STUDIES ON SOIL STRUCTURE AND SOIL INVERTEBRATES IN REHABILITATED SAND MINES AT ENEABBA

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Introduction

Invertebrates living within the soil perform a number of useful functions. They may accelerate the decomposition of plant material, incorporate such decaying material into the soil strata and they also influence the physical structure of the soil in a number of ways. For instance, Abbott et al (1979) noticed that when ploughing and stocking of Western Australian wheatbelt soil was discontinued for 7 years there was a recovery in the density of large soil animals and concomitant improvements in soil water permeability, compactability and soil structure.

The tailings and topsoil returned to the sand mined areas at Eneabba initially lacks structure and is low in nutrients (Majer et al 1982) Thus the early colonization of soil dwelling invertebrates is clearly desirable. The soil structure and abundance of soil invertebrates in some of the rehabilitated plots at the Allied Eneabba Ltd. (A.E.L.) minesite was studied in July 1980. Two heathland controls were also investigated.

The present work aimed to repeat the July 1980 observations (see Majer et al 1982) and also to follow the trends in soil structure and large soil invertebrates (≥ 2 mm long) in six rehabilitated plots which were selected to represent a time span of rehabilitation ranging from 1977-1982.

Methods

The AEL minesite was visited from 11 - 13th July, 1983 and plots were selected for investigation. These are listed in Table 1, with details of their rehabilitation history. In the mid-line of each plot a 100 m transect was marked out to provide the basis for subsequent samples and recordings. The original transects and sampling positions were used in those plots previously studied in 1980(Table 1).

At equal distances along each transect ten 9.1 cm deep and 5.5 cm diameter, soil cores were taken. The soil was dried in an oven at 105°C and the soil bulk density was calculated by dividing the soil dry weight by the calculated volume of the corer. Percentage soil moisture was also calculated. At each of ten intercepts recordings were made of soil penetrability using a Proctor® penetrometer. The plunger was pressed in to the soil to a depth of 5 cm. At 20 m intervals along the transect the soil infiltration rate was measured by placing a 6 cm diameter plastic cylinder vertically on the soil surface. This was filled with water and the drop in water level was measured after 4 minutes.

Large soil animal density was assessed by taking 14 cm cubes of soil at 10 m intervals along the transect. The soil samples were sealed in plastic bags and those invertebrates which exceeded 2 mm in length were counted out shortly afterwards.

The plot mean and standard deviations of the above mentioned variables were calculated and the plot means were compared by one-way analysis of variance. The individual plots whose means did not significantly differ at $p < 0.01$ were then elucidated using the Sheffé procedure (Nie et al 1975)

Results

The 1983 plot means and standard deviations and, where available, the 1980 plot means are presented for each variable in the tables given. The order of plots in each table is ranked to illustrate the trends in 1983 plot means and, where possible, the control plots are placed to the left hand side of the tables.

Percentage soil moisture values are shown in Table 2. With the exception of the oldest plot (77A), all rehabilitated plots had a higher 1983 soil moisture than control plot 1 and, with two exceptions, control plot 2. As with the 1980 recordings, control plot 2 had an exceptionally high soil moisture content. This may have resulted from the presence of water-retaining slimes which had emanated from an earlier slime spill.

The Sheffé tests indicate that plots 77A and control 1 had significantly lower soil moistures than the other plots, whereas plots 82F and 79B had significantly higher soil moistures than other plots. No consistent time-trends were observed when the 1980 and 1983 means were compared.

Table 3 shows the soil bulk density values. As in 1980, the rehabilitated plots all had higher soil bulk density values than the control plots and with the exception of plot 81B, all rehabilitated plots had significantly higher values than the control plots. Plot 80A also had a significantly higher value than all other rehabilitated plots. It may be of interest that the two most recently rehabilitated plots, 81B and 82F, had soil bulk density values most similar to those of the control plots.

Soil penetrability values are shown in Table 4. Two plots, 78G and 81B, had soil of lower penetrability than the controls. Only the two plots with the highest soil penetrability, 79B and 80A, had significantly different means to the remaining control and rehabilitated plots.

All rehabilitated plots had slower infiltration rates than the control plots (Table 5). Infiltration was significantly more rapid in control plot 1 than in the rehabilitated plots; it was probably retarded in control plot 2 by the presence of slimes on the sand. The oldest two plots, 77A and 78G had the most rapid infiltration rates and these did not differ significantly from those of control plot 2.

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Table 1. Listing of plots selected for soil studies in 1980 and 1983 showing details of their rehabilitation history.

Plot name	Rehabilitation date	Topsoil treatment	Subsoil treatment	*Fertiliser treatment	Cover crop	Source of native plants	Used in 1980 study
77A south	April 1977	single stripped	none	yes	cereal rye	topsoil	yes
78G north	Aug 16 1978	"	"	"	"	"	"
79B	Feb 22 1979	double stripped	"	"	sudax	"	"
80A east	June 2 1980	"	"	no	cereal rye around margin	"	no
81B east	Feb 27 1981	"	clay, silt	yes	sudax	seeded	"
82F north	July 14 1982	"	"	"	sudax & cereal rye	"	"
Heath 1 MC7003 north	#n.a.	n.a.	n.a.	no	n.a.	n.a.	yes
Heath 2 MC7003 south	n.a.	n.a.	n.a.	no	n.a.	n.a.	"

\# n.a., not applicable

* Standard fertilizer treatment was 90 kg superphosphate, 50 kg ammonium nitrate, 8 kg potassium chloride and 4 kg trace elements per hectare.

Table 2. Mean and standard deviation values of percentage soil moisture per plot. The horizontal bars connect those plots where 1983 means do not statistically differ at $p < 0.01$.

	77A	Control 1	81B	78G	Control 2	80A	82F	79B
July 1980 mean value	4.43	4.44	*	6.14	5.45	*	*	7.23
July 1983 mean value	4.43	4.55	5.50	5.54	5.75	5.91	7.21	8.49
1983 standard deviation	0.85	0.56	0.76	0.93	0.66	0.80	1.30	1.72

(Horizontal bars connect 77A–Control 1 and 81B–80A.)

* not measured in 1980

Table 3. Mean and standard deviation of soil bulk density (gm per square cm) per plot. The horizontal bars connect those plots where 1983 means do not statistically differ at $p < 0.01$.

	Con-trol 2	Con-trol 1	81B	82F	79B	78G	77A	80A
July 1980 mean value	1.50	1.49	*	*	1.74	1.61	1.74	*
July 1983 mean value	1.55	1.61	1.66	1.69	1.69	1.71	1.73	1.82
1983 standard deviation	0.06	0.06	0.13	0.07	0.04	0.08	0.04	0.08

* not measured in 1980

Table 4. Mean and standard deviation values of soil penetrability (KPa) per plot. The horizontal bars connect those plots where 1983 means do not statistically differ at $p < 0.01$.

	78G	81B	Con-trol 1	Con-trol 2	77A	82F	79B	80A
July 1983 mean value	443	507	545	611	690	723	865	1023
standard deviation	184	198	65	128	231	700	147	305

Table 5. Mean and standard deviation values of soil water infiltration rate (ml in 4 minutes) per plot. The horizontal bars connect those plots where 1983 means do not statistically differ at $p < 0.01$.

	Con-trol 1	Con-trol 2	77A	78G	82F	81B	79B	80A
July 1983 mean value	641	463	458	419	303	279	264	213
standard deviation	69	104	131	91	46	40	18	38

Table 6. Mean and standard deviation values of large soil invertebrate density (nos per square metre) per plot. The horizontal bars connect those plots where 1983 means do not statistically differ at p 0.01.

	Control 1	Control 2	78G	77A	80A	79B	81B	82F
July 1980 mean value	13	26	0	0	*	0	*	*
July 1983	510	1010	26	10	5	0	510	0
1983 standard deviation	861	2439	36	22	16	0	1612	0

* not measured in 1980

Soil invertebrates collected in the control plots comprised spiders (1.3%), centipedes (0.3%), millipedes (0.3%), adult beetles (2%), larval beetles (2.1%), larval flies (0.3%), bristletails (0.3%), ants (46.5%) and termites (46.9%). Those in the rehabilitated plots comprised cockroaches (1%), adult beetles (4.5%) and ants (94.5%). Table 6 shows the number of larger soil animals per square metre in each plot. None of the 1983 values differed statistically due to the extremely high variance of the data The 1980 values are much lower than those for 1983 due to differences in weather and to less efficient extraction procedures. However, the 1980 values indicate that although animals were present in the control plot soils, none were found in the three rehabilitated plots studied. In 1983 soil animals were present in four of the rehabilitated plots although, with the exception of plot 81B, they were in much lower numbers than in the control plots. The high numbers in plot 81B resulted from one soil core coinciding with the location of an ant nest and are not representative of the plot as a whole. When this is taken into account there appears to be an increase in large soil animal density with time from rehabilitation

Discussion

The results of this brief survey indicate that by comparison with control plots, the rehabilitated plots have soil of high bulk density, generally high soil moisture, low water infiltration characteristics and a low density of large soil invertebrates. Soil penetrability values were not so clear cut although four out of six rehabilitated plots had higher soil penetrability means than those of the controls.

The high soil moisture in the rehabilitated plots is probably due to the presence of fine clay particles (slimes) mixed with, or stratified below, the soil layer. This is further substantiated by the high soil moisture in slime-contaminated control plot 2. The soil's water infiltration characteristics may be related to soil moisture levels since the plot means for these variables were negatively correlated ($r = -0.87$, $p < 0.05$).

It is noteworthy that the rehabilitated plots with the highest overall soil animal density, plots 77A and 78G, had relatively rapid infiltration rates. Possibly the burrowing activity of these animals contributed to penetration of surface water. This is in keeping with these plots having soil moisture levels relatively close to those of the two control plots.

The data indicate that although there is evidence of some recovery in large soil animal density with time, the density in older rehabilitated plots is still not approaching that in the native vegetation. The soil still differs physically from control plot values, even after six years from the time of rehabilitation. Although the altered soil conditions may impede soil animal colonization, the subsequent appearance of these animals may bring about improvements in soil properties and associated plant growth. The addition of mulch may be useful for encouraging the build up of such fauna. It is therefore important to continue monitoring soil animal density as rehabilitated plots mature and also to find ways in which to encourage colonization by soil fauna.

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