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Influence of Vegetation and Soil Types on the Mound Density and Distribution of the Wheatbelt Termite in Western Australia: Using a Geographic Information System (G.I.S.)*

Geographic Information System(G.I.S.)을 이용한 서부호주 밀재배 지역의 흰개미집 밀도와 분포에 있어서 식물상과 토양형이 미치는 영향평가

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ABSTRACT Vegetation rather than soil types, is the predominant factor in determining density and distribution of *Drepanotermes tamminensis* (Hill) mounds within the Durokoppin Nature Reserve in Western Australian wheatbelt *D tamminensis* mounds reach the highest densities in Woodland (dominated by *Eucalyptus capillosa*) and Casuarina (dominated by *Allocasuarina campestris*) vegetation associations. There appears to be no influence of soil type on mound distribution, although higher mound densities tend to be found on the Booraan soil type.

KEY WORDS Termites, Isoptera, *Drepanotermes tamminensis*, mound density, mound distribution, G.I.S.

초 록 서부호주 밀재배 지역의 Durokoppin 자연보호 구역내 흰개미(*Drepanotermes tamminensis*(Hill)) 집의 분포와 밀도에 있어서 토양형보다는 식물상이 주된 영향을 미치는 것으로 밝혀졌다. *D. tamminensis*의 집은 Woodland(우점종-*Eucalyptus capillosa*)와 Casuarina(우점종-*Allocasuarina campestris*) 식물군에서 가장 높은 밀도를 보였다. 비록 Boorann 토양형에서 개미집 밀도가 높은 경향을 보였으나, 개미집 분포에 있어서 토양형이 미치는 영향은 없었다

검색어 흰개미, 흰개미목, *Drepanotermes tamminensis*, 개미집 밀도, 개미집 분포, G.I.S.

Social insects in general, and termites in particular, are extremely important in the soil because they are involved in the breakdown of organic material and consequently in the recycling of nutrients. They also influence soil-water properties (Robinson 1958, Lee & Wood 1971a, b; Johnson & Whitford 1975, Whitford *et al.* 1982, Culver & Beattie 1983, Elkins *et al.* 1986). The role of social insects on breakdown of organic material is illustrated by work in the northern Chihuahuan Desert, New Mexico In this study it was estimated that subterranean termites (*Gnathamitermes tubiformans*) consumed at least 50% of the net primary production (Johnson & Whitford 1975, Whitford *et al.* 1982) and fed upon several kinds of plant material (wood, grasses, litter and herbs). Therefore, because termites process such a large fraction of the net primary production, they should also have large and measurable effects on nutrient cycling.

Termites are found predominantly in the tropical and subtropical regions of the world. According to Watson & Gay (1991), there are over 2300 species world-wide, of which there are 258 described and 90 undescribed species in Australia. Whilst termites are relatively abundant in central Australia (Watson *et al.* 1973), they are more predominant in open

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forests and woodlands in the semi-arid and subtropical regions (Lee & Wood 1971b). Termites are poorly represented in the cool-wet end of the climatic range.

Most termites are grass-feeders or feed on decaying wood and they often construct extensive and massive nest systems in response to food availability and other environmental factors. As a result, they have a profound effect on redistribution of soil particles (Lepage 1974, Anderson & Wood 1984, Nutting *et al.* 1987), on physical and chemical properties of soils (Lee & Wood 1971a, Lee & Butler 1977, Wood & Sands 1978, Coventry *et al.* 1988), and consequently on vegetation (Harris 1969, Lee & Wood 1971b, Watson *et al.* 1973, San Jose *et al.* 1988). Little is known of the extent of these activities on the habitat in which termites live, but the interactions within the termite-soil-vegetation system are complex and are not fully understood. The objectives of this survey were as follows:

First, to evaluate the influence of vegetation types on termite mound distribution and density. Secondly, to assess the influence of soil types on the aforementioned parameters was also considered an important prerequisite, in understanding the way in which termite mound distribution is controlled.

MATERIALS AND METHODS

The study area (Fig. 1) is located within the Durokoppin Nature Reserve (117°45'E, 31°24'S), 250 km east of Perth, Western Australia (WA). The reserve is 1030 ha in size, consisting of ten vegetation types and five soil types. Prior to this present study, this area had been gridded out at a 50×100 m intervals by the Australian Survey Office in June 1986.

All *Drepanotermes tamminensis* mounds were counted during March 1990 within a 25 m radius of every grid-point (circular point) in the eastern section of the reserve: mounds were not checked to see if they were active or not. In order to compare the differences among vegetation and soil types in terms of mean density of mounds per point which supported mounds, one-way Analysis of Variance (ANOVA) followed by Kramer's multiple comparison test (non-parametric test, Zar 1984) was used. Chi-square (X^2) statistics (Zar 1984) were then used to compare the effects of vegetation and soil types on mound frequency within each vegetation and soil category. Field data were also illustrated by a Geographic Information System (G.I.S.), IMGRID^{TM} computer package, to create a map in which selection and generalization procedures are explicitly defined and consistently executed.

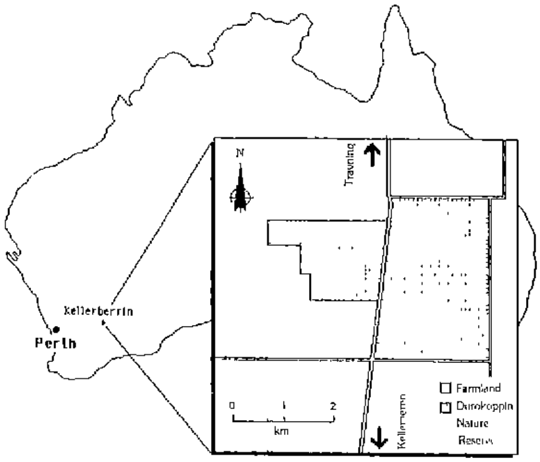

Fig. 1. Location of the study area

A total of 4643 mounds were encountered at the 407 circular points within the reserve. The data were then expressed for each vegetation and soil types as total number of points, total number of mounds, total number of mounds per point, the percentage of points with mounds, mean number of mounds per point and expected number of points. The expected number of points (E) were calculated by the following equation:

$$E=[\{(T_p/T)\times 100\}\times T_{pm}]/100$$

where T_p is the total number of points in each vegetation type, T is the total number of points in the reserve, and T_{pm} is the total number of points with mounds in the reserve.

RESULTS

Vegetation Survey

Table 1 illustrates the summary of mound density parameters on each vegetation type. The total num-

Table 1. Summary of density of mounds within specific vegetation types. The significance of the differences between vegetation types were tested by the Kramer's multiple comparison test

	Woodland	Casuarina shrubland	Mallee	Open low heath	Dense heath	Mixed heath	Leptospermum heath	Rock outcrops
Total number of points	139	67	28	69	32	49	15	8
Tptal number of mounds	1990	1538	294	271	123	369	7	51
Total no. of points with mounds	90	62	21	18	14	35	2	6
Percentage points with mounds	64.8	92.5	75.0	26.1	43.8	71.4	13.3	75.0
Mean density of mounds per point (where present)	22.1	24.8	14.0	15.1	8.8	10.5	3.5	8.5
Significance	ab+	a	abc	abc	c	bc	c	c

+Means with the same letter do not differ significantly ($p<0.01$)

Table 2. Comparison of the observed and expected frequency of points where mounds occur within each vegetation type. The significance of the differences were evaluated using the Chi-square test

	Woodland	Casuarina	Mallee	Open low heath	Dense heath	Mixed heath	Leptospermum heath	Rock outcrops	Total
Observed No. (O)	90	62	21	18	14	35	2	6	248
Expected No. (E)	84.7	40.8	17.1	42.0	19.5	29.9	9.1	4.9	248
$\chi^2=(O-E)^2/E$	0.33	11.0	0.89	13.71	1.55	0.87	5.54	0.25	34.1
d.f.=7									$p<0.001$

ber of points within each vegetation type which supported mounds were: Woodland (Wandoo, Acacia and Salmon were combined) (90), Casuarina (62), mixed heath (35), mallee (21), open low heath (18), dense heath (14), rock outcrops (6) and leptospermum heath (2). According to the Kramer's test, differences among vegetation types in terms of the mean density of mounds per point which supported mounds were significant ($p<0.01$). Density values were highest in Casuarina shrubland (24.8 mounds per circular plot), second highest in Wandoo woodland (22.1 mounds per circular plot) and lowest in leptospermum heath vegetation type (3.5 mounds per circular plot)

Table 2 shows the results of the χ^2 analysis of vegetation types on mound frequency. Since the calculated χ^2 was 34.1, the influence of vegetation types on mound distribution is significant ($p<0.001$). The size of the value in individual cells provides an indication of the magnitude of the influence of vegetation type on mound frequency. Of particular interest was the fact that the observed number of mounds in Casuarina shrubland was considerably higher than the expected number, while it was less in open low heath and leptospermum heath vegetation types.

Figs. 2 and 3 are G.I.S. maps which illustrate the mound density in the reserve. Fig. 2 is a 3D-view of mound density in the reserve, and it illustrated that the mound density is higher in the south-eastern area of the reserve than in other areas.

Fig. 3 shows that, invariably, mound density is closely associated with the vegetation types. The Woodland, Casuarina and small area of Mixed heath vegetation types support a higher mound density (i.e over 72 mounds per circular plot) than other vegetation types.

Soil Survey

Table 3 summarises the mound distribution parameters on each soil type. Using a Kramer's test procedure, differences among soil types in terms of the mean density of mounds per point which supported mounds was significant ($p<0.01$).

Mound density was highest on the merredin soil type (34.2 mounds per circular plot), intermediate

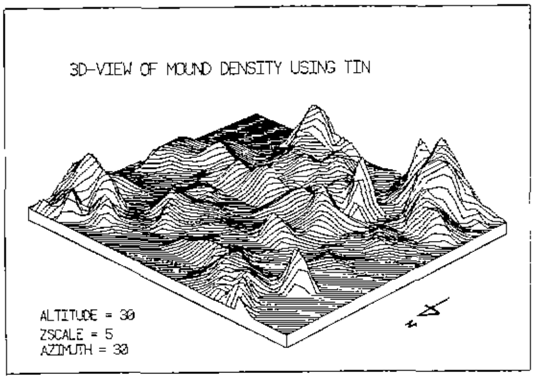

Fig. 2. G.I.S. map showing a 3D-view of mound density of *D. tamminensis* within the study area.

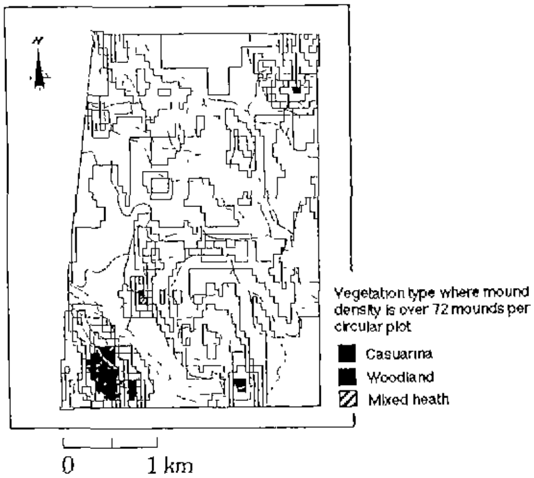

Fig. 3. G.I.S. map showing vegetation types where mound density is over 72 mounds per circular plot within the study area. The curved lines indicate boundaries of the different vegetation types.

on the collgar and booraan soil types (26.9 and 20.9 mounds per circular plot respectively) and lowest on the Danberrin and Ulva soil types (15.2 and 15.1 mounds per circular plot respectively

Table 4 shows the results of the χ^2 analysis of the influence of soil types on mound frequency. Since the calculated χ^2 analysis was 4.19 ($p>0.9$), there appears to be no influence of soil type on mound frequency.

Fig. 4 is a G.I.S map which shows the soil types upon which particularly high mound densities were found. Those soil types supporting the high mound density values were Collgar, Booraan and Ulva The high values on Collgar and Booraan substantiate the trends of moderately high overall density values on these two soil types (Table 3). The high values

Table 3. Summary of density of mounds within specific soil types. The significance of the differences between soil types were tested by the Kramer's multiple comparison test

	Booraan	Collgar	Danberrin	Merredin	Ulva
Total number of points	162	22	18	5	200
Total number of mounds	2262	377	198	171	1635
Total no. of points with mounds	108	14	13	5	108
Percentage points with mounds	66.7	63.6	72.2	100.0	54.0
Mean density of mounds per point (where present)	20.9	26.9	15.2	34.2	15.1
Significance	ab+	ab	bc	a	c

+Means with the same letter do not differ significantly ($p<0.05$)

Table 4. Comparison of the observed and expected frequency of points where mounds occur within each soil type. The significance of differences were evaluated using the Chi-square test

	Booraan	Collgar	Danberrin	Merredin	Ulva	Total
Observed No. (O)	108	14	13	5	108	248
Expected No. (E)	98.7	13.4	11.0	3.0	121.9	248
$\chi^2=(O-E)^2/E$	0.88	0.03	0.36	1.33	1.59	4.19
d.f=4						NS

NS means not significant by Chi-square test.

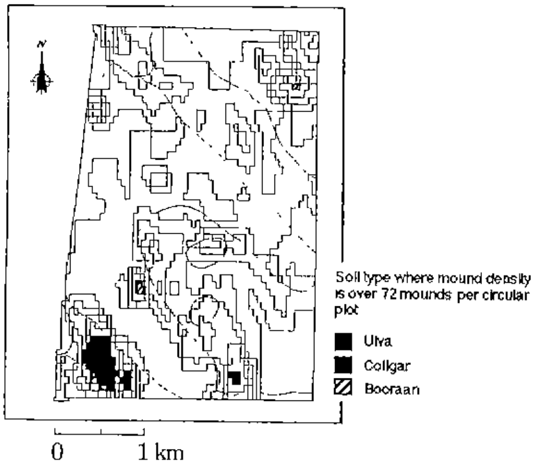

Fig. 4. G.I.S. map showing soil types where mound density is over 72 mounds per circular plot within the study area. The curved lines indicate boundaries of the different soil types.

mapped on the Ulva soil type was probably not typical of this soil type in a whole, since it supported the lowest overall mound density values (Table 3). Similarly a high density of termite mounds existed on the Merredin soil type (Table 3), although this density was <72 mounds per circular plot (Fig. 4).

DISCUSSION

Vegetation, rather than soil types, is the predominant factor in determining density and distribution of termite mounds within the Reserve. The trends between different vegetation and soil types may be summarised as follows. *Drepanotermes tamminensis* appears to be able to build their mounds on all soil types, although it does attain higher densities on certain substrates. This refer specifically to the Merredin, Collgar and Booraan soil types respectively Watson and Perry (1981) noted that *D. tamminensis* occurs most commonly on hard-setting or clayey loams, which are characterised by a gradual or duplex texture profile. Unfortunately, the specific soil types associated with this termite's distribution were not monitored by the aforementioned authors so it is not possible to directly compare their observations with ours. In addition, mound densities and frequencies are highest on the Wandoo woodland and Casuarina shrubland. In other study, *D. tamminensis* shows higher activity in the woodland and shrubland than other vegetations and this is related to the differences of litter quantity and nutrient concentration the study area (Park 1993, Park *et al.* 1993). Mounds are generally present at low densities or frequencies within the heathland associations. This finding is consistent with Watson and Perry's (1981) observation that colonies of *D. tamminensis* are commonly found in eucalypt forests, in mixed woodlands or shrublands.

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