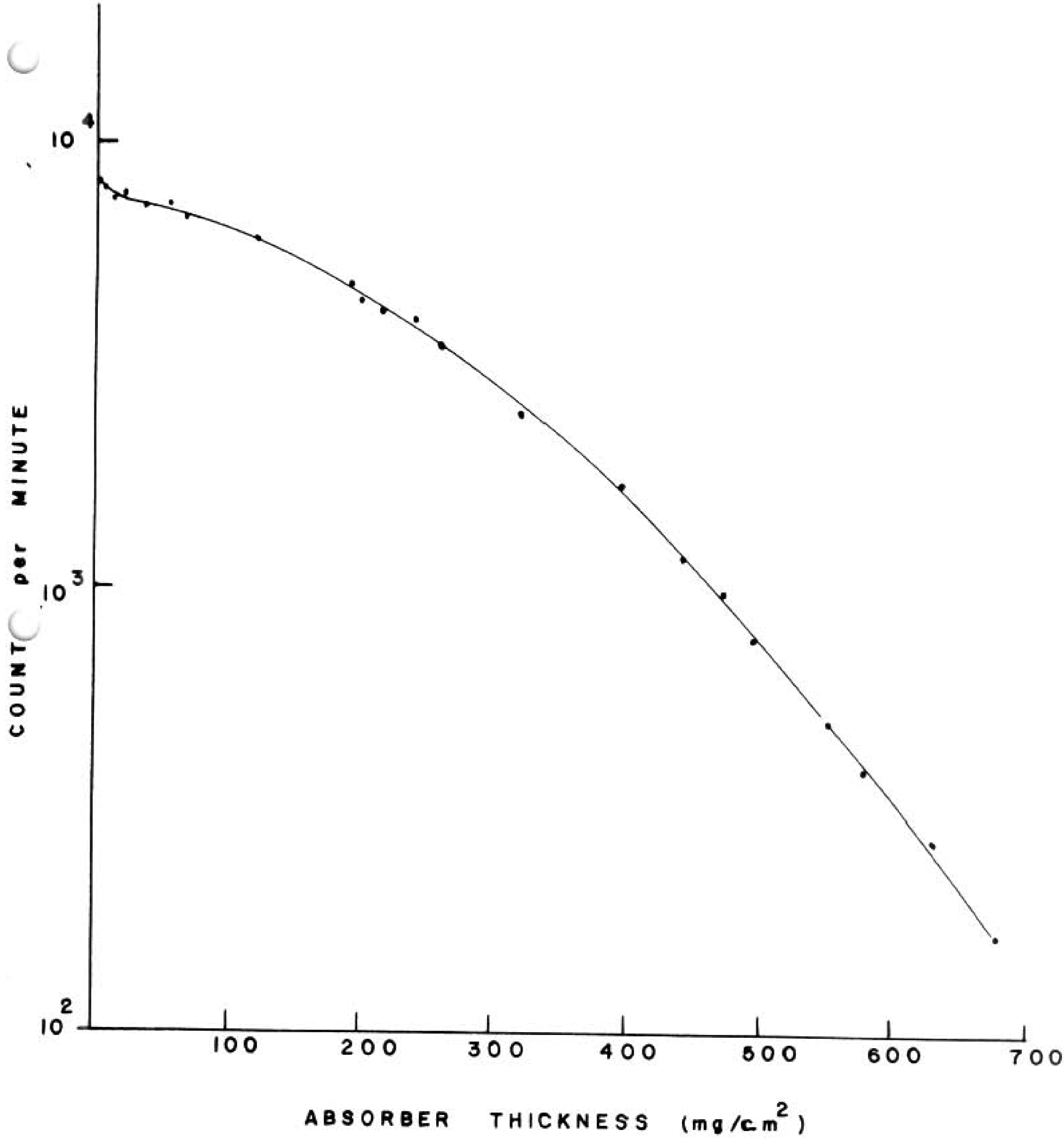

Fig. 1. Absorption of beta particles from a ^{90}Sr-^{90}Y source in aluminum absorbers.

this figure, 100 mg/cm^2 is equivalent to approximately one millimeter of soil depth.

The radioactive source used was strontium-90 because it decays to Yttrium-90 which emits a 2.27 MeV beta particle which is of sufficient energy to enable one to detect reasonable differences in soil fluctuations. The 30-year half life of this isotope allows the continuation of investigation over a considerable period of time without need to replace the source.

Fig. 2 illustrates field use of the beta attenuation method. A 0.5 microcurie aliquot of strontium-90 in liquid form was placed in a notch filed on a nail, allowed to dry, and then sealed with Krylon (commercial name, Krylon, Inc.) and silver spray enamel. The source was sealed on the nail to prevent leaching of the isotope into surrounding soil. The radioactively tagged nail was then centered in a triangle formed by the orange plot markers in such a manner that the radioactive notch is a few millimeters below ground. The depth of the source is established by inserting the nail until the count rate is approximately 20% of the initial count rate obtained with no soil over the source. By placing the nail in this manner, both soil accumulation and removal can be determined from the usable portion of the calibration curve. When soil builds up or is removed from over the source to such a degree that the count rate is not on the mid-portion of the calibration curve, the tagged nail is reset in the necessary direction. When placing plots in the field, any standing vegetation that was between the source and the detector window was clipped over an area about 2.5 cm in diameter, while all litter was left in place. This was done to remove any absorbance of beta particles by fixed material that was not directly subject to movement by agents such as wind and water.

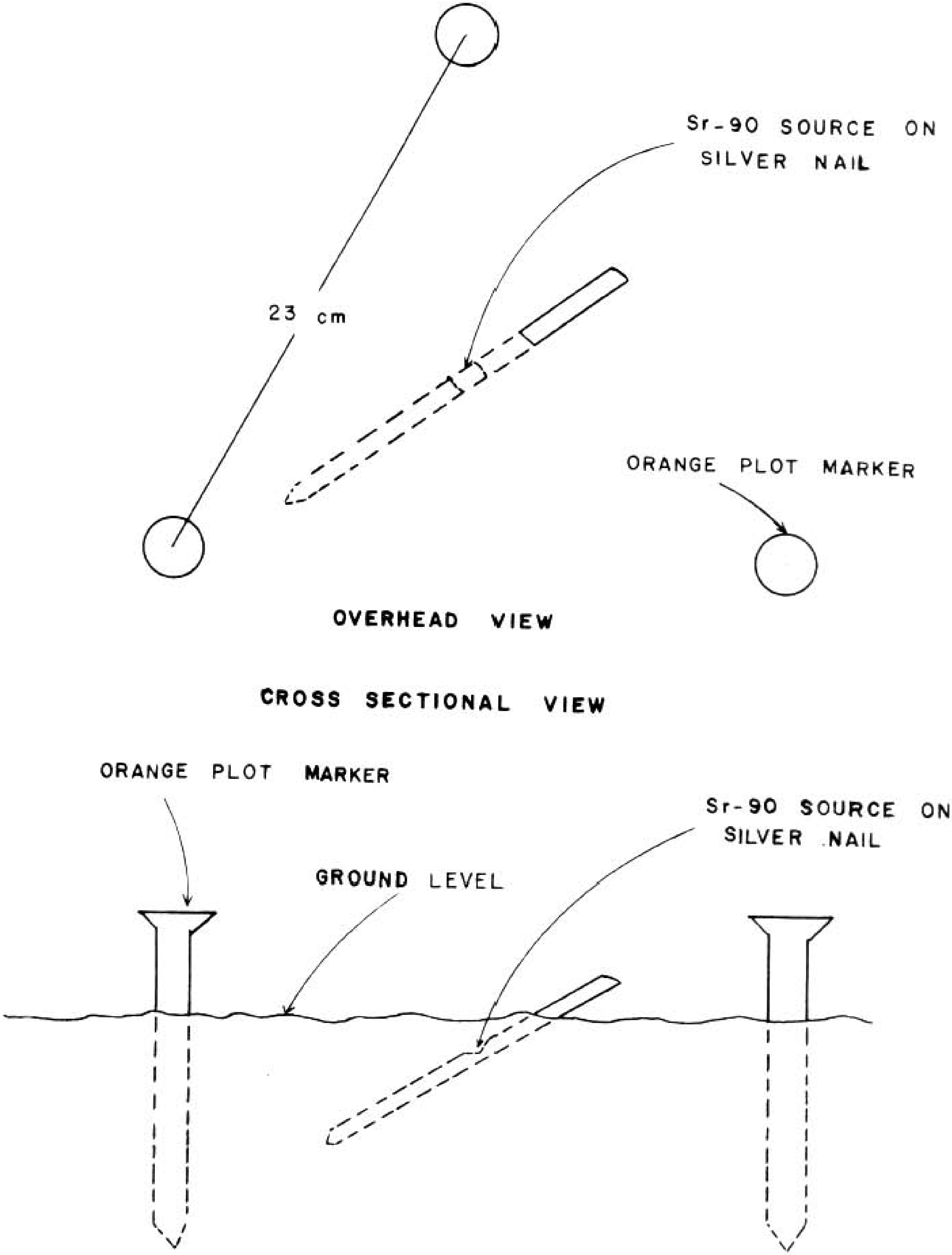

Fig. 2. Schematic representation of permanent field plots for measurement of soil movement (not to scale).

The orange plot markers (Fig. 2) serve as legs for a portable tripod that contains the GM probe used in counting. The markers were placed so as to leave an open area to the northwest, as this is the direction of prevailing winds, and it was assumed that this would eliminate any wind shadow that might have been caused by the markers. The silver nail containing the source was set at a 90° angle to the prevailing wind in an attempt to eliminate any wind shadow effect of the nail itself. The source nail protrudes above the ground only about 5 to 8 mm which presents a very small barrier relative to microterrain variations and vegetation.

Counting is done with a GM probe attached to a portable Ludlum model 20-A scaler. The probe is encased in a tube on the tripod which is placed over the radioactive source with arms resting on the orange plot markers. The source to window distance, which is constant for repeated measurements, is approximately 5 cm. A three minute count is taken at each plot. In conjunction with the plot count, a standard strontium-90 source and a background are counted periodically during the day when plots are counted to assure reproducibility and reliability of the counting system.

Experimental Design

A total of 265 plots were established in the summer grazing pastures at the Pawnee Site in the Fall of 1970. Table 1 presents a scheme designed to assess the influence of grazing, season, and soil type on soil movement. Table 2 represents an investigation being conducted in the moderate use pasture to determine the effect of soil type and season on soil movement within this pasture. To examine the influence of exposure on soil movement,

Table 1. Experimental design for between pasture soil movement investigations at the Pawnee Site.

Between Pasture Soil Investigation

		Ascalon	Vona	Undifferentiated	Shingle-Renohill Complex
Light:	S				
	SS				
	F				
	W				
Mod:	S				
	SS			15 Observations/Cell	
	F				
	W				
Heavy:	S				
	SS				
	F				
	W				

(Units: Soil measured in g/m^2/unit time.)

Anova Table for Three-way Soil, Grazing, Season

Source	D. F.
Total	720
Mean	1
Soil Type	3
Grazing	2
Season	3
Soil Type × Grazing	6
Soil Type × Season	9
Grazing × Season	6
Soil × Grazing × Season	18
Error	672

Table 2. Experimental design to investigate season and soil type influences on soil movement in a moderately grazed pasture.

Moderate Use Pasture Investigation

	Season			
	Spring	Summer	Fall	Winter
Renohill				
Manzanola				
Gravelly & Cobbly				
Shingle		15 Observations/Cell		
Ascalon				
Vona				
Undifferentiated				
Shingle-Renohill				

Two-way Anova Soil Type and Season

Source	D. F.
Total	120
Mean	1
Soil Type	7
Season	3
Interaction	21
Error	88

four transects were established as indicated in Table 3. Further investigations are being conducted on the ephemeral Lynn Lake, and on some of the undifferentiated sinks present in the study area.

In establishing the plots, sites were selected on the basis of similarity of slope, exposure, and surrounding soil type. A detailed topographic map was examined to determine possible sites, and field reconnaissance verified the decisions. Plots are generally on a linear transect within a given soil type. Distance between plots was dictated by transect length, which in turn was dependent upon the spatial extent and shape of the soil type. Plots were located on the transect by pacing the selected distance and casting the tripod used in counting on the ground. The tripod landing site then became the plot location.

RESULTS AND DISCUSSION

A limited amount of data have been collected to date, which are summarized in Table 4. These type means are based on two observations taken during September and November, 1970. These preliminary results seem sensible and indicate that grazing or grazing related factors may influence soil movement since movement is greater in the heavily grazed pasture. The Shingle-Renohill soil complex appears the most unstable of the soils investigated as was speculated by Franklin (1969). Lynn Lake, the bottom of which is covered with erosion pavement in the fall, showed a net loss of soil while the buffalograss (*Buchloe dactyloides*) covered sinks increased in soil content.

A high degree of variability existed along transects (Table 5). This transect (Shingle-Renohill soil) begins on a wind blown east slope and proceeds west. At plot 82, the vegetation is well established with little

Table 3. Experimental design to examine the effect of exposure on soil movement.

Effects of Exposure

	Season			
	Spring	Summer	Fall	Winter
Ascalon (Heavy Use)				
Northeast	5 Observations/Cell			
Southwest	5 Observations/Cell			
Renohill (Moderate Use)				
Northwest	7 Observations/Cell			
Southeast	8 Observations/Cell			

Table 4. Net soil movement recorded during the fall of 1970 in light and heavy summer grazed pastures.

Soil Movement (g/m^2/month)

Soil Type	Heavy Grazed Pasture	Light Grazed Pasture
Undifferentiated	-174	225
Vona Loam	-100	64
Shingle-Renohill	-42	-102
Ascalon	74	77
Lynn Lake	-166	
Sinks	250	

Table 5. Net soil movement recorded for Shingle-Renohill soil during the fall of 1970 in a light grazed summer pasture.

Plot Number	Soil Movement (mg/cm^2)
76	55
77	- 60
78	-195
79	- 50
80	- 10
81	- 15
82	25
83	10
84	15
85	25
86	0
87	15
88	- 20
89	- 30
90	- 10

or no slope evident. Moving down the transect, the ground begins to slope to the north west and wind scour is evident in plots 87-90. A high degree of micro-environmental variation between plots appears to considerably influence soil movement data.

From initial observations, measurements of soil movement with the aid of beta attenuation appears promising. This method is cynamic, allowing measurement of both deposition and removal of soil in small quantities over short periods of time. The only disturbance to the study area is the initial establishment of plots, which once placed, are quite unobtrusive.

Monetary investment per plot is low as the only materials involved are four nails, paint, and the radioisotope.

Problems, which appear minor, have arisen with this method. Soil moisture alters the count rate significantly and at present all data have been adjusted to allow for moisture. This adjustment is complicated by non-uniform distribution of moisture in the soil. Investigations are being undertaken in an attempt to calibrate for moisture, or to pre-dry plots prior to counting. Counting may need to be restricted to periods when surface soil is dry. Plot markers have been observed to trap litter creating an artificial situation. In these cases, the data have been discarded and the litter removed. Disturbance of plots by livestock has been observed and again the data have been discarded and the plot re-established. Over a three month period when cattle were present in the pastures, only 1% of the plots were disturbed.

Future plans include further investigations of problems involved in the beta attenuation method coupled with continuing study of the cesium-137 tag method. It is hoped that application of both methods will provide an eventual check of figures for soil movement. Continued readings will be made on the field plots to establish patterns of soil movement and to evaluate variables associated with the movement.

LITERATURE CITED

Franklin, W. T. 1969. Mineralogy of representative soils at the Pawnee Site. U.S. IBP Grassland Biome Tech. Rep. No. 30 (Fort Collins, Colo.). 13 p.

APPENDIX I

FIELD DATA

Soil Movement Data

Soil movement data collected in 1970 at the Pawnee Site is Grassland Biome Data Set A2U708B. The data set containes data in three formats which are described below. Following this description is a listing of the data.

Format 1 (Plot Data)

Columns	Contents
1-3	Plot Number
4-5	Month
6-7	Day
8-11	Year
12-15	Time (24 hour clock)
16-18	Time Zone (MDT or MST)
19-25	Observed Counts
26-28	Counting Time (minutes)
29	Background Identifier
30	Standard Identifier
31-50	Remarks

Format 2 (Standard Calibration Data)

Columns	Contents
1-3	The Letters STD
4	Standard Identifier
5-6	Month
7-8	Day
9-12	Year
13-16	Time (24 hour clock)
17-19	Time Zone (MDT or MST)
20-26	Observed Counts
27-29	Counting Time (minutes)
30-49	Remarks

Format 3 (Background Calibration Data)

Columns	Contents
1	Background Identifier
2-3	Month
4-5	Day
6-9	Year
10-13	Time (24 hour clock)
14-16	Time Zone (MDT or MST)
17-23	Observed Counts
24-26	Counting Time (minutes)
27-46	Remarks

+++ FIELD DATA +++

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
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