Some Comparative Studies of the Fauna in Soils developed under Natural Forest, Pine and Bluegum

Thesis for the Degree of M.Sc., Rhodes University.

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AUGUST, 1951.

Frontispiece: Passerina sp. invading grasslands.

CONTENTS

LIST OF PLATES

INTRODUCTION.

" Habent enim rationem cum terra,
quae numquam recusat, imperium
nec umquam sine usura reddit quod
accepit, sed alias minore, plerumque
maiore cum faenore. "
Ciceronis, De Senectute, 51.

It has been said that, "If a nation saves its trees, the trees will save the nation." The truth of this assertion is apparent in many parts of the world today. In South Africa, fires and demands in the past for timber have led to extensive depletion of the Natural Forests. In many cases, natural revegetation has been slow to develop and deterioration of the soil has resulted. The desire to replace the tree cover and at the same time to meet an increasing internal demand for timber, has led to widespread planting of Pine and Bluegum. It is probable that more trees have now been planted than were destroyed in the past. The silviculturist however, who develops a pure stand on land which previously supported the mixed stand, should anticipate a change in soil properties as a natural accompaniment of such an undertaking. The nature of this change is the primum mobile of the present comparative study.

The forest soils studied were taken in the Cape Province in the following areas:- Grahamstown; Amatola

/ Mountains....

Mountains, District Alice; Witte-els-Bosch, District Humansdorp, during the course of a year. The physical and chemical properties, and the faunal composition of the soil samples were examined in relation to the different tree covers. Because of the necessity of taking large numbers of samples and thorough examination of these to arrive at a definite conclusion, the work is necessarily incomplete. It is felt however that the results obtained justify a further study of this aspect of soil biology.

Though in general the identifications were made by the author, for general information and the identifications of the Araneida, Scorpionidea and Amphibia, he wishes to record his thanks to Dr. J. Hewitt of the Albany Museum, Grahamstown. The author is also much indebted to Professor J. Omer-Cooper of the Zoological Department, Rhodes University, for advice, and to African Explosives & Chemical Industries Ltd., for financial assistance. Special thanks are due to Mr. Z. Deenik, (Agronomist) of the Cape Explosives Works Ltd., Cape Town, for carrying out the physical and chemical analyses on the Witte-els-Bosch soils.

Historical Review.

The earliest attempt to study the soil fauna in Europe was made by Diem (1903). He was followed by Holdaus in 1910.

Zoologists in America followed these European workers by studying the oecology of insects and other invertebrates in the soil. MacAtee (1907) made a preliminary survey of the forest floor for insects and other invertebrates in order to study their relationships for bird food. Insect surveys of the soil then commenced, and the work of Shelford (1937), Vestal (1913), and Adams (1915) is of significance. McCulloch and Hayes (1922) investigated the reciprocal relationships between the soil and insect population. Meanwhile in England, a series of intensive researches were carried out. Cameron in his first four papers (1913, 1916, 1917, 1925) conducted the first soil fauna survey in England, and his work greatly contributed towards the knowledge of this subject in that country. Buckle (1921, 1923) came to the conclusion that the soil fauna of grassland was more stable in distribution and numbers than in arable land. His papers describe the effect of farm manure on arable land at Rothamsted. Thompson (1924) confined her investigations to pasture land and concentrated upon the quantitative and qualitative seasonal changes in the

/ soil fauna....

soil fauna. Ford (1935) made a study of the animal population of the soil and vegetation along ridges, which traversed a meadow. He indicated the numbers and density of the fauna.

Trägårdh (1929) studied insects and other invertebrates in the soils of some Swedish forests, and Grimmett (1926), Bornebusch (1930), Jacot (1939), Scourfield (1940), and Williams (1941) investigated the fauna of forest floors. Recent work contributing to the knowledge of this environment, and the forest fauna in general, has been published by Dowdy (1944, 1947), and Jones (1946) in America. Dowdy (1944) investigated the influence of temperature on the vertical migration of the invertebrates inhabiting different soil types, while Beebe (1916) and more recently Dammerman (1925, 1937), and Salt (1950) studied the fauna in tropical soils. Salt found that the Arthropod population of East African soils was markedly and consistently lower than in English soils.

The bionomics of the soil fauna is thus a relatively recent study and one which has been largely confined to the Northern Hemisphere. Recent work has emphasised the relationship between the soil fauna and plant cover, and the part that is played by the fauna in the general economy of the soil.

Strickland (1945, 1947) made a study of experimental

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plots in Trinidad. In his first investigation, he noticed that the fauna from the native forest appeared richer than the soil fauna from the cocoa plantations. In his second investigation he came to two conclusions:-

(1) That there was a tendency to migrate from the surface layers to the deeper layers as a response to decreased humidity.

(2) There was a difference in qualitative populations in the savannah and cocoa plantations in spite of the soil being the same.

This suggests a correlation between the soil fauna and plant cover. He noticed that the fauna obtained from samples in native forest and cocoa plantations were richer in numbers of families, genera and species than those obtained from savannah. We may conclude from his work that the oecological environment would seem to exert a greater influence on the composition of the soil fauna than the gross soil type. Baweja (1939) came to a similar conclusion when he found that the profuse growth of grass on his plots was the outcome of sterilisation, and it had a marked effect upon the recolonisation of the soil organisms.

Hoff (1947) investigated 15 Aspen groves and the bordering climax and subclimax coniferous forest, at 7,600 feet and 10,000 feet above mean-sea-level, in Colorado and Wyoming. He found

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that soil invertebrates were much more numerous in the Aspen groves, and with one exception, the soil from the Aspen groves was slightly more alkaline and had a higher water content than the soil from the coniferous forest. Hetzer and Eaton (1948) compared the soil population developed under prairie and natural forest and found immensely greater numbers in the latter soil. Gavrilov (1950) came to the conclusion that if the microflora and fauna of soils were compared under comparable stands of different tree covers:- Oak, Birch, Spruce, Pine, and Larch, the bacterial counts were higher in the Oak stands than in the Birch, Larch, Spruce or Pine. Earthworms and insects were highest in numbers under Oak and Birch, and much lower under all Conifers. Oak soils were also richer in species than the others. The relatively higher biological activity of the Oak soils was reflected in the higher content of humus, nitrogen, phosphorous, higher pH values, and better structural conditions. Differences between different stands of timber were most evident in the A. horizon and tended to disappear in the B. horizon.

Franz (1942), and Franz and Leitenberge (1948) stressed the importance of the macrofauna as direct producers of humus and consequently of soil fertility. Kühnelt (1948) points out that evidence is accumulating that the larger animals, particularly insects and earthworms, play a much greater part,

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and micro-organisms a much smaller part, in the process of humification. Chastukim (1948) found that insect larvae were of considerable importance in the decomposition of Pine stumps, while V.d.Drift (1949) calculated that 7 percent of the litter in the Beech woodland that he investigated was accounted for by the millepede, Cylindrojulus silvarum. Reznik (1946) describes an interesting experiment with two larvae of Gryllotalpa gryllotalpa, which aggregated the soil in which they were placed by means of a sticky black mucus from their intestines. Franz (1950) studied the rotting process of stable manure and concluded that humus material was composed predominately of faunal excrement. The role of bacteria and fungi being mainly to make the organic matter of the soil available for the nutriment of the lesser macrofauna. Fenton (1947), Jahn (1950), and V.d. Drift (1951) concluded that the richer the variety and greater the numbers of the soil fauna, the more satisfactory is the working of the organic-matter cycle.

CHAPTER 1.

A REVIEW OF PAST SAMPLING AND EXTRACTION TECHNIQUES IN RELATION TO THE METHODS EMPLOYED IN THIS INVESTIGATION

A special effort was made to find a suitable technique, which was both rapid and efficient, so that the best use could be made of the time and apparatus available, and a balance obtained between the degree of accuracy and the labour involved.

The extraction of the soil fauna may be divided into two phases.

(A). Field Techniques.

A method must be adopted which will give an average estimation of the population living below the surface of the ground. Such an estimation is difficult when compared with that of aerial forms, because observation is of no great value here. Grimmett (1926, p.425) describes two methods for studying the animals found on the forest floor.

(1) The field naturalist's method, which consists of making excursions to as many areas as possible at all times of the year and noting the frequency, distribution, and species of animals occurring.

(2) Sampling, sorting and preserving the catch.

The former method presents certain difficulties as there is a tendancy to observe the most active species and those with no protective coloration. The latter method while

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overlooking local variations, life histories and habits, nevertheless enables an investigator to study the complexity of distribution and bionomics with the aid of laboratory facilities.

The estimation of populations necessitates the taking of a large number of samples, but it is facilitated by the investigator considering only one species. King (1939, p.273) gives a method which has been found impracticable for the present investigation. He suggested an intensive examination of a square foot unit for abundant forms such as Collembola supplemented by less intensive coverage over as much as possible of the rest. This method was used by Frenzel (1936), who took soil from a quadrate 25x25 cms to a depth of 25 cms. Within this a smaller quadrate of 100 sq cms was used for counting the small organisms, while larger forms were counted from the whole large quadrate by handpicking.

Sampling is considerably restricted in investigations dealing with the minute fauna owing to limitations of time and labour.

Krumbein and Pettijohn (1938, p.13-20) give three types of soil sampling methods for geological work:-

(1). Spot Sampling. This is an isolated sample taken at a particular point, which is valid only for the point

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sampled. The individuality of the data is thus preserved, and not obscured by a general, average composition.

(2). Serial Samples. These are spot samples, which are part of a related set of samples, collected in accordance with some predetermined plan involving an arbitary but usually unequal interval of spacing:-

(a) Linear Series, arranged along a line of traverse.

(b) Grid Series, a square pattern of lines superimposed over the area with samples collected at the points of intersection.

(3). Compound Samples. A mixture of a number of spot samples combined to give an aggregate single sample. This method affords average values and merges any variation into a single value.

In this investigation, the method of spot sampling was chosen due to the restrictions on time for field work and the difficulties of transport.

The bigger the area and the greater the number of sampling units, the more accurate will be the representation of the soil population, but this ideal is dependent upon the organised work of several soil investigators, the use of an apparatus which can deal with a number of samples, and the size of the species under study. With large soil insects, such as

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wireworm larvae, a great reduction of the technique gives a corresponding decrease in the time factor and enables one to take a large number of samples. Cockbill, Henderson, Ross and Stapley (1945, p.154) devised an apparatus for extracting wireworms which could take 10 samples each 4 inches in diameter and 6 inches in depth, and they were dealt with at the rate of 13 per man per hour, giving a total of 250 samples by 4 men. On the small scale however, where the minute soil fauna are taken into account, the above method is impossible and a method must be chosen which will reduce the time and number of samples, and yet maintain a sufficient degree of accuracy.

Forests probably provide a greater uniformity in the soil conditions under any one particular tree cover than do other types of plant cover, nevertheless there are many underlying and concealed factors such as aggregations, either by chance or in communities, accummulations or suitability of food material, conditions of changing physical factors, which may be favourable or otherwise. It is obviously impossible to eliminate by choice of site such aggregations, and it is thus unwise to draw conclusions from a few scattered samples as to the qualitative and quantitative populations over a large area. Apparently Bornebusch (1930), Dammerman (1925, 1937), and Jorgensen (1934) took spot samples as they do not

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mention any other specific arrangement.

It was with these factors in mind that the method of spot sampling was chosen, so as to obtain samples from soils developed under the three tree covers which were studied. It must be pointed however, that the results obtained from the analysis and the extraction of the cores, apply to the actual core and not to any other site under a similar tree cover. Thus comparisons between cores does not involve the conception that similar conditions and density of populations must exist over the whole area from which the sample was taken. The comparisons merely serve as a basis for some conclusions to be drawn regarding the relationship existing between the faunal composition of the core under the particular tree cover, and the conditions provided by the soil as a habitat in that core; the plant cover acting as one of the external factors which modify the soil environment.

(a). Frequency of Sampling.

The frequency with which samples are taken must depend upon the object of the investigation and the situation of the areas to be investigated. Glasgow (1939) examined an average of 1-2 samples per month, while Ford (1938) was able to study samples at 2-3 day intervals in his investigations into seasonal fluctuations. In the present investigation, the forest areas were at some distance from the laboratory, and owing to the

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difficulties of transport, frequent sampling at short intervals was found to be impracticable. As the total faunal content was extracted, the examination of each sample was necessarily slow. The minimum interval between the collections was governed by the time required for the extraction and the analyses of the samples. This was one month.

(b). Soil Sampling Instruments.

Flemming and Baker (1936) have shown that the determining factor of the sampling unit depends on the size of the unit and not the shape. To ensure regularity of sampling, various tools have been employed. Krumbein and Pettijohn (1938, p.23-25) mention some of these:-

(a). Earth augers constructed from a steel bit.

(b). A hollow tube with a slot at the side, of diameter 1 inch and provided with a cross bar for a handle.

(c). Pest-hole diggers and Golf-hole diggers.

(d). Drive-pipe samplers.

The disadvantages in the employment of such implements for soil sampling are important. Some crumble the soil so that inaccuracies arise as to the depth from which the soil was taken, an important fact if vertical distribution is being studied. Fragments may fall in from the walls of the hole, or material may be scraped from the wall. Compacting and subsequent destruction of the large organisms is liable to occur

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in hard soils. Variabilities in the texture of the soil are responsible for changes in the volume of the sample. Breaking up the soil disturbs the fauna, causing many of the active and larger species to escape, so giving lower population counts. These inaccuracies are however, impossible to avoid and must be considered when interpreting the data.

For qualitative and quantitative soil sampling, the unit employed must not be too small, as a larger number of units would have to be examined to obtain the equal volume of soil of the fewer, larger samples. As the majority of the fauna in many soils has a very irregular distribution, even a core of 3 inches in diameter is liable to give negative results. There would also be less chance of obtaining the larger species. Strickland (1947, p.1) used a core-auger of 3.6 inches internal diameter, and 3 inches in length. The depth of penetration of his implement was not however, sufficient to obtain a representative sample of the faunal population in soils with relatively deep Ao horizons. Augers have been used for sampling to depths of one foot, but from the soil biologists point of view, this is excessive. It is generally acknowledged that the bulk of the fauna inhabit the top 9 inches of the soil body.

Amongst a rather varied assortment of soil sampling instruments introduced by soil workers, may be mentioned those

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of:- (a) Ford (1935, p.196), who cut his samples from a large block brought to the laboratory. Morris (1922a) and Baweja (1939, p.129) drove a number of iron plates into the ground, forming a box, so that a block was cut 3x4x9 inches. The chamber formed by the plates was withdrawn from the soil by means of hooks. The tool measured 9 inches from the base to the holes used for the insertion of the hooks on withdrawl. Jones (1937, p.124) used metal fans with an area of 1 square foot, and $\frac{1}{4}$ square foot. A steel tamper was used to remove the $\frac{1}{4}$ square foot fan.

These instruments, which are designed to cut blocks, all require excessive hammering to force the implement into the ground.

(b) Glasgow (1939, p. 352) used a tool consisting of a sharpened galvanised iron pipe of 3.2 inches diameter, giving a sample of 8 square inches. This tool had a slot at the lower end to facilitate the removal of the core. It was found particularly useful in clay soils without many stones.

(c) Salt, Hollick, Raw, and Brian (1948, p.139) used a boring tool which cut cylinders of soil 4 inches in diameter and 6 inches in depth. By reinserting the tool into the hole formed, a sample could be obtained

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from a lower level. By examining each sample separately, the vertical distribution of the soil fauna could be estimated. The area of the sample was 12.6 square inches.

Such tools are liable to compact the soil, even if they do not disturb the fauna. A suitable choice of site is therefore necessary for their utilisation.

During the present investigation, samples were obtained by means of a heavy iron cylinder, 3 inches in diameter and 12 inches in length, supplied with a handle and a toothed lower edge (Figs.1,2). This could easily be introduced into the forest soils, where the presence of organic matter reduced compacting. The tool had great penetrating powers, its sharply toothed base enabling roots to ba cut. An entire core could be removed in one operation or the implement could be reinserted into the hole, and a sample taken at a lower level. Its chief disadvantage lay in its weight.

For sampling the Ao horizon a marker was used, consisting of a steel box measuring 12x12x6 inches, with a sharpened lower edge. This was driven into the Ao horizon to the required depth and the enclosed material removed (Fig.2).

(c). Sample Size.

In any investigation involving the sampling of a large population irregulary distributed, there is always a conflict between the ideal of a high degree of accuracy and the labour

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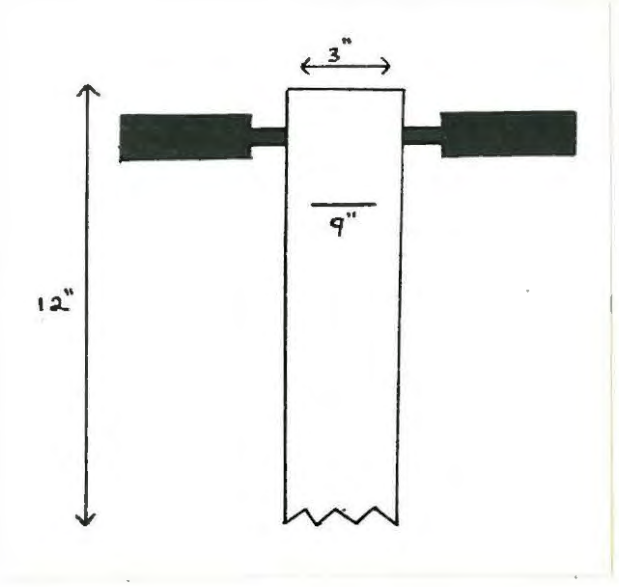

Fig.1- Soil Sampler.

Fig.2 - Soil Sampler and Litter Marker.

involved to obtain it. This conflict can perhaps best be resolved by studying the most efficient way of using a given amount of labour, and the increase of accuracy to be gained at any time by increasing the labour. In the sampling of populations, it is not however always possible to ascertain whether an increase in the number of the samples and thus the labour, would be accompanied by a proportionate increase in the accuracy obtained.

The depth to which soil organisms penetrate depends upon the depth at which food is found and upon the texture of the soil. Ford (1935, p.203) found no organisms below a depth of 8 inches. His samples were obtained in a heavy clay soil, which was except during the summer months, very damp and usually waterlogged. Morris (1922a) came to the conclusion that the greatest numbers of insects and other invertebrates were confined to the upper 6 inches of the soil, although some species penetrated to greater depths. Strickland (1945, p.10) found that the distribution in depth falls away rapidly after the first 2 or 3 inches. Many Arthropoda did not apparently migrate deeper than 6 inches from the soil surface. He recorded however, mites and ants at the 9 inch level. A convenient depth acknowledged by soil biologists to include the bulk of the fauna is 9 inches. In the present investigation, all borings were made to this depth after the Aoo horizon and surface growth had been cleared

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to exclude above ground forms.

The volume of the sample is largely dependant upon the capacity of the apparatus available for the extraction. Thompson (1924) believed that a 9 inch cube was the most satisfactory size from the point of view of statistical accuracy. Ford (1935, p.196) found such a cube unsatisfactory for those soils which were largely composed of clay. Whatever the choice of sample size may be however, its uniformity must be maintained throughout the investigation.

Here, the apparatus used for extracting the fauna was designed to take a sample of 64 cubic inches. The restrictions in transport made it desirable that the sample should not be too bulky, and samples of this size conveniently fitted into 4 pint screw-top Ball jars. The size of the sample was thus a cube measuring 4x4x4 inches, or a cylinder of 3 inches diameter and length 9 inches. The boring tool previously described conformed to the required dimensions.

(d). Storage and Transport.

The transport of the soil samples for faunal examination was made in screw-top Ball jars, those for chemical analysis in cloth bags, and those for physical determinations in test tubes fitted with well fitting corks (Fig,3).

To prevent drying out of the soil, the screw-top jars were fitted with rubber-ring washers. Samples have been kep't

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for three weeks or more and the fauna extracted in perfect condition. Other workers have used tins or paper bags, but the choice of container appears a matter of convenience, providing no loss of moisture can occur, and contamination is avoided.

(e). Environmental Conditions at the Time of Sampling.

As much as possible of the physical environment was noted at the time of sampling, so that if peculiarities in the counts were observed, correlation with a particular physical feature could be made.

(B). Laboratory Techniques.

An examination of the papers published by Buckle (1921, 1923), Cameron (1913, 1916), MacAtee (1907), and Morris (1920) show that in all the investigations dealing with the fauna of the soil, their efficient separation was a matter of great difficulty.

Table. 37 (Appendix) shows that many earlier workers examined the soil by hand. Limitations to handsorting are apparent when such methods are compared with more modern techniques. Cockbill, Henderson, Ross and Stapley (1945, p.149-151) showed that when the extraction values for the more modern flotation processes and manual methods were compared, an extremely variable proportion of the catch was detained by the latter method. This was due to the variable efficiency of individuals under conditions of fatigue, and

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the definite physiological limits to the numbers of animals that the eye can detect.

Improvements on the older methods may be placed in three main classes (Ladell, 1936, p. 863):-

(a) Voluntary movement of the fauna from the soil.

(1) Attraction to warmth.

(2) Attraction to warmth, aided by the repulsion from light.

(b) Separation by sieving.

(1) Washing soil through sieves with or without agitation.

(c) Separation by Flotation.

(1) On the residue after washing through sieves.

(2) Without preliminary sieving.

a(1) Berlese (1905, p. 85-89) devised a method for collecting minute insects and parasites of vertebrates from decomposing material by means of a double-walled metal funnel fitted with a fine mesh sieve across the top, and a tube at the bottom of the inverted cone leading into a collecting vessel. The space between the walls was filled with water, which was kept warm. The soil being gently heated, desiccation occurs, which drives the fauna into the collecting vessel. Thompson (1924) and Strickland (1945, 1947) demonstrated this positive geotropism under natural conditions

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within the soil body. The whole method is based upon this reaction to a rise in temperature and a fall in humidity. Figure 4 shows the type of Berlese funnel used. The water in the jacket was heated by means of a gas ring.

The chief disadvantages of the apparatus may be summarised as:-

(1) The uncertainty of extracting all the fauna from the soil sample.

(2) The amount of time involved.

It was with a view to the elucidation of the first, that a brief investigation into the efficiency of the funnel as compared to the flotation process was undertaken.

Table 1 gives the result obtained by passing the sample through the funnel as a preliminary measure and then through Ladells flotation machine. It will be seen that a partial correlation exists between the initial moisture content of the sample and the percentage of the total extracted by the funnel. This is due in part to the reaction of the Collembola and Acarine populations to a decrease of humidity and a rise of temperature (Table,2a,2b).

Unfortunately it is not possible to reverse the order of treatment, nor is it possible to control the moisture content of the sample so as to give a more complete range of data. It is suggested however, that when the bulk of the

/ fauna....

TABLE 1.

Sample	% Initial Moisture	% Terminal Moisture	% Extraction. Funnel	Machine	Faunal Total
a	30.75	4.47	86	14	899
b	27.48	3.82	79	21	213
c	16.23	3.56	70	30	70
d	15.41	3.09	46	54	52
e	14.36	3.98	57	43	47
f	14.26	3.34	37	63	24
g	13.59	5.85	37	63	46
h	10.08	3.40	49	51	37

TABLE 2a

Acarines.

Sample	Total	% Extraction. Funnel	Machine
a	726	95	5
b	139	94	6
c	46	74	26
d	22	59	41
e	31	74	26
f	18	44	56
g	24	61	39
h	17	55	45
Total	1023		

TABLE 2b.

Collemboles.

Total	% Extraction. Funnel	Machine	% Moisture
134	51	49	30.75
70	50	50	27.48
20	60	40	16.23
18	35	65	15.41
11	37	63	14.36
5	25	75	14.26
9	22	78	13.52
6	0	100	10.08
Total 273			

Fig.3 - Air-tight containers for transporting soil samples.

Fig.4 - Berlese Funnel.

fauna consists of Collembola and Acarines, the efficiency of decreasing the humidity by raising the temperature, as a means of extraction, is in proportion to the increase in the initial moisture content of the sample.

Ford (1937, p.101) used a Berlese funnel operating at 50 degrees centigrade and found that the greater part of the catch came through in 24 hours. The present findings were consistent with this result.

The Berlese funnel was used in this investigation for the extraction of the Ao horizon, as this was composed largely of organic matter. A high organic content in the sample was found to lower the efficiency of the flotation process, due to the difficulty of separating the fauna from the residue during the final treatment. The funnel was maintained at a temperature of 50 degrees centigrade, which gave a soil temperature at 1 inch depth of 31 degrees at the periphery, and 30.5 degrees at the centre. The faunal extract was collected in 70% alcohol, and examined under the low power of the binocular microscope, with the aid of a black filter paper and the source of illumination suitably adjusted. A wetting agent was employed to reduce the surface tension and facilitate the sorting of the catch.

The extraction was divided into four phases:-

(1) An initial maximum phase due to small lumps of soil on

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the sieve drying rapidly, while the main bulk of the sample was unaffected.

(2) A maximum phase due to a change in temperature in the seventh hour, and shown by the reaction of the fauna against this.

(3) A maximum phase correlated with the fall in humidity.

(4) Emigration small,as all the fauna have either been expelled or killed by the low humidity.

Table 38 (Appendix) illustrates these four phases. The second maximum occurs during the tenth hour. There is no regularity in the build up to the maxima, the greatest numbers of animals are expelled over a period covering eight hours, and at the termination of this period, there is a sharp fall in the numbers captured. Figure 5 shows this in the form of a histogram.

Figure 6 gives a curve showing the water content of a sample during desiccation in the Berlese funnel. The moisture content shows a regular decrease except at the initial stage with which phase 1 is coincident. This stage covers from one to two hours, and corresponds to that period of time required to bring the contents of the funnel to a uniform temperature.

Trägårdh (1933, p.208) has shown that the point of desiccation exerting the most active influence on the migration

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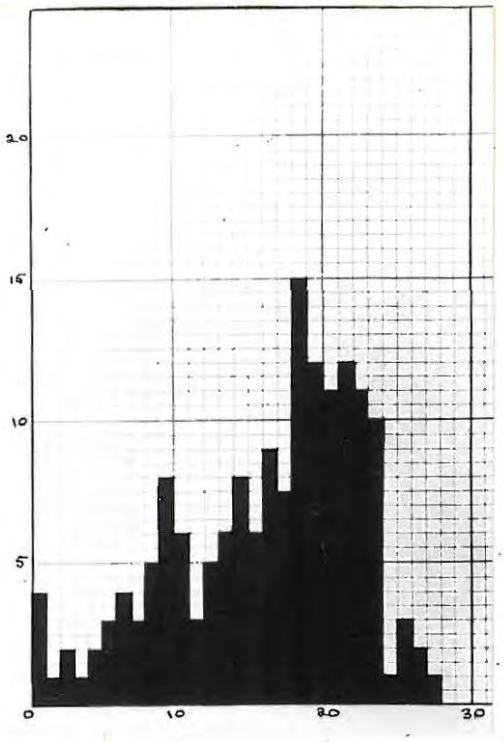

Fig.5 - Numbers of Fauna extracted hourly from a sample during desiccation in the Berlese Funnel.

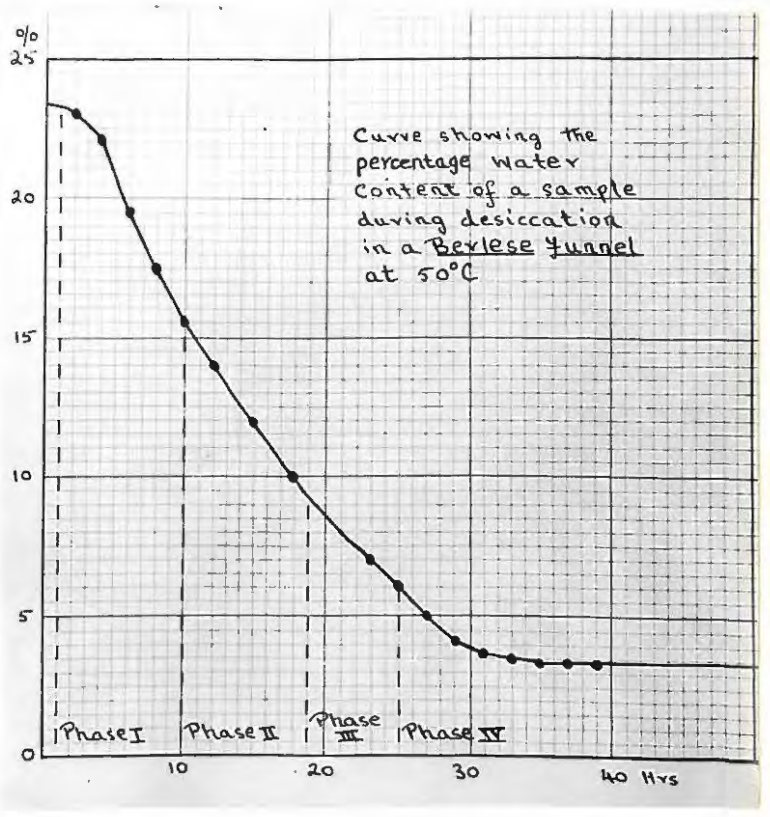

Fig.6 - Moisture curve of a sample during desiccation in the Berlese Funnel.

of the fauna was 20 percent. The data from this experiment seems to indicate a somewhat lower value.

a(2). Ford (1937,p.101) used a modified form of Tüllgrens apparatus (Tüllgren.1917) in which a battery of 12 funnels were electrically heated from above by wire coils. Bornebusch (1930,p.21) used a carbon filament electric bulb of 35 candle power as a source of light. His extraction values were somewhat lower than Trägårdh (1933), who believed the discrepancy to be due to the intense heating from the lamp. Haarlov (1947, pp.115-120) showed that Tüllgrens apparatus could be modified according to the nature of the habitat. He modified the original design so that it could be used in the three habitats of Common, Forest, and Lake Banks.

Two sources of error occur in the use of this apparatus:-

(1) Formation of dew on the inside of the funnel.

(2) Paralysis of the fauna, if the temperatures rise too high or too rapidly.

b(1). Morris (1922, p.197) made an important step forward when he introduced a method for washing soil through sieves . There were however, serious disadvantages in the use of this method. The agitation and friction was found to damage the fauna, and it was impossible to use the apparatus for dealing with a large number of samples required

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by experiments designed in accordance with modern statistical procedures. King (1939, p.277) points out that these washing and sieving techniques cause loss of immature or fragile forms, and besides it was often difficult to distinguish between species alive or dead, prior to the process. Shirck (1930, pp.991-994) modified Morris's method for the extraction of eggs and the young of earthworms. Lane (1928, pp.934-936) used a sifter with screens which were shaken to and fro' by a handle, and Jones (1937, p.125) developed a more mobile power sifter.

c(1). Thompson (1924) and Edwards (1929) both sifted the soil as a preliminary treatment and washed small portions at a time. This process of subdivision was very tedious and time-consuming, and the minute fauna might easily be lost by tending to adhere to the walls and mesh of the sieve. A similar difficulty was encountered when attempts were made to centrifuge soil, as the debris was retained on the walls of the centrifuge tubes.

c(2). Ford (1935, p.196) cut a sample 3x3x9 inches in half inch layers, and each layer was broken up under water with the aid of needles.

Daniels (1933) devised a method, which proved successful for obtaining the larvae and pupae of Epitrix cucumeris. This consisted of agitating the soil in pans filled with

/ water....

water. The fauna floated on the surface and were caught on screens of increasing fineness.

Ladell (1936, pp.862-869) described an apparatus (Fig. 7) for the rapid and efficient extraction of the soil fauna, the principle of which depended upon the flotation of the animals in a strong solution of Magnesium sulphate, the specific gravity of which was greater than that of the fauna. The freeing of the fauna from soil lumps was facilitated by means of a fine stream of air bubbles and stirring. The air stream freed the fauna from the soil and these rose to the surface of the liquid in a froth, mixed with organic debris, most of which was held back by a coarse sieve placed just below the surface of the liquid in the flotation cylinder. The level of the liquid in the cylinder was raised by a gradual inflow of Magnesium sulphate solution by gravity from a reservoir.

By using this apparatus, Ladell obtained counts for the soil insect population far in excess of those recorded by the majority of workers. It has been employed by Baweja (1939) and Glasgow (1939). Recent modifications have been introduced by Salt and Hollick (1944), Cockbill, Henderson, Ross and Stapley (1945), and Strickland (1945).

TECHNIQUE USED IN THE PRESENT INVESTIGATION.

A modified form of Ladells machine (Fig. 8) was used,

/and....

Fig.7 - Ladells Flotation Machine.

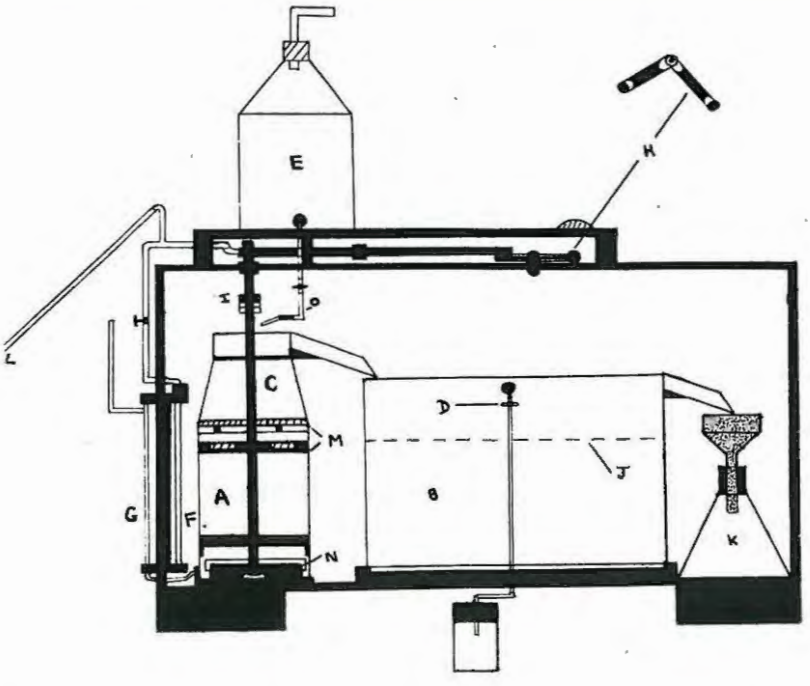

Fig.8 - Ladells Flotation Machine. (Schematic diagram).

Ladells Flotation Machine.

Fig.8.

a - Flotation Tank.
b - Sedimentation Tank.
c - Conical Head.
d - Stopcock attached to Sedimentation Tank.
e - Reservoir of Magnesium sulphate solution.
f - Manometer.
g - Solution-level indicator attached to Flotation Tank.
h - Driving-gear to give oscillatory movement to sieves and air-jets.
i - Coupling.
j - Sheet metal partitions.
k - Buchner Funnel.
l - Compressed air pipes.
m - Sieves.
n - Air-jets.
o - Outlet pipe from reservoir.

and the following system of operation adopted.

Large stones and other material were separated from the main bulk of the sample and stirred in a vessel containing a solution of Magnesium sulphate (Sp. Gr.1.2). This salt is convenient to use on account of its cheapness, innocuous qualities, and non-dispersive action on the clay fraction of the soil. The solution was then transferred to the machine during the course of the operation. The remainder of the soil sample was placed on the bottom sieve of the apparatus and solution poured into the flotation cylinder, so as to bring its level just below the rectangular opening of the conical head. The air pump was started and continued for five minutes. This helped to extricate those animals which were not embedded in the soil. The stirrer was then started and maintained for ten minutes. If all the debris floated immediately, the stirrer was stopped to avoid damaging the fauna. Immediately after starting the stirrer, solution was run in at a rate of 150 ccs per minute, and as the level rose in the flotation cylinder, the stopcock attached to the sedimentation tank was opened. This maintained the level of the solution in the tank below the outlet opening, and prevented suspended soil from being carried over with the froth into the Buchner Funnel when later closed. The Buchner Funnel, fitted with a No.41 Whatmans filter paper, was connected to

/ an....

an exhaust pump, which maintained a negative pressure of 5 inches of Mercury. Froth and debris sticking to the sides of the flotation cylinder and sedimentation tank were removed by brushing, and the soil remaining in the former tank examined for the larger fauna.

The circulation of air through the solution is the most important part of the extraction process, and if too vigorous the fauna is liable to be damaged. The pressure must be adjusted according to the volume of soil to be extracted. This was 10 cms of Mercury for a volume of 64 cubic inches.

The final phase of the extraction technique was the presentation of the faunal concentrate in a suitable state for a rapid and efficient examination under the binocular microscope. Boiling the debris was preferable to reduction of pressure or treatment with paraffin and benzene, in the final separation of the fauna from the debris. The former killed the animals in an extended state, a method suited for the delicate forms of the soil and facilitating their identification. The vegetable debris sank to the bottom on cooling and provided a dark background against which the fauna show up, if the source of illumination was suitably adjusted.

The residue to be examined was less than one percent

/ of....

of the original soil, while in Morris's sieving technique the quantity was from 30-60 percent. The flotation process is thus both efficient and accurate, and possesses many advantages over previous techniques, the chief being its rapidity, nontoxicity and cleanliness.

The improvements on the older techniques may thus be summarised as follows:-

(1) Deflocculation.

(2) Separation of the fauna and vegetable debris from the mineral soil particles.

(3) Separation of the fauna from the vegetable debris with the assistance of paraffin, benzene, or boiling. This step was omitted by Ladell.

CHAPTER 2.

THE DESCRIPTION AND LOCATION OF THE SAMPLE SITES.

Factors in the choice of the Sample Sites.

Marbut (1935) defined soil as follows:-

"The soil consists of the outer layer of the earths crust, usually unconsolidated, ranging in thickness from a mere film to a maximum of somewhat more than ten feet, which differs from the material beneath it, also usually unconsolidated, in colour, structure, physical constitution, chemical constitution, biological characteristics, probably in chemical processes, in reaction and in morphology".

This definition distinguishes between soil and parent material and emphasises the characteristics of the soil as a natural body. It is however more than a mere mixture of weathered rock and decayed organic matter. Among the features which differentiate the soil from other parts of the earths crust are the following:-

(a) Certain well defined groups of soils are confined to distinctive regions of the earth, whereas geological formations are not.

(b) Soils are generally layered, the morphology of the body depending upon the conditions under which it developed.

/ (c) The....

(c) The soil bears a close relationship to the plant and animal life of the earth, the influence being reciprocal.

It is this last feature with which the present investigation is concerned. In order to study this relationship, samples of the soil were taken under Natural Forest, Pine, and Bluegum, and the choice of the sample sites was governed by the following considerations:-

(1) The sample to be representative as far as possible of the particular stand of timber.

(2) Contamination from other stands of timber to be avoided.

(3) The samples to be obtained as close to each other as possible, consistent with 1 and 2 above.

(4) The substratum to be uniform throughout the area to be investigated.

(5) The location of the sites away from any immediate disturbance of the environment due to the activities of man. (Figs. 9, 10, 11)

The above considerations were complied with by making the following rules the desiderata:-

(1) The samples were located away from the edges of the plantations. (Fig. 12)

/ (2) The....

Fig.9 - Litter collected during the cleaning of a fire-belt of E. diversicolor.

Fig.10 - Organic layers cleared from beneath a stand of P. pinaster.

Fig.11 - Pits constructed in a fire-belt, and filled with the organic surface layers.

Fig.12 - Kersehout (*Pterocelastrus tricuspidata*) invading a stand of *E. diversicolor*.

(2) The samples were obtained in dense stands of the desired timber. (Figs. 13,14,15)

(3) The samples were obtained within an area of not more than one square mile.

(4) Uniformity of geological formations persisted in the areas investigated, and the samples were taken, when possible, during periods of normal climatic conditions.

(5) The effect of man's activities upon the environment was in many cases impossible to avoid. The obvious effects were however eliminated by a suitable choice of site. (Fig.16)

The Soil Profile.

In normal forest soils, the bulk of the organic matter lies on or near the surface. This top portion of the soil has been termed the "Humus Layer", which owes its characteristic properties to its content of humus. Forest humus layers have been divided into two main groups. (Heiberg and Chandler.1941,p.89).

(a) Mull. A humus layer consisting of mixed organic and mineral matter. The transition to the lower levels is not sharp.

(b) Mor. A humus layer of unincorporated organic matter, usually matted or compacted, distinctly delimited from the mineral soil, unless the latter has been blackened by the washing in of organic matter.

/ These....

Fig.13 - Natural Forest.

Fig.14 - Pine.

Fig.15 - Bluegum.

Fig.16 - Evidence of "selective cutting"in Natural Forest at Witteels-Bosch.

These forest humus layers are by no means uniform throughout their depth, and horizons can be distinguished within them. Lutz and Chandler (1947, p. 168, quoting from Hesselman, 1926) recognised three layers:-

(1) Litter (Aoo Horizon). Consisting of the dead and unaltered remains of plants and animals.

(2) Formultningsskiktet (Ao Horizon). Consisting of partly decayed organic matter.

(3) Humusamneskiktet. (Al Horizon). Consisting of well decomposed amorphous organic matter mixed with the mineral soil.

Figure 17 shows the relationship that these three humus layers bear to the soil profile. In the present study, Hesselman's scheme of dividing the humus layers was adopted, using the annotations which the majority of American foresters prefer.

Sampling the Soil Profile.

The Aoo horizon was removed before sampling to exclude the above-ground fauna. Strictly speaking, the Aoo horizon is not part of the soil, but it must be considered since it is an important source of food for the fauna. Samples of this horizon were not however taken, as they were bulky and difficult to separate from their faunal contents. A field collection was substituted, and portions taken which

/ were....

were used in the experiments to be described in Chapter 7. The line of contact between the Aoo and Ao horizons was included within the cores.

Samples for pH, organic, moisture content, and nitrogen determinations were obtained from the sides of the boring at a depth of 4.5 inches, if this depth fell within the mineral soil. Material for the examination of the Protozoan fauna was also taken at this level. The choice of this depth for these extractions was arbitary, the depth being half that of the total depth to which the borings extended, viz. 9 inches. The depth of 4.5 inches was also taken as the line of division between the upper and lower levels of the cores examined in series A.

The texture of each sample was observed in situ, and the depths to which each horizon extended measured with the aid of the graduated iron rod illustrated in Figure 18.

It was found that moistening the sides of the boring, when sampling dry or friable soils, and those rich in organic matter, prevented material from falling in from the upper levels of the hole. This was unnecessary when the complete core was extracted entire, but proved useful when extractions from different levels were required.

Soil Colour.

Colour is frequently mentioned in the description of

/ these....

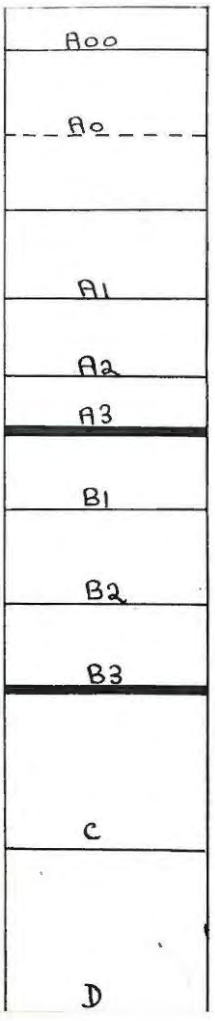

Fig.17 - Hypothetical soil profile showing the principal horizons.

Fig.18 - Graduated iron rod for measuring the depth of the organic horizons.

Hypothetical Soil Profile showing the principal Horizons.

Fig.17.

AOO Horizon - Litter consisting of fresh or only slightly altered organic material.

AO Horizon - (a) Partly decomposed organic matter that still retains sufficient structure to permit identification of its source.
(b) Composed principally of amorphous organic matter.

A1 Horizon - A dark-coloured horizon, containing a relatively high content of organic matter, but mixed with the mineral soil.

A2 Horizon - A light-coloured horizon, often represent- the zone of maximum leaching.

A3 Horizon - Transitional to B, but more like A than B.

B1 Horizon - Transitional to B, but more like B than A.

B2 Horizon - Deeper-coloured horizon, often representing the zone of maximum accumulation.

B3 Horizon - Transitional to C.

C Horizon - Weathered parent material.

D Horizon - Underlying stratum consisting of any stratum below the soil regardless of the nature, which is not parent material.

these samples. Colour is of all the soil characteristics the most obvious and yet one which is difficult to express exactly. It is an aid in differentiating soil horizons and in classifying soils. Soil organic matter is dark and is the most common cause of black or brown soils. The colour is however also influenced by soil texture. A large number of schemes for the specification of soil colour have been proposed.

In 1928, Hutton described a method for obtaining rather precise measurements of soil colour. Four standard discs, with the segments of each exposed, are rapidly rotated, and the composite colour compared with that of the soil. Colour is then specified in terms of percentage white, black, yellow or red (Table 3, from Piper, 1942, p.114). Unfortunately Hutton's apparatus was unavailable for this investigation, but soil colour was estimated with the aid of the colour class given in the Table. It was hoped that some degree of uniformity of description could thus be obtained.

Description of the Samples.

A set of samples, taken at the same time and from the same locality, constituted a series. Each series contained samples of Natural Forest, Pine and Bluegum, and were numbered serially.

A total of 29 samples were obtained from August, 1950-

/ June,1951....

TABLE 3.

1. Colour Class.	2. % Black.	3. % White.	4. % Yellow.	5. % Red.
Black.	87.5	6.0	3.0	3.5
Very dark Grey.	79.5	8.5	6.5	5.5
Dark Grey.	69.5	14.0	9.0	7.5
Grey.	57.5	19.0	18.5	10.0
Light Grey.	44.5	25.5	18.0	12.0
White.	-	-	-	-
Brownish Black.	86.0	2.0	5.0	7.0
Very dark Brown.	79.0	0	8.0	13.0
Dark Brown.	72.5	1.0	9.5	17.0
Brown.	56.5	4.0	16.0	23.5
Light Brown.	42.0	9.0	19.5	29.5
Dark greyish Brown.	75.5	5.0	9.5	10.0
Greyish Brown.	55.0	9.0	14.5	21.5
Light greyish Brown.	44.0	14.0	20.5	21.5
Dark yellowish Brown.	55.5	0.5	18.5	25.5
Yellowish Brown.	34.5	3.0	27.5	35.0
Yellow.	45.5	4.5	26.0	24.0
Light Yellow.	23.0	12.5	36.0	28.5
Greyish Yellow.	46.5	8.5	25.0	20.0
Reddish Brown.	65.5	0.5	10.0,	24.0
Light reddish Brown.	44.0	1.5	16.0	38.5
Chocolate.	83.0	0	6.0	11.0
Red.	-	-	-	-

June, 1951 in the localities listed below.

Series A. Grahamstown District.

The samples were taken from a slope with a South East aspect, situated at approximately 1800 feet above mean-sea-level, and facing the coast 30 miles due South. The locality from which the samples were taken is known as "Fernkloof".

The substratum consisted of Witteburg quartzites, forming scattered outcrops on the face of the slope.

The locality provided samples for a preliminary survey of the proposed sampling and extraction techniques to be employed in the investigation. These samples were not included in the data. Local conditions of drought prevailed at the time of sampling.

(1) This sample was taken from a belt of soil lying between a plantation of Pinus pinaster to the East, and Natural Forest to the West. Pinus pinaster formed the dominant tree cover.

The surface growth consisted of scattered creepers and grass. The substratum was encountered at the bottom of the boring.

Aoo Horizon (2 inches). Poorly developed, and largely composed of pine needles, twigs, and mixed debris from the surface growth.

Ao Horizon (1 inch). Matted and spongy.

/ A1 Horizon...

A1 Horizon (1 inch). Very dark grey.

A2 Horizon. Friable at the deeper levels. Dark grey.

Mor soil, inclined to podzolisation.

(2) This sample was taken from soil developed under a covering of Pinus pinaster, 200 yards to the East of the previous site. The trees were closely spaced and surface-growth was negligible.

Aoo Horizon (2 inches). Well developed carpet of pine needles.

Ao Horizon (1 inch). Matted and moist.

A1 Horizon (2 inches). Moist, dark grey passing to a lighter shade with depth.

A2 Horizon. Light grey.

Mor soil, inclined to podzolisation.

(3) This sample was taken from soil developed under a Natural Forest covering, which formed a belt extending down the slope to the West of the previous site. This belt was an extension of the "Temporate Forest", which attains a maximum development on the strip of country forming the coastal belt, between the mountains and the sea, between George on the West and Humansdorp on the East. Here the forest forms the natural covering over most of the ground up to an altitude of between 2,500 and 3,000 feet. A characteristic feature of this type of forest is its growth under

/ uniformily....

uniformily distributed moisture, either from rain or mists, relatively low temperatures and freedom from frost. Samples were taken within the same forest type on the Amatola Mountains and at Witte-els-Bosch. Both these regions will be dealt with later in this chapter.

The forest covering this site was undisturbed due to the broken nature of the ground. The trees were closely spaced and surface-growth was sparse. The predominant species surrounding the site belonged to the genera Cunonia, Podocarpus, Olea, and Xymalos.

The substratum was encountered at the bottom of the boring.

Aoo Horizon (1 inch). Undecayed and partly decayed remains of leaves and twigs.

Ao Horizon (Mixed). Loose and spongy with incorporated undecayed organic matter.

A1 Horizon (Mixed). High moisture content. Dark brown. Mull soil, well developed.

(4) This sample was taken from soil developed under a stand of Eucalyptus diversicolor, 600 yards along the slope towards the site of sample 3. The stand was poorly developed and consisted largely of young trees. A site was chosen however, surrounded by relatively mature trees.

The surface vegetation was sparse.

Aoo Horizon (2 inches). Dead leaves and bark.

/ Ao Horizon....

Ao Horizon (3 inches). Matted.

A1 Horizon (1 inch). Sandy.

A2 Horizon. Light grey.

Mor soil, inclined to podzolisation.

Two further samples were obtained within 20 miles of the coast, due South of "Fernkloof", in the direction of the Kariega river's mouth. They thus fall outside a circumscribed area of one square mile, and so do not strictly fall within this series. They were obtained for comparative purposes.

(5) This sample was taken from soil subjected to much trampling by cattle. The surface was covered by short grass tufts and a few Acacia karroo.

The substratum was composed of quartzitic sandstones, and the topography was smooth in contour.

Aoo Horizon. Nil.

Ao Horizon. Nil.

A1 Horizon. Negligible. Grey.

A2 Horizon. Light grey.

Compacted soil.

(6) This sample was taken from soil developed under Coastal Bush, four miles North of the Kariega river's mouth. The flora consisted of species belonging to the genera Euphorbia, Plumbago, Acacia, Commiphora, Aloe, and Schotia.

The surface vegetation consisted of scattered flowering plants and creepers.

/ Aoo Horizon....

Aoo Horizon (½ inch). Not well developed, consisting of debris from the surface vegetation and bushes.

Ao Horizon (2 inches). Difficult to differentiate.

A1 Horizon. Sandy, dark brown.

Mull soil, not well developed.

Series B. Amatola Mountains.

The samples of this series were taken from a slope with a South East aspect, situated at approximately 4,000 feet above mean-sea-level.

The topographical features of the region are erosional, formed from nearly horizontally placed Beaufort Shales. The continuity of the shales are however, interrupted by Dolorite intrusions, which give the overlying soil a characteristic reddish colour. The soils are deeper and exhibit fewer outcrops of the underlying strata than in the previous series.

The choice of suitable sites was made difficult by the paucity of Bluegum stands, and as a consequence the distance between the sample site exceeded those chosen in the other series. (Fig. 19).

(1) This sample was taken from soil developed under Pinus insignis. The trees were closely spaced and no surface-growth occurred. (Fig. 20).

Aoo Horizon (4 inches). A mat of pine needles and twigs.

/ Ao Horizon....

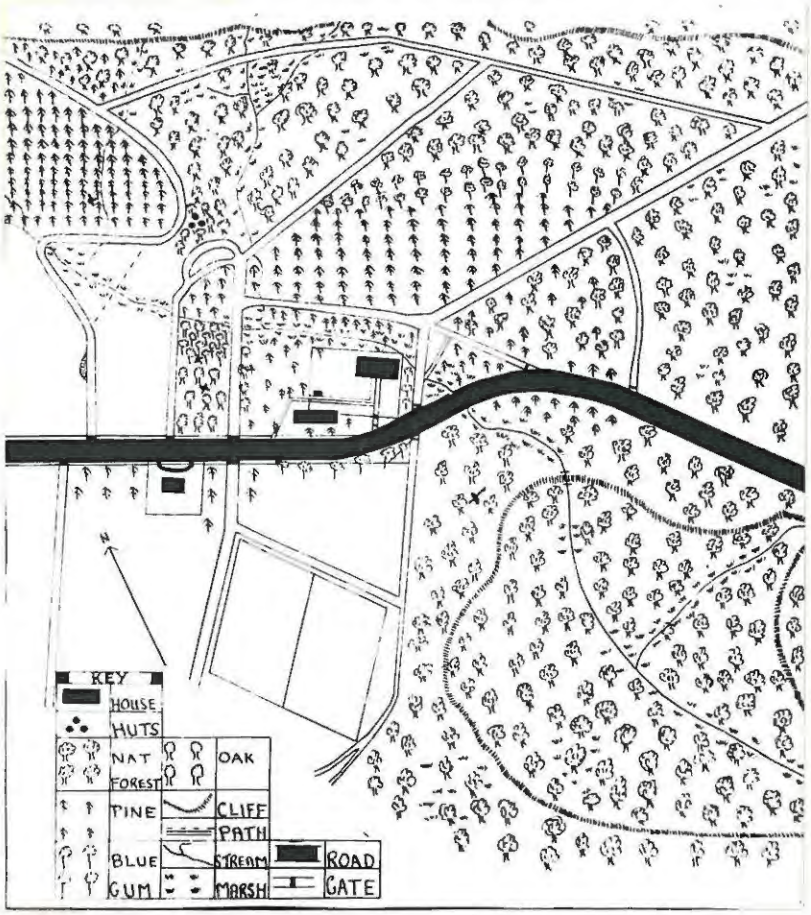

Fig.19 - Sketch Map of the sampling area in the Amatola Mountains.

Fig.20 - Forest floor under P. insignis, Amatola Mountains.

Ao Horizon (2 inches). Matted and moist.

A1 Horizon. Light and friable. Brownish black.

Mor soil.

(2) This sample was taken from soil developed under Quercus pedunculata, lying 500 yards to the South of the previous site. The surface vegetation consisted of scattered grass and a few creepers.

Aoo Horizon (1 inch). Leaves and twigs.

Ao Horizon (2 inches). Undecomposed and partly decomposed organic material.

A1 Horizon. Lumpy and inclined to crumble when handled. Black.

Mull soil.

(3) This sample was obtained from soil developed under Eucalyptus diversicolor, lying 50 yards from the previous site. The site was not very satisfactory from the point of view of obtaining a representative sample, but in view of the scarcity of Bluegum stands in the region, it was decided to include this sample.

The trees were mature but mixed with young Pinus insignis and Pinus pinaster. The surface-growth was composed of grass-tufts and creepers.

Aoo Horizon (2 inches). Decayed leaves, the bark of the trees, and a little surface-

/ growth....

growth.

Ao Horizon (3 inches). Matted.

A1 Horizon (3 inches) . Grey.

A2 Horizon. Powdery and compacted with depth. Grey.

Mor soil, inclined to be podzolised.

(4) This sample was taken from soil developed under a Natural Forest covering, about 1000 yards South of the previous site. (Fig. 21). The forest was of the Temporate type, similiar to that found at Grahamstown and Witte-els-Bosch.

The surface-growth was dense with creepers forming a carpet upon the forest floor. Lianes and epiphytes were not abundant. The site was situated near a Xymalos monospora.

Aoo Horizon (2 inches). Debris from the trees and surface-growth.

Ao Horizon (Mixed). Friable and spongy.

A1 Horizon (Mixed). Lumpy and compacted. Black.

Mull soil, well developed.

(5) This sample was obtained from soil developed under Sclerophyll Bush, bordering the Natural Forest, 1500 yards from the previous site.

The site was situated near a Gymnospora harveyana. The surface vegetation consisted of grass.

Aoo Horizon. Nil.

/ Ao Horizon....

Fig.21 - Natural Forest on the Amatola Mountains.

Ao Horizon. Nil.

A1 Horizon. Difficult to differentiate.

A2 Horizon. Compacted. Grey.

Series C, D, E, (FG). Witte-els-Bosch District.

The four series will be considered together as all were obtained in the same region, but at monthly intervals.

The region is situated at the foot of the Tsitsikama Range, at a distance of seven miles from the coast. The whole area is forested, the Natural Forest occupying the slopes and meeting the Pine and Bluegum plantations on flat ground. The altitude on the coastal plain does not exceed 700 feet above mean-sea-level.

The underlying formations consisted of Table Mountain Sandstones with a Bokkeveld strip lying immediately to the South. This latter formation did not enter the sampling area. A peculiarity of the soils from this region was the presence of a fine white clay-like material, which proved on laboratory examination to consist of quartz crystals, whose mean diameter was 10μ.

Figure 22 gives the monthly rainfall in relation to the period of sampling. It will be noticed that the samples were taken at the end of a period of relatively low rainfall.

The map given in Figure 23 illustrates the location of the sites which were chosen to represent this region.

/ Series C....

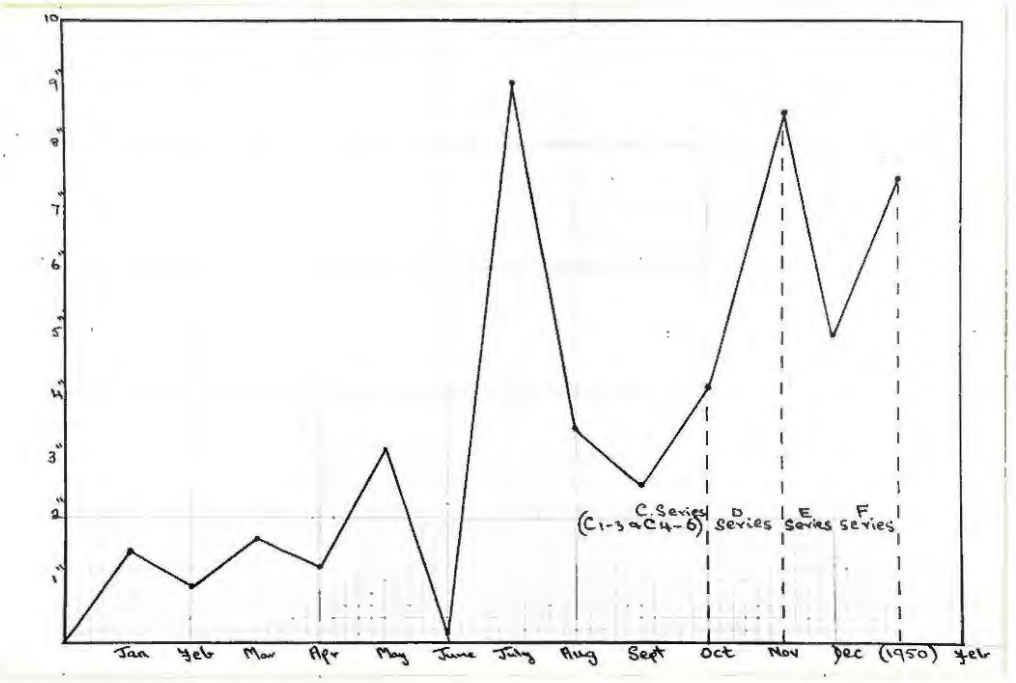

Fig.22 - Mean Monthly Rainfall for 1950 at the Forestry Station, Witte-els-Bosch.

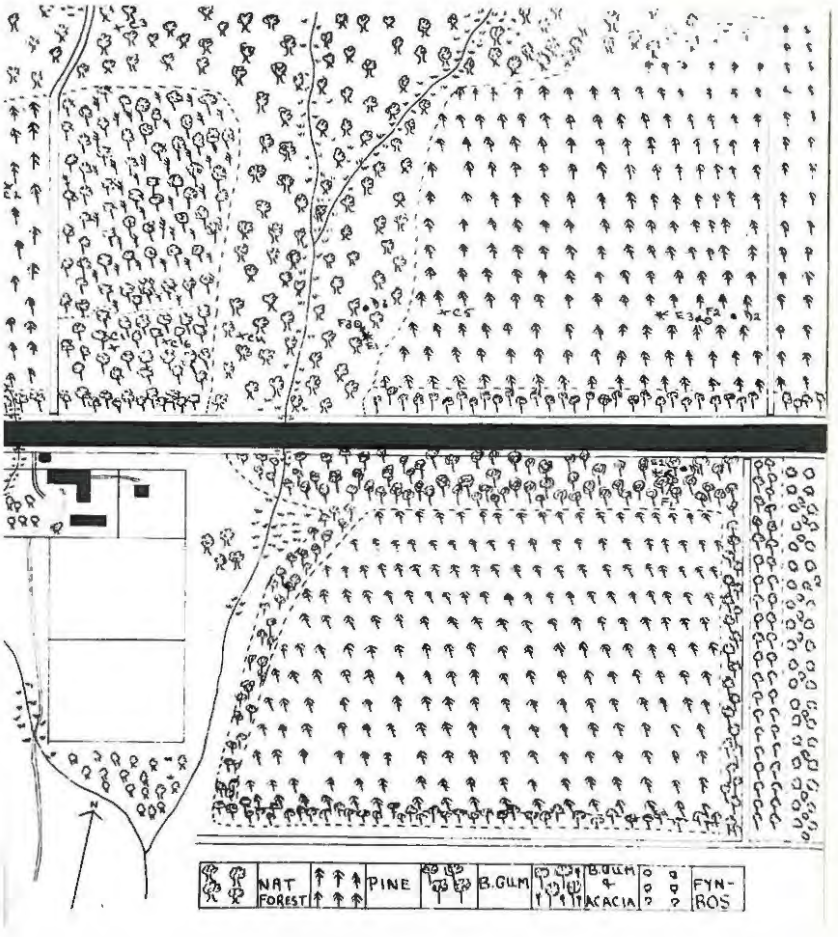

Fig.23 - Sketch Map of the sampling area at Witte-els-Bosch.

Series C.

(1) This sample was taken from soil developed under Eucalyptus diversicolor. The trees were spaced at close intervals. No surface-growth was present.

Aoo Horizon (4 inches). Well developed, consisting of the leaves and bark of the trees.

Ao Horizon (2 inches). Matted and spongy.

A1 Horizon (1 inch). Powdery and grey.

A2 Horizon. Powdery and light grey.

Mor soil, inclined to podzolisation.

(2) This sample was obtained from soil developed under Pinus pinaster. (Fig. 24).

Aoo Horizon (3 inches). Carpet of pine needles.

Ao Horizon (1 inch). Matted and spongy.

A1 Horizon. Grey and compacted with depth.

Mor soil, inclined to podzolisation.

(3) This sample was taken from soil developed under a Natural Forest covering, 200 yards from the previous site. Lianes and epiphytes were not very abundant. The surface vegetation formed a carpet upon the forest floor (Fig. 25). The site was near a Gonioma kamassi.

Aoo Horizon (1 inch). Shallow and composed of mixed debris.

/ Ao Horizon....

Fig.24 - Sample site in a plantation of Pinus pinaster at Witte-els-Bosch.

Fig.25 - Natural Forest at Witte-els-Bosch.

Ao Horizon (Mixed). Black.

A1 Horizon. Sticky and black.

Mull soil, well developed.

(4) This site was situated 400 yards from the previous site within the Natural Forest. The sample was taken near a Trichocladus crinitus.

Aoo Horizon (1 inch). Shallow and composed of mixed debris.

Ao Horizon (Mixed). Black.

A1 Horizon. Not as sticky as in the previous sample. Black.

Mull soil, well developed.

(5) This sample was taken from a soil developed under Pinus pinaster. There was no surface vegetation.

Aoo Horizon (4 inches). Carpet of pine needles.

Ao Horizon (1.5 inches). Matted and spongy, largely composed of faecal pellets.

A1 Horizon. Powdery when dry, Dark grey.

Mor soil, inclined to podzolisation.

(6) This sample was obtained from a soil developed under a stand of Eucalyptus diversicolor, adjacent to the previous site. No surface vegetation was present.

Aoo Horizon (4 inches). Well developed.

/ Ao Horizon....

Ao Horizon (4.5 inches). Matted and compacted.

A1 Horizon (1 inch). Difficult to differentiate.

A2 Horizon. Powdery and light grey.

Mor soil. inclined to podzolisation.

Series D.

Rain fell a few hours previous to sampling. The moisture contents of the samples are therefore higher than normal.

(1) This sample was taken under a stand of Eucalyptus diversicolor.

Aoo Horizon (1 inch). Leaves and bark of the trees.

Ao Horizon (4.5 inches). Matted and spongy.

A1 Horizon. Difficult to differentiate.

A2 Horizon. Powdery and light grey.

Mor soil, inclined to podzolisation.

(2) This sample was taken under Pinus pinaster, 200 yards from the previous site.

Aoo Horizon (2 inches). Carpet of pine needles.

Ao Horizon (1.5 inches). Matted and spongy.

A1 Horizon. Powdery when dry. Dark grey.

Mor soil, inclined to podzolisation.

(3) This sample was taken in Natural Forest.

Aoo Horizon (1 inch). Debris from the trees

Ao Horizon (Mixed). Black

/ A1 Horizon....

A1 Horizon. Sticky and black.

Mull soil, well developed.

Series E.

Samples were taken of the Ao horizon. The location of the sites is the same as for the previous series.

Series (FG).

Two samples were taken as cores, one yard from the previous series, and bulked.

CHAPTER 3.

SOME PHYSICAL AND CHEMICAL ASPECTS OF THE SOIL ENVIRONMENT.

The different methods of extracting the fauna from the soil and the factors determining the choice of the sample sites have been discussed in some detail, with the object of:-

(1) Choosing a method which would give maximum efficiency in sampling and extracting the fauna.

(2) Choosing suitable sites so as to obtain a representative sample of the soil environment.

(3) Adopting a standard sampling technique. Since laboratory methods are standardised, the methods of taking samples must be as far as possible systematised.

We cannot hope to analyse all the physical, chemical and biological interactions which must take place within the soil, but it is perhaps desirable to enumerate a few of the more important factors, which acting together are determinants in this portion of the Biosphere, and which are relevant to the present investigation. These factors may be arbitrarily grouped under three sections.

(1) Physical interactions.

(2) Chemical interactions.

(3) Biological interactions.

As a considerable body of knowledge has been collected

/ concerning....

concerning the physical and chemical properties of the soil, they have received more attention here, in the hope that some light may be shed upon the biological interactions, which are relatively unknown.

Section 1. Physical Interactions.

The physical properties of the soil are very important from the standpoint of both soil science and soil oecology. Some of the more important differences existing between soils are closely linked with their physical characteristics. A soil may be regarded as a system of three phases:-

(1) Solid.

(2) Liquid.

(3) Gaseous.

(1) Solid Phase.

The solid phase is represented by an intimate admixture inorganic and organic matter. The inorganic constituents, derived from the parent rock, are highly variable in particle size. Of these particles, those of colloidal dimensions are of great importance in relation to surface effects. The large differences in the surface areas of coarse-textured and fine-textured materials explains many of the physico-chemical differences of soils. Soils with high clay and colloid fractions are " Heavy ". They exhibit such properties as cohesion and adsorption to a marked degree. In

/ distinction....

distinction to this, soils with high sand and gravel fractions, which tend to function as individual units, are " Light ". The soil is characterised by low cohesion and low water holding capacity.

Table 4 gives the result of a mechanical analysis on the soils from Witte-els-Bosch. According to Lyon and Buckman's (1937) classification, the soils fall within the Loam Class, which is characterised by a mixture of particles. It will be noticed from the Table that there is a slightly higher quantity of the coarser fractions in the Pine and Bluegum soils. If the fine sand fraction is made the lower limit, then the following values are obtained:-

	Natural Forest.	Pine.	Bluegum.
Coarse fraction.	8.1%	8.2%	9.8%
Fine fraction.	91.9%	91.8%	90.2%

Soil texture, or the relative proportion of these various size groups, determines many of the properties of soils. An expression of the soil texture is its Volume Weight, which may be defined as the ratio between the dry weight of a given volume of undisturbed soil and the weight of an equal quantity of water. The presence of coarse fractions and a low organic content will favour high values for the ratio, whereas the presence of fine fractions and a higher organic content favours relatively low values.

/ In....

In soils which are inherently similiar, low volume weight values signify a relatively porous condition, and high values indicate greater compactness (Table 5).

The pore volume of soils is related to the volume weight, and any factor that tends to decrease the volume weight will increase the pore volume. The volume and nature of the pores whether capillary or noncapillary determines field capacity, aeration, and internal drainage. The amount and nature of the organic matter reaching the soil surface, together with the character and activity of the fauna and flora, influence pore volume by affecting soil structure and content of organic matter. King (1914) was able to produce by "Packing" a soil with a minimum pore volume of 6.73 percent, while the largest possible pore volume was calculated to be 72.58 percent. His results indicate that the arrangement of the soil particles is a factor influencing pore volume.

The development of stable aggregates in the soil is a complex process, which involves the binding together of the soil particles into structural units which are not dispersed in the liquid phase of the soil. The organic material within the soil plays an important part in the formation of such aggregates. The organic colloids bind the soil grains together and after dehydration relatively

/ stable

TABLE 4.

	Percentages.		
	Natural Forest	Pine	Bluegum
Coarse Sand (2-1 mm)	0.7	0.6	0.5
Medium Sand (1-½ mm)	2.0	3.5	3.9
Fine Sand (½-¼ mm)	5.4	4.1	5.4
V. Fine Sand (¼-$\frac{1}{25}$ mm)	62.4	55.2	59.8
Silt and Clay(< $\frac{1}{25}$ mm)	29.5	36.6	30.4
Stones (> 2 mm)	Nil	Nil	Nil

TABLE 5.

Volume Weight Ratios. (Witte-els-Bosch Soils.)

	Ao Horizon	A Horizon
Natural Forest	0.50	0.63
Pine	0.22	0.65
Bluegum	0.23	0.81
Podzol (Pine)		0.97
Sand		1.53

stable aggregates result.

Figure 26a.1,2,3 shows the degree of dispersion of the aggregates in the three soils on the addition of water. The aggregations in the Natural Forest soil are somewhat larger and more perfectly developed than in either of the other two soils.

Figure 26b.1,2,3 illustrates the degree of aggregation obtained on dehydration in the same soil types. The Pine and Bluegum soils both show quartz crystals.

(2) Liquid Phase.

The liquid phase of the soil is perhaps the most important factor involved in the physical, chemical and biological interactions which take place within the soil. The other physical properties of the soil, which have already been discussed, all influence the liquid phase to some degree, but in many cases the relationship which they bear to this phase alone is of importance. From the oecological standpoint, the liquid phase is of great significance, acting in many instances as a single determinant.

The relationship between water and temperature is well known. The importance of this relationship in soil oecology lies in the fact that the overall effect of water in the soil tends to reduce temperature fluctuations. A moist cool soil is thus more favourable to life than a

/ hot....

Fig.26a, 1. - Natural Forest soil (X 10).

Fig.26a, 2. - Pine soil (X 10).

Fig.26a, 3. - Bluegum soil (X 10).

Fig.26b, 1. - Natural Forest soil (X 10).

Fig.26b, 2. - Pine soil (X 10).

Fig.26b, 3. - Bluegum soil (X 10).

hot dry soil (Table 6).

Briggs (1897) was the first to recognise three forms of soil water. He distinguished between Gravitational, Capillary, and Hygroscopic water. Of the three forms of soil water, capillary water is of the greatest oecological importance, since it occupies the small pores within the soil and is thus in intimate contact with the soil particles. It is at the liquid-solid interfaces that the important chemical and biochemical transformations occur.

Since organic matter influences the pore volume, it has a profound effect on the capillary capacity of the soil. The tendancy of organic and inorganic colloids to swell on wetting, results in a reduction of the soil pores which favours a greater capillary capacity. Lutz and Chandler (1947, p. 297, quoting from Keen and Coutts, 1928) state that organic material takes up 4.4 times its own weight of water, and inorganic material 2.7 times its own weight.

Keen (1931) has shown that soil depth influences the amount of capillary water that can be held. The deeper the soil, the greater must be the curvatures which water films in the upper part of the soil body have to assume to balance the downward pull. Consequently less capillary water is held in the upper layers of a deep soil body than in one more shallow. This fact is of importance when we

/ consider....

consider that the bulk of the fauna live in the upper levels of the soil.

The values for the percentage of capillary water in the Witte-els-Bosch soils are given in Table 7. They are related to the volume weight ratios, and are therefore an expression of the differences in the organic content.

The moisture status in the soil body represents an equilibrium between additions and losses. Precipitation is the principle source of water in soils, and it is generally understood that the annual precipitation is usually greater in forest regions (Omer-Cooper, 1948). Vegetation and the organic debris contributed to the soil by the plant cover plays an important role in determining the disposition of the rainfall, as the presence of a cover of organic matter usually provides more favourable conditions for infiltration to occur. The effect of both living and nonliving cover is pronounced in preventing undue moisture loss through evaporation. This however, may not be the case if a large concentration of organic material rests upon the mineral soil. Such concentrations appeared to increase the rate of moisture exchange between the atmosphere and the soil in the Witte-els-Bosch mor profiles.

Data relative to the influence of a forest cover on evaporation rates are scanty, but many investigators have

/ demonstrated....

TABLE 6.

Degrees Centigrade.

Wet Soil	Dry Soil
6.5	7.0
7.5	8.0
8.0	9.0
10.5	11.5
11.0	12.0
15.0	17.0
21.0	24.0
22.0	24.5
23.0	26.0
23.5	27.0
Av. 14.7	Av. 16.6

TABLE 7.

Percentages

	Ao Horizon	A Horizon
Natural Forest	55.50	43.06
Pine	72.26	40.41
Bluegum	60.57	32.60
	Podzol (Pine)	23.58
	Sand	15.64

Percentages of Capillary Water.

demonstrated that the relative humidity of the air in a forest is higher than in the open. Forests favour the development of higher soil moisture values, but differences in tree cover may cause significant differences in soil moisture. It will become apparent later that when the soil moisture contents of the three soil types investigated are compared, one of the effects of the growth of the Pine and Bluegum trees has been to noticeably lower the moisture values. Their growth has also lowered the organic content. The lower organic content influences the moisture values in proportion to the effect that organic material has upon the physical properties of the soil. If reference is made to these physical properties, it will be appreciated that a considerable degree of difference must exist between the environments offered by the Pine and Bluegum soils, when compared with that of the Natural Forest. This difference is reflected in the numbers and composition of the soil fauna.

(3) Gaseous Phase.

The gaseous phase occurs as free air in those pores of the soil that are free from water. The moisture status and pore volume of the soil are thus factors influencing the aeration of the soil. As would be expected, soils having a high air-capacity are well aerated, and infiltration

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of water is rapid. The highest air-capacity values need not necessarily be associated with the best soils.

Section 2. Chemical Interactions.

From a chemical point of view, soils are composed of a large number of constituents, ranging from simple salts to highly complex organic and inorganic compounds. Differences of opinion exist concerning the oecological importance of the chemical properties of the soil. Some investigators believe that the physical properties are of greater importance, but whatever view may be held, investigators agree that soil chemistry has an important relationship with the formation of soils and with their physical and biological characters.

The liquid phase surrounding the soil particles carries in solution traces of all the elements present in the soil. From an oecological point of view, this soil solution occupies a central position, related to plant and animal life on the one hand and to the soil on the other. The ionic exchange between colloids and soil solution is of great importance to organisms within the soil.

The colloidal fraction may be considered as the most active part of the soil, since it determines to a large extent soil character. It contains a larger proportion of the available nutrients and thus functions as a "Store-house". The release of the nutrient material into the soil

/ solution....

solution is intimately bound up with the exchange complex.

An important property of colloidal clay material is its capacity for cation exchange. When colloidal clay particles are suspended in water, partial ionic dissociation occurs, with the formation of an electrical double layer. Cation exchange involves the process whereby cations from the clay crystals are exchanged for cations in the soil solution. The capacity for replacement may be effected by the entering ion having a high replacement capacity, or a Mass Action effect. The content of exchangeable Hydrogen plus the content of exchangeable metallic cations is equal to the "Total Cation Exchange Capacity". The exchange capacity is partly related to the base-status and organic content of the soil. A high organic content is known to favour higher values for the exchange capacity. The differences between the values for the Witte-els-Bosch soils, given in Table 8, are thus probably a result of the differences in the nature of their organic contents.

Flocculation of the organic colloids by bases is believed by soil chemists to be a factor in the formation of stable soil aggregates. It is well known that clays, whose exchangeable cations consist mainly of H^+ and Ca^{++} tend towards flocculation rather than with Na^+. Since in forest soils, the dominant cations are Hydrogen and Calcium,

/ the....

the organic colloids would tend to be flocculated (cf. Fig. 26a.1,2,3; Fig.26b.1,2,3). The higher Calcium content in the Natural Forest soil in part accounts for the better formed aggregates, and for the relatively higher pH values (Table 9).

Section 3. Biological Interactions.

The physico-chemical relationships are in many cases obscured by biological interactions within the soil body, since the introduction of the biological element into the physico-chemical complex results in an oecological complex. About this little is known. Such a complex involves all the interactions which furnish the requirements necessary to maintain life, and these influence the capacity of the environment to support life. The influence of the biological factor tends to modify the physico-chemical complex. The modifications favour the processes of life up to the point at which the reciprocal relationships breakdown. This point is determined by the power of living matter to adjust its mechanism to suit new environmental conditions.

The soil environment is a dynamic system influenced by both internal and external conditions. Small changes in the external conditions are magnified by the complexity of the internal conditions, so that the resulting change in the environment is profound. If the change is in a direction

/ which....

TABLE 8.

Total Cation Exchange Capacity.

	Elements in M.E/100grms of soil
Natural Forest	8.672
Pine	2.182
Bluegum	1.220

TABLE 9.

Available Phosphate, Potash and Calcium.

	Percentages.			
	Potassium Phosphate	Potash	Calcium Oxide	pH
Natural Forest	0.001	0.0072	0.050	4.3
Pine	0.001	0.004	Nil	4.1
Bluegum	0.001	0.0025	Nil	3.9

which is unfavourable to life, adaptations to meet the new conditions, and a decrease in the mass of living matter with corresponding reduction in biological activity, is to be expected. This is outwardly expressed as a quantitative and qualitative change in the composition of the living matter within the soil. Such a change may be used as a measure of the suitability of the environment for life.

In the present investigation, the changes in the soil environmental conditions, due to differences in tree cover, were reflected in the quantitative and qualitative composition of the soil fauna.

CHAPTER 4.

CHANGES IN THE SOIL ENVIRONMENT UNDER THE INFLUENCE OF NATURAL FOREST, PINE AND BLUEGUM.

In the previous chapter, an attempt was made to outline the more important characteristics of the soil environment in order to construct a framework of known facts into which the data resulting from the present investigation could be fitted. The significance of the data would thus be more readily appreciated by referring to the factors of the physical, chemical and biological environments which were implicated.

This chapter deals with the data resulting from a quantitative physical and chemical analysis of the soil, and a quantitative examination of the soil macro and meso-fauna. Its mathematical analysis is the subject for separate treatmant in Appendix 1.

The data may be divided into two sections:-

(1) That applicable to the Ao horizon.

(2) That applicable to the cores, which includes the Ao and A1 horizons, and in the case of the podzolised soils, the A2 horizon.

It will be evident later that a reciprocal relationship exists between the data appertaining to the two sections.

/ Section 1....

Section 1.

The Moisture Content.

The water content is an important factor in the general economy of the soil, because of its influence on the various physical, chemical and biological properties of the soil environment. Its role in the biological sphere of the soil is closely linked with its distribution, since it serves as a solvent and medium of transport for nutrients and supplies essential to the life of organisms in the soil. Any internal or external factor, which tends to alter the content and distribution of the organic material within the soil body, must necessarily alter the moisture status.

The distribution of organic debris plays an important part in determining the disposition of the rainfall. If a cover of organic material is present, conditions for detention and infiltration are more favourable. A thick Ao horizon would thus be expected to favour a moist A horizon. This is however not entirely true, as Ramann (1906) and Wittich (1938) have reported unfavourable effects when thick layers of organic matter resistant to wetting formed the Ao horizon. It will be remembered that similar accummulations of unincorporated organic material were found during the present investigation under the Pine and Bluegum. The resistance of their Ao horizons to wetting does not appear to be the

/ only....

only factor which would prevent the percolation of water through to the A horizons. If Figures 27 and 28 are compared, it will be apparent that the differences between the moisture contents of the three soils is an expression of the differences in the distribution of their organic material. This suggests that the absorptive capacity of the organic matter forming the Ao horizons is partly responsible for the differences between the moisture contents of the A horizons. The relatively thick Ao horizons under the Pine and Bluegum must be responsible for the absorption of a large volume of water. This would effectively prevent massive infiltration into their A horizons under conditions of light rainfall. In the Natural Forest soils, which have no surface accumulations of organic matter, water is able to percolate readily into the mineral soil under the same conditions of rainfall.(Table 10). The rate of infiltration would be assisted by the larger pores between the individual soil particles or aggregates, which would tend to increase the noncapillary pore volume (Ref. Chp.3, p.51). Wollny (1893) observed much higher percolation rates in soils having a crumb structure than in soils that were structure-less.

Evaporation is probably another contributory cause of the differences in the moisture contents. The desiccation

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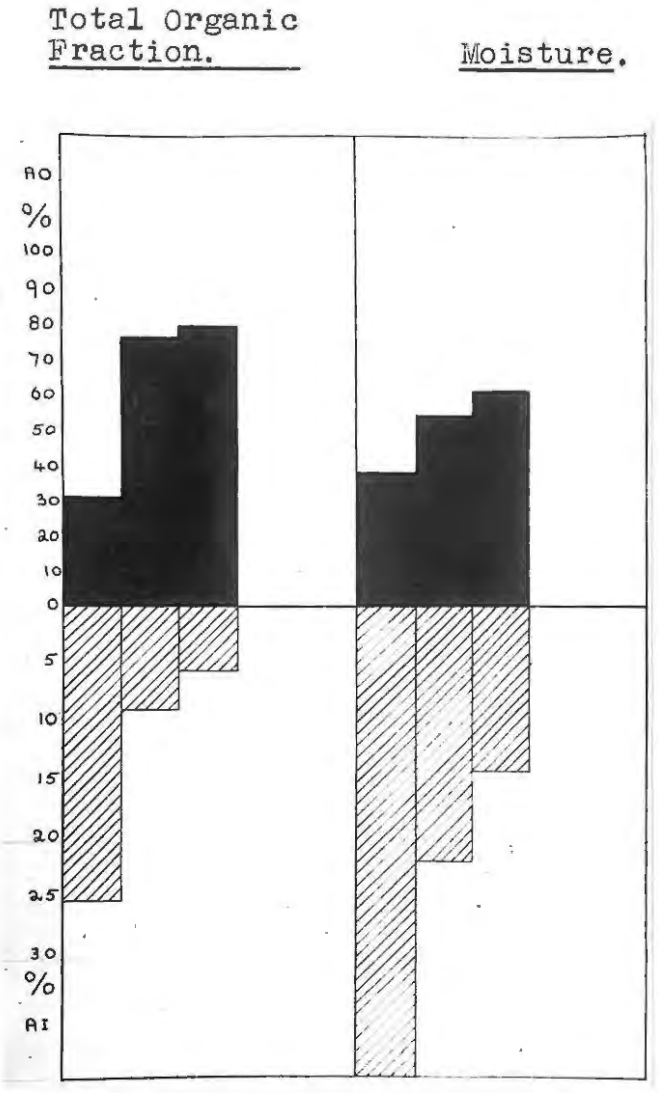

Fig.27 - Moisture Content of soil fractions.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

Ao Horizon - P.
Decayed Fraction.

A1 Horizon - Humus
Fraction. Moisture.

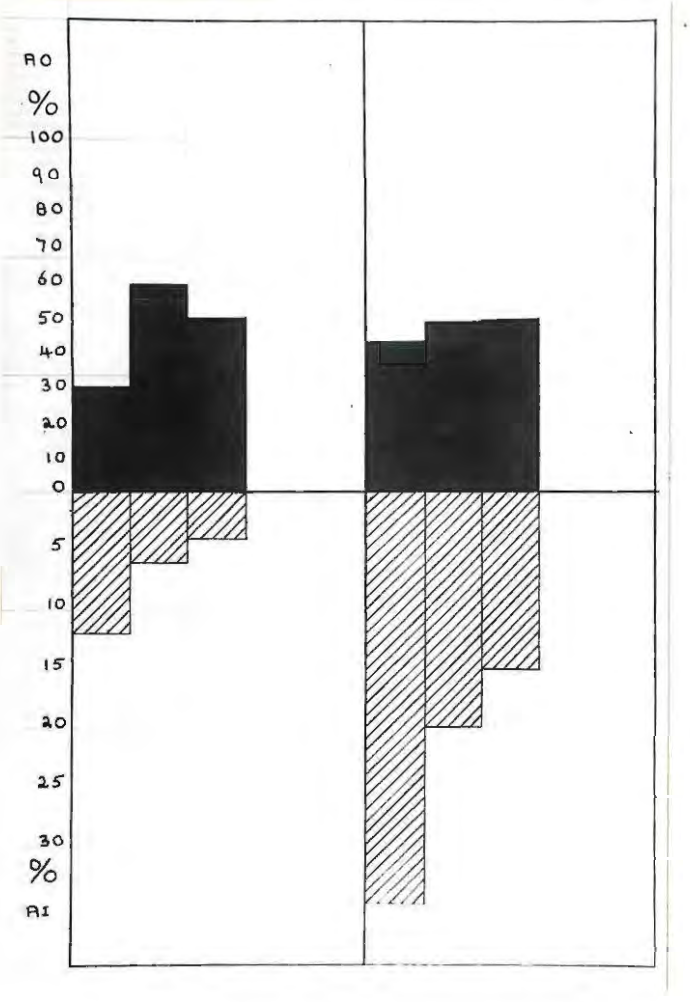

Fig.28 - Moisture Content of soil fractions.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

of the soils in the Pine and Bluegum plantations is assisted by the open nature of the leaf-canopy, and by the fact that considerable quantities of water are held at the surface of the soil. In distinction to this, the Natural Forest soils are protected by a denser leaf-canopy, and water is held within the deeper layers of the soil body.

The capillary and noncapillary capacity is also related to the organic distribution, and differences in the capacity are reflected in the differences in moisture retention during and after periods of precipitation, (Table 10). The rate at which water enters the soil is thus governed by its initial moisture content. Under conditions of heavy precipitation, percolation through to the B horizons is more likely to occur in the Pine and Bluegum soils than in the Natural Forest soils. A layer of acid organic material on the mineral soil would be more conducive to the formation of a podzol in the Pine and Bluegum soils, than in the Natural Forest under similar conditions of precipitation.

The pH Values.

Before discussing the significance of the pH of the Ao horizons, it is thought desirable to direct attention to the four most important factors which influence the H.ion concentration. Of these, the drying of the soil and the

/ time....

time of sampling may be disregarded by adopting a suitable sampling technique. The soil-water ratio must however be standardised before comparisons can be made. The pH of dry soils are meaningless since H.ions can only exist in solution. Determinations of pH,therefore refer to soil pastes or suspensions, and different results are obtained according to the soil-water ratio used (Table 11). A ratio of 1:2 was used throughout this investigation. The last and most important factor, since it particulary concerns the present study, is the influence of the plant cover upon the pH of the soil.

Vegetation is known to exert a strong influence on soil acidity through the litter which it supplies, and also through its effects on soil temperature and moisture. It is to be expected then,that the pH of the Ao horizon would reflect the base status of the leaves as well as the type of decomposition taking place within the horizon.

Table 12 shows that the relatively high pH of the foliage of the Natural Forest is related to a higher mean ash content. This is expressed in the higher pH values for the Ao horizon. On the other hand, the lower ash values for the foliage of the Pine and Bluegum trees are indicative of an acid condition of the organic layers. This is largely due to a fungal type of acid decomposition, which is favoured

/ by....

TABLE 10.

Moisture Contents of the Ao and A Horizons.

After light Rain	Percentages	
	Ao Horizon	A Horizon
Natural Forest	41.68	41.23
Pine	57.27	22.06
Bluegum	62.26	14.33
Normal Conditions		
Natural Forest	40.85	35.02
Pine	46.27	20.14
Bluegum	49.80	15.63

TABLE 11.

Soil-water Ratios.

ccs/grm of soil	pH
10	7.4
8	7.4
6	7.4
5	7.4
4	6.9
3	6.8
2	6.6
1	6.4
0.5	6.4

TABLE 12.

Ash Content of Foliage.

	% Ash	pH of Leaves	pH of Ao Horizon	pH of A Horizon
Natural Forest.				
Xymalos monospora	14.72	5.8		
Trichocladus crinitus	7.32	5.4		
Gonioma kamassi	7.54	5.4	5.8	5.3
Podocarpus sp.	12.26	5.6		
Mixed forest leaves	12.20	5.6		
Pine.				
Pinus pinaster	3.14	4.6	5.3	5.0
Pinus insignis	2.36	4.6		
Bluegum.				
Eucalyptus diversicolor	4.10	5.0	5.2	4.8

Ash content expressed as a percentage of the dry weight of leaves.

by the foliage and other organic debris with a low relative base status, reaching the soil surface.

Waksman (1924) found that fungi are more tolerant to low pH values than bacteria; the ratio between the numbers of bacteria and the number of fungi widened as the H.ion concentration decreased due to the increase in bacterial numbers. The production of organic acids from carbohydrates by fungi would thus tend to inhibit bacterial growth (Waksman, 1932). As the acids produced in the organic layers are moved downwards by percolating water, they attack the soil minerals, leach out exchangeable cations, and generally decrease the pH of the mineral soil. Organic and inorganic colloids are dispersed and moved downwards with the percolating water. Quartz is resistant to attack by the acid soil solution, and as a consequence its relative proportion in the surface layer of the mineral soil increases as leaching progresses. The loss of exchangeable metallic cations results in a lower total cation exchange capacity, and the dispersion of the organic and inorganic colloids is unfavourable for aggregate formation.

The differences between the physical and chemical properties of the Natural Forest, Pine and Bluegum soils are thus due to the process of podzolisation. This is characterised in the field by a layer of unincorporated

/ organic....

organic matter and a grey mineral soil. The podzolisation in those Pine and Bluegum soils which have been studied, has not proceeded as far as in some adjacent soils supporting older stands, and it is natural to assume that the age of the stand plays an important part in determining the degree of podzolisation.

The Nitrogen Content.

Figure 29 shows the nitrogen contents for both the Ao and A horizons. The higher values correspond to the Natural Forest soils. The leaf-fall is an important source of nitrogen to the soil, but it will be seen from Table 13 that it is not necessarily a primary one. The relatively high values for nitrogen in the Pine and Bluegum foliage, and the low values for nitrogen in the Natural Forest foliage, are not expressed in their Ao and A horizons. The leaching of nitrates may be responsible for the low nitrogen values in the A horizons of the Pine and Bluegum soils, but differences in biological activity must play some part as well. Romell (1935) has shown that mull soils are more favourable for nitrification than mors, and that the bacterial population is higher in mull soils. Svinhufund (1937) believed that poor soils show a greater activity by denitrifying bacteria than rich soils. The activities of denitrifying bacteria would partly account for the low

/ nitrogen....

TABLE 13.

Nitrogen Content of Foliage.

Natural Forest	Percentage of Nitrogen
Xymalos monospora	0.32
Trichocladus crinitus	0.38
Gonioma kamassi	0.50
Podocarpus sp.	0.10
Mixed forest leaves	0.37
Pine	
Pinus pinaster	0.70
Pinus insignis	0.75
Bluegum	
Eucalyptus diversicolor	0.84

Expressed as a percentage of the dry weight of leaves.

Ao Horizon - Total Organic Fraction.

A1 Horizon - P. Decayed and Humus Fraction.

Ao Horizon - P. Decayed Fraction.

A1 Horizon - Humus Fraction.

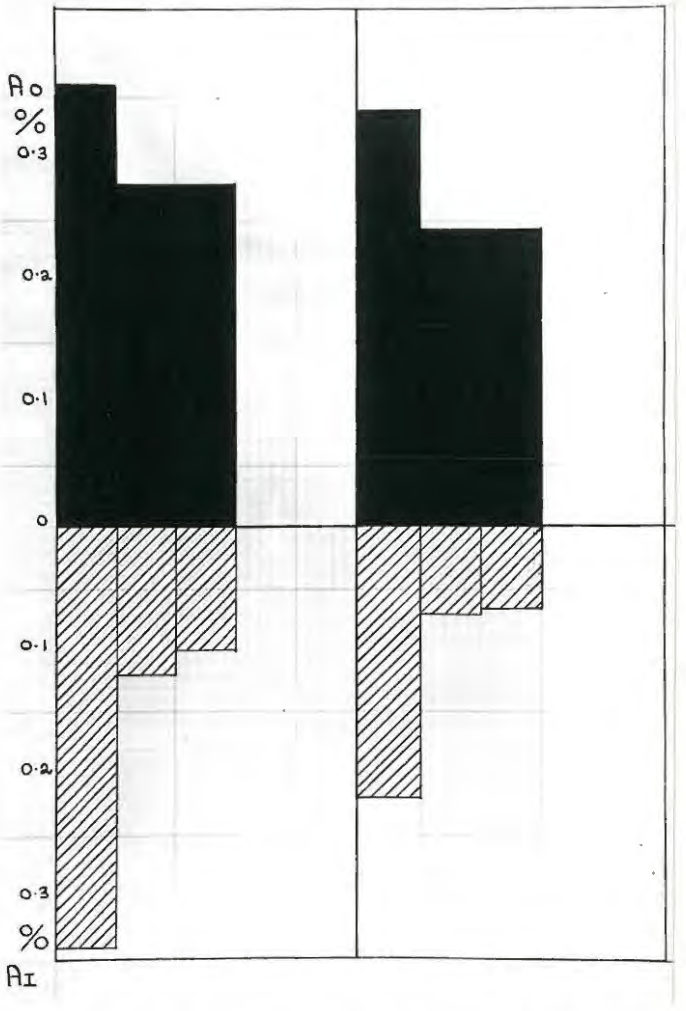

Fig.29 - Nitrogen Content of soil fractions.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

nitrogen values shown by the Pine and Bluegum soils, but whether this is actually the case is not known.

The Vertical Distribution of the Soil Fauna.

It has been known for some time that the bulk of the fauna within the soil is largely confined to the top layers of the soil body, a fact which was used to determine the depth to which the cores were extended in the investigation. A division of the cores into two equal parts will illustrate this. Table 14 shows the striking difference between the contents of the two halves of the core. It will be noticed that the magnitude of the differences between the numbers of fauna from the two portions of the core, increases with the increase in thickness of the Ao horizon. This is an indication that the bulk of the fauna live in the organic humus layers and not in the mineral soil below. If however, the organic material is mixed with the mineral soil, the physical and chemical characteristics of the soil body are altered, and this is reflected as a change in the vertical distribution of the fauna.

In the mull soils of the Natural Forest, the soil population is relatively evenly distributed within the soil body, since mixing of the organic material with the mineral soil has occurred. In the mor types developed under Pine and Bluegum, there is little mixing and the soil population

/ is....

TABLE 14.

Vertical Distribution of the Soil Fauna in the Cores.

Depth of Ao Horizon	Top 4.5 Inches	Bottom 4.5 Inches	Faunal Total
0 Inches	4	6	10
1 "	27	7	34
1 "	47	4	51
2 "	158	23	181
2 "	173	21	194
Mean.	82	12	94

Extractions by the flotation process.

is largely confined to the organic humus layers. Since the mean depths of the Ao horizons of Natural Forest, Pine, and Bluegum were 2.0 (arbitrary depth), 1.6, and 3.7 inches respectively, it follows that a core from a mull soil should yield a greater number of fauna than a core from a mor soil (Figs. 30, 31). This is an expression of the relatively greater volume of organic material in the cores of the mull soils.

Section 2.

An examination of the data appertaining to the Ao horizon has shown that conditions tend to be more favourable within the soil body under a Natural Forest cover. A sample taken in the form of a core from a Natural Forest soil should therefore give higher values for moisture, organic and nitrogen contents than a similar core from a Pine or Bluegum soil.

Figure 32 shows that higher values, related to the distribution of the organic material within the soil body, were obtained for the faunal population in cores taken from the Natural Forest soils. The moisture-organic relationship also showed higher values for the Natural Forest soils (Figs. 33, 34, 35). The relatively low values for the Pine and Bluegum soils are to be expected in view of the podzolisation taking place within these soils.

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Percentage of Fauna. Depth of Horizons.

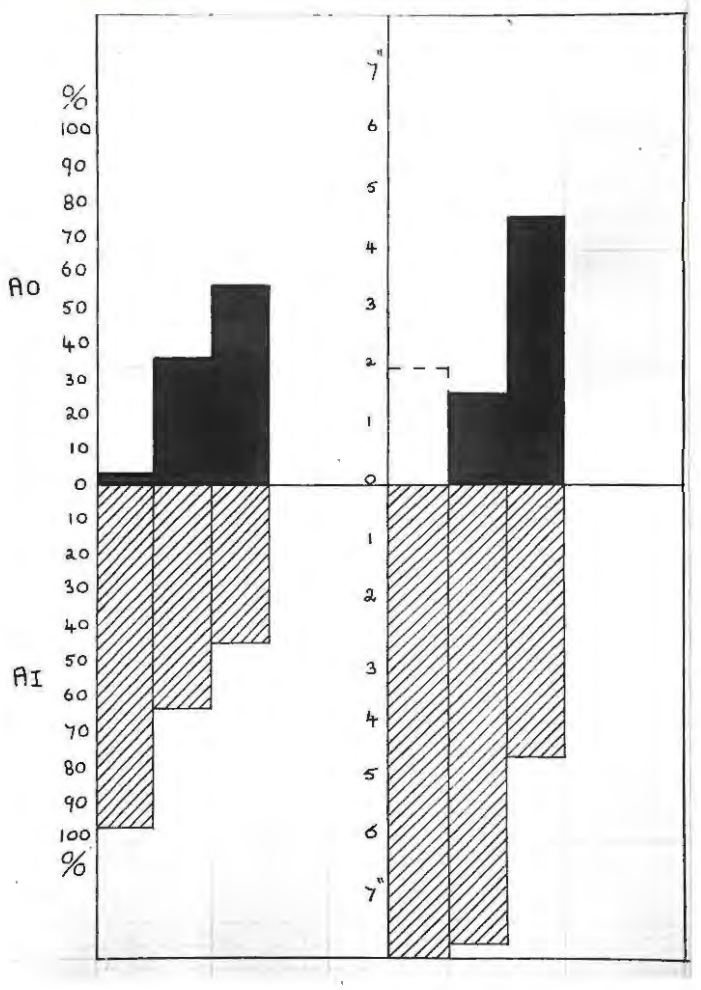

Fig.30 - Percentage of Fauna in Ao and A Horizons.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

Histograms read from left to right, Natural Forest, Pine, and Bluegum.

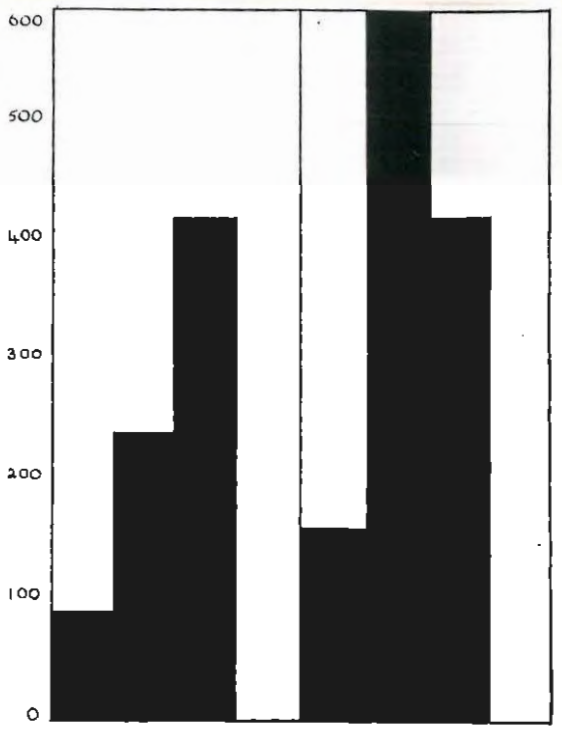

Fig.31 - Numbers of Fauna in an average volume (356 cu. ins.) of Ao Horizon.

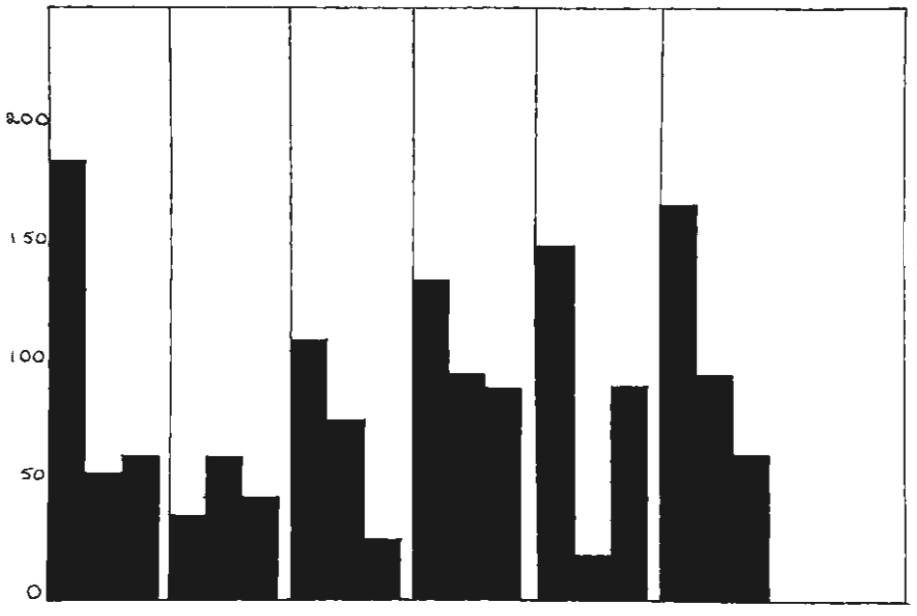

Fig.32 - Numbers of Fauna in the Cores. L.-R. A, B, C, D, FG Series.

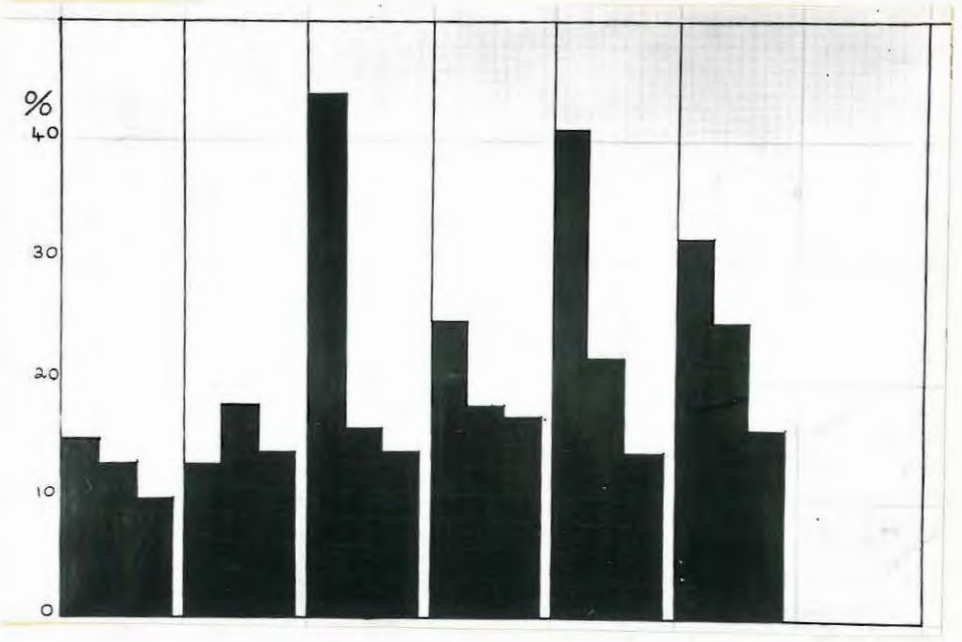

Fig.33 - Moisture Content of A Horizon. L.- R. A, B, C1-3, C4-6, D, FG Series.

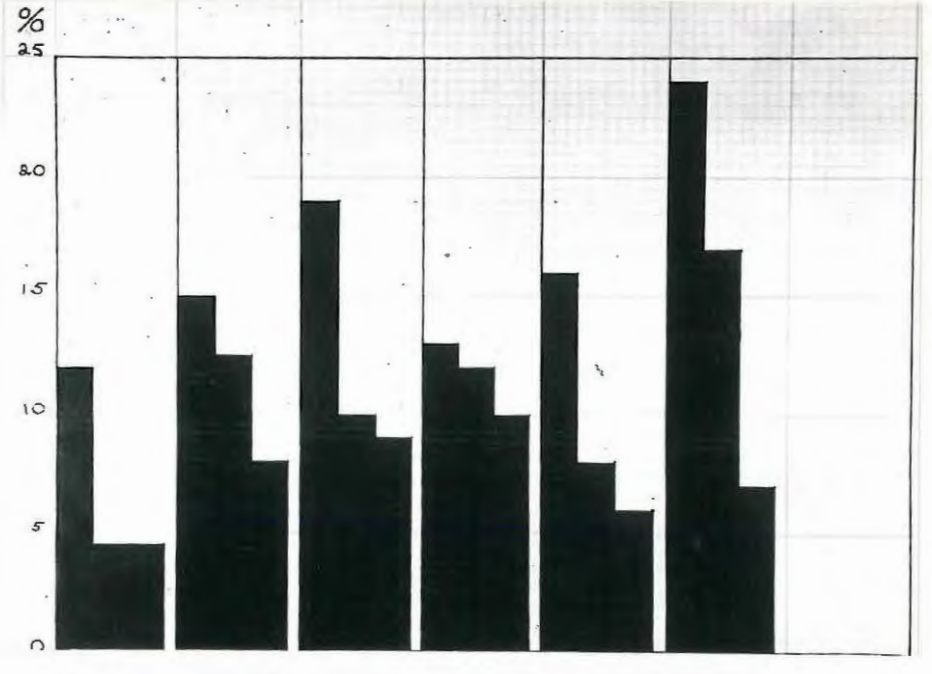

Fig.34 - Partly Decayed and Humus Fraction of A Horizon. L.- R. A, B, C1-3, C4-6, D, FG Series.

Histograms read from left to right, Natural Forest, Pine, and Bluegum.

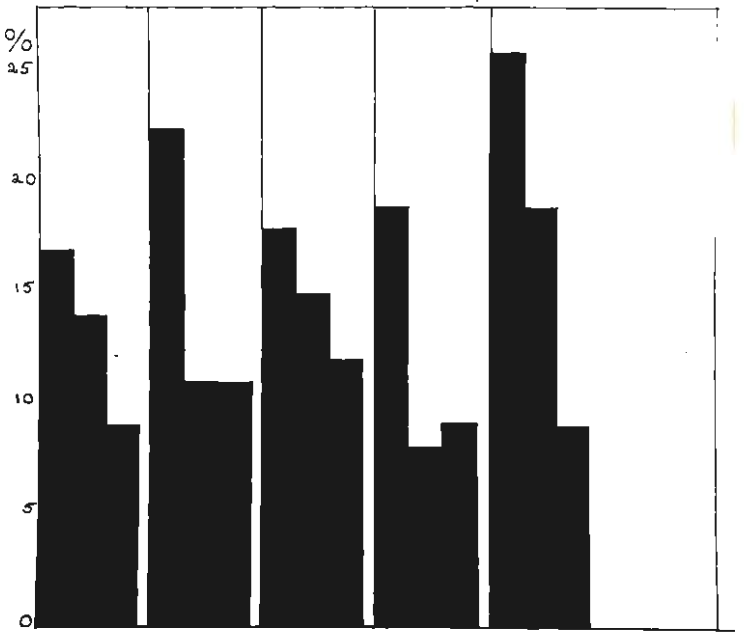

Fig.35 - Total Organic Fraction of A Horizon. L.- R. B, C1-3, C4-6, D, FG Series.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

The Water-Soluble Mineral Fraction.

Data on the water-soluble mineral fraction are given in Table 40 (Appendix). The slighty lower values for the Pine and Bluegum soils is probably a result of podzolisation. In the D series, which were sampled immediately after a rainfall, the values are decidedly higher than the corresponding Natural Forest soil. This suggests that the water-soluble minerals have been washed in from the humus layers.

The Carbon/Nitrogen Ratio.

The values for the nitrogen content are given in Table 15, against the corresponding soil organic fractions upon which the analyses were made. It will be seen that the lower values correlate with a lower organic content. On the other hand, comparing the nitrogen values for the Ao horizons show that a higher organic content is correlated with a lower nitrogen value. The effect of leaching appears to be partly responsible for the differences between the A horizons of the Pine and Bluegum soils, but a biological factor is probably responsible for the decrease of nitrogen in their Ao horizons, in view of the higher nitrogen content of the foliage.

An expression of the rate of decomposition, and thus to some extent a measure of biological activity, can be given by means of the C/N ratio. The outstanding principle of

/ change....

TABLE 15.

Nitrogen Content of the Mineral Soil.

Sample	Percentages: Partly Decayed and Humus Fraction	Nitrogen
Natural Forest		
a	16.90	0.34
b	13.54	0.34
Pine		
a	8.17	0.12
b	12.23	0.14
Bluegum		
a	6.03	0.10
b	10.43	0.13

	Humus Fraction	Nitrogen
Natural Forest	13.79	0.22
Pine	6.55	0.077
Bluegum	4.48	0.068

Expressed as a percentage of the dry weight of soil.

change in regard to this ratio is that it will tend to become narrower in moving from regions whose conditions are less favourable to decay of organic matter, to conditions where decay is more rapid. The carbon in the form of carbon dioxide being dissipated more rapidly than nitrogen.

In agricultural soils, the C/N ratio of the organic matter is about 10:1, but in forest soils it is usually much wider (Lutz and Chandler, 1947: p.173). According to Heyward and Barnette (1936), the mean C/N ratios of the organic matter in various horizons of longleaf pine soils were as follows:-

Aoo Horizon.	101:1
Ao Horizon .	47:1
A1 Horizon .	33:1

Figures 36 and 37 give a diagrammatic representation of the C/N ratios for the Ao and A horizons. The values for the ratios are given in Table 39 (Appendix). It will be seen that the ratio:-

(1) Narrows with increasing depth below the surface.

(2) Tends to widen with increasing organic content.

(3) Narrows in the Natural Forest soils.

The narrowing of the ratio in the Natural Forest soils suggests favourable conditions for decomposition, which is expressed in the shallow nature of the organic layers, and the prompt incorporation of the organic material within the

/ soil....

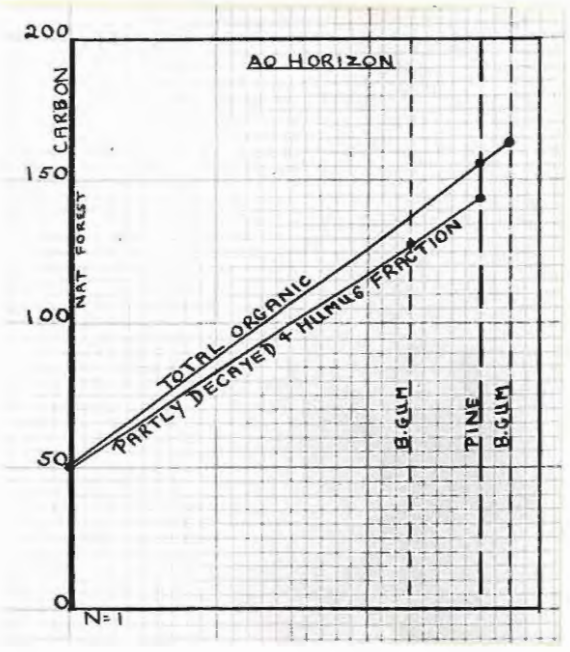

Fig.36 - C/N Ratios of the Ao Horizons.

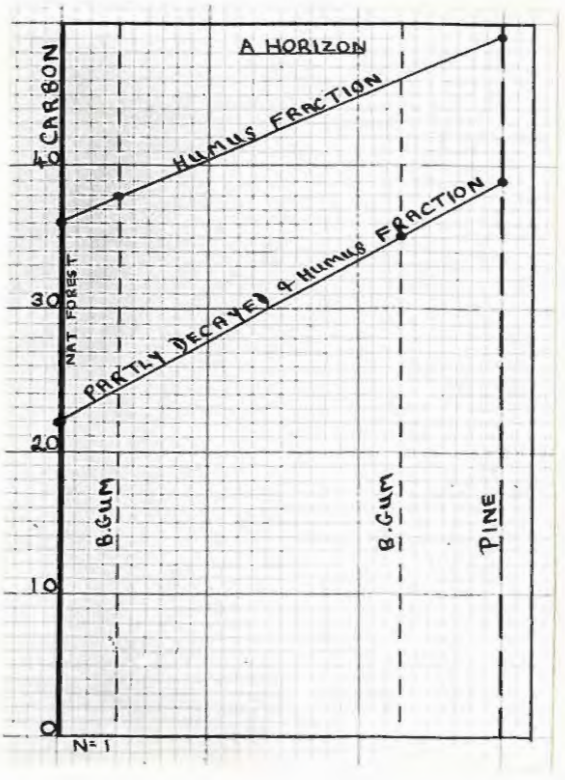

Fig.37 - C/N Ratios of the A Horizons.

soil body. On the other hand, the wider ratios for the Pine and Bluegum are expressed in unincorporated organic layers covering the mineral soil, which suggest lower rates of decomposition. Although the C/N ratio cannot be used with certainty as an index of the rates of decomposition in the A horizons of the Pine and Bluegum, relatively lower values are to be expected in view of the leaching of nutrients from the soil. Such leaching results in the development of undesirable biological conditions and physical properties.

Romell (1935) has advanced the view that the mixing of the organic debris with the mineral soil, directly or indirectly, tends to weaken the fungus flora of mor humus layers, and stimulates the development of a richer bacterial and animal life. The relatively greater biological activity, and larger numbers of animals in the Natural Forest soils appears to support this view.

The Ether and Chloroform Soluble Humus Complexes.

The attack on organic debris by micro-organisms leads to chemical changes as a result of oxidation, hydrolysis, reduction and condensation. As decomposition of fresh plant material proceeds, the water soluble compounds and carbohydrates decrease rapidly, but there is a much slower decrease, resulting in a relative accumulation of fats, waxes, resins,

/ lignins....

lignins and other complexes. Quantitatively these complexes constitute a relatively small proportion of humus substances, but their nature and abundance seems to depend on the type of forest vegetation, the degree of decomposition, and environmental conditions. Some investigators have observed that certain of these complexes appear to inhibit decomposition.

Table 16 gives the values for the Ether and Chloroform soluble complexes. It will be seen that the values are related to the distribution of the organic material within the soil. The fact that the higher values correlate with the higher numbers of fauna, does not rule out the possibility that these complexes may exert a repellent action on the fauna, and by selection give a qualitative difference in the faunal composition.

The pH Values.

Figure 38 shows the pH of the mineral soil. The mean values for the three soils are as follows:-

Natural Forest.	5.2
Pine.	5.0
Bluegum.	4.8

Since the pH of the mineral soil is largely influenced by the base-status of the surface organic layers, the oecological significance of the differences between the values is obscured by their relationship to podzolisation. It may

/ be....

TABLE 16.

Ether and Chloroform Soluble Humus Complexes.

	Percentages
	Chloroform Soluble
Ao Horizon	
Natural Forest	1.6
Pine	3.2
Bluegum	4.0

	Ether Soluble	Chloroform Soluble	Total
A Horizon			
Natural Forest	0.13	1.32	1.45
Pine	0.10	0.35	0.45
Bluegum	0.06	0.57	0.63

Expressed as a percentage of the dry weight of soil.

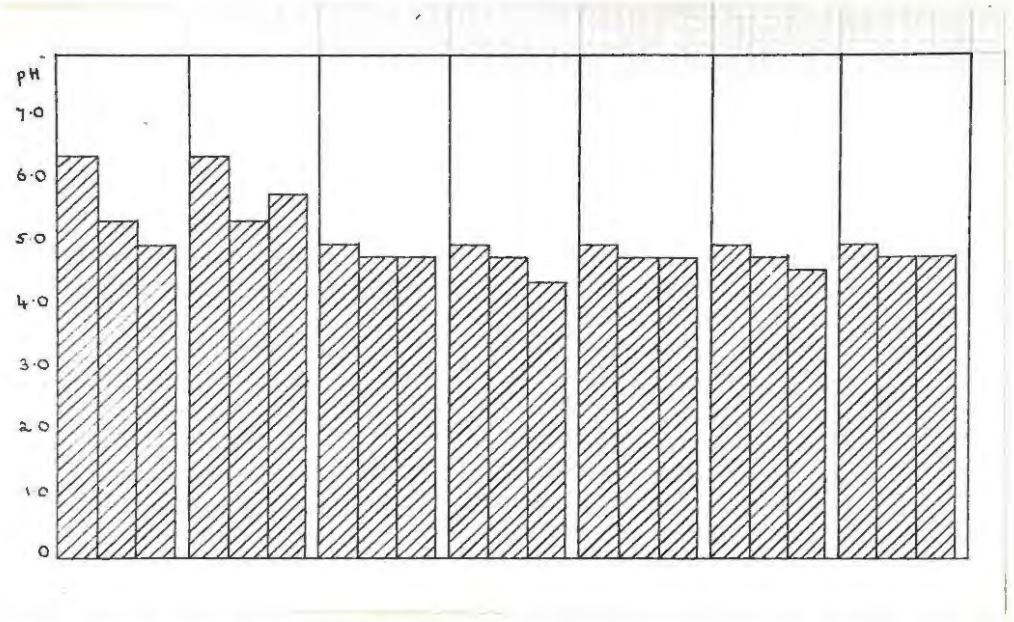

Fig.38 - pH Values for the A Horizon. L.- R. A, B, C1-3, C4-6, D, E, FG Series.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

be however, that as a consequence of a relatively higher concentration of H.ions, the soil fauna undergo a change in an unfavourable direction, and nutritional disturbances due to difficiences of nutrients (Calcium or Magnesium), and to toxicity of certain elements (Manganese or Aluminium) develop.

The evidence resulting from the examination of the data appertaining to some of the physical and chemical properties of the soil, points to the fact that the Natural Forest soils offer more favourable conditions for an active soil population than either the Pine or Bluegum. This is due in part to the composition of the foliage. The low relative base-status of the Pine and Bluegum foliage, and the unincorporated layers of organic material on the soil surface, have resulted in the formation of a podzol profile with decreased faunal numbers within the mineral soil.

CHAPTER 5.

DIFFERENCES IN THE QUALITATIVE COMPOSITION OF THE SOIL MACRO- AND MESOFAUNA.

The Concept Soil Fauna.

The term soil fauna as used by Baweja (1939, p. 121) includes all the macro-organisms, which at one time or the other in the course of the development from the egg to the adult stage, spend a part or whole of their life time beneath the surface of the soil. According to this definition, they may be permanent denizens of the soil or temporary visitors for the purpose of food, shelter, reproduction, etc. The fauna of the soil can thus be divided into a number of groups based upon different principles.

As a first criterion, the size of the animals can be used. Fenton (1947, p. 83) divided the soil fauna into micro, meso and macrofauna, the distinction of which he takes at 40μ and some centimeters. Van der Drift (1949, p.2) classified woodland soil fauna into four size groups- micro, meso, macro and megafauna, the limits set being such that the mean length of the organisms in each class was 10 times that of the previous class.

If the fidelity of an organism to the soil habitat is used as a distinguishing principle, then the system devised

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by Jacot (1940, p. 50) may be adopted, which is as follows:-

(1) Geobiontic Species. Those species that spend their whole life-cycle within the soil. Earthworms, millepedes, many mites, and collemboles.

(2) Geophilous Species. Those species that spend only a part of their life-cycle in the soil. Larvae of many Diptera, wireworms, beetles, etc.

(3) Geoxenes. Those animals, which as a consequence of some course or other, have strayed into the soil.

A further classification may be based upon the preference that certain animals have for the different soil organic layers. Krausse (1929, pp. 110-111) distinguished amongst the geobionts:-

(1) Hyperedaphon. The inhabitants of the surface vegetation. These are not true members of the soil community, but they must be considered in any investigation dealing with the oecology of the soil fauna.

(2) Epedaphon. The inhabitants of the surface of the soil.

(3) Hemiedaphon. The inhabitants of the litter (Aoo and Ao horizons).

(4) Eudaphon. The inhabitants of the mineral soil (A horizons).

/ A....

A final classification, which demonstrates the different functions of the elements of the soil community, may be based upon food relations. According to Imms (1923), the classification of the soil invertebrates is only significant if the groups are analysed according to the feeding habits of the various members. Jacot (1940) based a classification upon the mutual relationships between the elements of the soil community and between these and their abiotic environment. He distinguished between such groups as phytophages, predators, fungivorous animals, saprophages, coprophages, and necrophages.

The majority of such schemes depend to a greater or less extent upon information concerning the bionomics of the soil community, as they are based upon such vital functions as reproduction, feeding, and dispersion. An oecological analysis of this nature is however, beyond the scope of the present study, but nevertheless use was made of the terminology for descriptive purposes.

In the present investigation, the elements of the soil community were divided for convenience into three groups. The term Microfauna referring to the Protozoa, Mesofauna to those animals whose sizes lay between 1-5 mms, and Macrofauna to all other invertebrate elements of the soil community. The difficulty of identifying

/ many....

many of the fauna made it necessary to use the larger taxonomic groups, such as sub-orders and families, rather than genera or species. In the quantitative examination, which was largely concerned with the response of the fauna as a whole to changes in the biotope, the imperfections which arose from such grouping were not incompatible with the object of the investigation. In the qualitative examination on the other hand, the grouping of the fauna in this manner obscured the relationships between the species and their merotopes. This was unfortunate as the bionomics of the species, rather than the bionomics of the taxonomic groups, would have supplied some further data on the extent to which changes in the biotopes of Natural Forest, Pine, and Bluegum were due to differences between the qualitative composition of their soil communities.

It is a well known fact that great numbers of different species of animals are found in the soil. Baweja (1939) found in some Rothamsted soils, 275 different species of soil fauna, but the majority of these according to Glasgow (1939, p. 323), which are commonly designated " Soil ", belong in reality to the surface or subsurface soil. These forms are active, have well developed sense organs, and live in the ill-defined region where stem merges into root. Below this lies a region of perpetual darkness, inhabited by a group of sluggish white and blind animals whose modifications recall that of cave fauna.

/ McCulloch and Hayes....

McCulloch and Hayes (1922, p. 288) give certain modifications in insects, which are associated with this subterranean life.

" Usually the body is more elongate, the eyes and wings reduced or wanting, and metamorphosis simple. While all these modifications do not apply to all soil insects, it may be stated that they are often present in direct proportion to the amount of time the insect lives in the soil."

The morphology of the geobionts is a reflection of the environmental conditions provided by the soil. King (1939, p. 270) has summarised these conditions as follows:-

(1) There is a relative chemical and physical stability within the soil.

(2) The low penetrability affords protection to the fauna.

(3) There is a reduction in temperature fluctuations, and protection from light, wind, evaporation, and climatic changes is given.

(4) The soil provides security for the performance of such vital functions as reproduction, hibernation, and feeding.

As an environment, the soil provides an optimum habitat for shelter, moisture, protection, heat, food supply, and a medium for travel.

Before enumerating the groups found in the soils examined during this investigation, it is thought desirable

/ to....

to discuss briefly their relationships to the soil community as a whole.

(a) Eudaphic and Hemiedaphic Mesofauna.

Microarthropods.

The Acari, smaller Collembola, Protura, Symphyla, and Pauropoda belong to this group. The Order Acari is divided into the sub-Orders:- Parasitiformes, Trombidiformes, and Sarcoptiformes. Of the Sarcoptiformes, the Oribatei, which are the most important of all mites living in the soil, were identified to genera where possible. The immature animals and Acaridiae were taken together as a group.

The Parasitiformes, according to the experiments of a few investigations, prey on thin-skinned mites, Diptera larvae, and Collembola. Because of their larger size and enormous gluttony, they are supposed to take an important place in the soil community in spite of their moderate density (Van der Drift, 1951, p. 90). The greater part of the free-living Trombidiformes feed on prey, chiefly eggs, mites, and Collembola. As predators, they therefore greatly influence the community of the soil, but as to the extent and kind of influence, is however, not known. The Sarcoptiformes appear to feed on a variety of substances including faeces, fungi and partly decomposed plant material. Their abundance in the organic layers gives them an important place in the soil community.

Of the smaller Collembola, principally the Poduromorpha

/ were....

were the most abundant. Members of the Entomobryomorpha occurred in smaller numbers.

According to literature, Collembola are partly specific in their feeding habits. Both vegetable and animal substances if soft are eaten. Litter, moulds, algae, exuviae, and dead animals are sources of food for most Collembola. They are supposed to form an important part of the staple-food in the litter layer. Strickland (1945, p. 2) believes that the presence or absence of mycelium in the organic layers probably determines their abundance in view of the large numbers of fungivorous forms. Ford (1935, p.204) has shown that Onychiurids become exterminated when the soil is not porous, and that they appear to move only through the soil pores.

The only representatives of the Order, Protura, belonged to the genus Eosentomon. Nothing is known about the bionomics of the specimens. They appeared to be the same species as that described by Farquhar (1947, p.19).

The Symphyla were represented by specimens of the Family Scutigerellidae. Some members of this family are considered to be saprophagous. Their in these soils is probably not great in view of their low density.

A few Pauropoda, belonging to the genus Pauropus, were found in Natural Forest and Pine soils. Nothing is known of the bionomics of the specimens. All were of the same species

/ and....

and similiar to that described by Farquhar (1947, p.122).

(b) Eudaphic and Hemiedaphic Macrofauna.

Macroarthropods.

Owing to their greater size and mobility, it is to be expected that the macroarthropods are less strictly bound to the litter layer than the microarthropods.

The Isopoda were not represented in the samples which were taken in the form of cores. This was probably due to their escape from the sample sites. Species were however, collected from the forest floor belonging to the genera Philoscia, Diploexochus, and Bethalus. From the contents of their intestines, it was concluded that they were litter-eaters.

The Amphipoda were represented by one species, Talitroides eastwoodae (Meth), which was collected in large numbers from the Natural Forest litter. An examination of the contents of their intestines, showed that they were saprophagous. Their abundance in the litter layer must give them an important place in the working of the organic-matter cycle.

Representatives of the Proterandria and Opisthandria of the Diplopoda were found in the cores and from the forest floor. Those from the cores were immature. The abundance of members of the Proterandria in the Natural Forests was striking, and in these soils, the excrement was mixed with the mineral substrate. The prompt incorporation of the organic

/ material....

material within the soil appeared to be partly due to their activities. Of the Opisthandria, the most abundant species was Sphaerotherium spinatum (Silv). This species was largely responsible for breaking down the litter in the Pine plantations at Witte-els-Bosch. The Ao horizon of these soils was mainly composed of its excrement.

The group of the Chilopoda that occurred most numerously in the cores was the Order Lithobiomorpha, represented by two species, Paralamyctes weberi (Silv) and Paralamyctes spenceri (Poc), which were immature. The contents of the intestine of P. weberi consisted of wood fibres. Members of the Scolopendromorpha and Geophilomorpha were numerous in the litter layers. An examination of the contents of their intestines showed that they were carnivorous. Their food consisting of small Arachnida, Collembola, and other invertebrates. As predators, they probably greatly influence the soil community.

The insects usually have a very great number of representatives in the litter layer, both in respect of the number of specimens, and species. Many of these are geobionts, but the greater part of the insect soil population however, belong to the geophiles.

As a predatory group, the Japygidae of the Thysanura must play an important part in the soil community, as numerous specimens were found in both the cores and litter.

/ The....

The Order Blattariae was represented by specimens in, and on, the litter layer. They probably assist in the breakdown of the litter, since the contents of their intestines consisted of vegetable debris.

Among the Coleoptera, were both geobiontic and geophilous species. Of the first group, the Staphylinidae were the most numerous in the cores and litter. According to literature, little is known about the exact feeding habits of these insects. Imms (1942, p.501) states that many members of the family abound where there is decaying organic matter, including dung and dead animals, while many are predaceous. The other geobiontic families, Ptiliidae, Carabidae, Curculionidae, and Scydmaenidae were found in small numbers. Of the geophiles, which spend their developmental stages in the soil, representatives of the Elateridae, Scarabeidae, and Tenebrionidae occurred in many of the samples. The importance of these larvae in assisting in the breakdown of the litter, and the mixing of the organic material with the mineral soil, is due to their large size, and in many cases, saprophagous feeding habits. Their intestines on examination yielded large quantities of organic debris.

Representatives of the Hemiptera were found on or in the litter in large numbers in the Bluegum plantations at Witte-els-Bosch. Nothing is known of the bionomics of the

/ specimens....

specimens. On one occasion, a sample taken from Natural Forest at Witte-els-Bosch yielded six immature specimens of Henicocephalidae. All were of the same species and similiar to that described by Farquhar (1947, p.73). Usinger (1932, p.145) found specimens of this group on the ground, under stones and debris or running among dead leaves in forests. This would account for the finding of immature forms in the soil. There is little information regarding their bionomics(Farquhar, p.73).

A number of larval Diptera were found belonging to the families Bibionidae and Asilidae. Their influence upon the decomposition of the litter is probably similiar to that of the coleopterous larvae.

Of the Hymenoptera, the Formicidae were the most important representatives of the order. Relatively few specimens were however, found in the cores and litter. Van der Drift (1951, p.116) points out that the importance of the ants in the community which he investigated, appeared in any case to be small.

The most numerous group of the macro-Arachnoidea were the Araneida. Of these, species of the families Drassidae, Salticidae,and Zodariidae were represented. Their abundance and carnivorous habits gives them an important place amongst the predators of the soil community.

The Scorpionida were represented by specimens of

/ Opisthocanthus....

Opisthocanthus brownii (Hwtt), which were found in the Natural Forest and Bluegum plantations at Witte-els- Bosch. Their retiring habits,and tendancy to fast for long periods, probably reduces their influence as predators on the soil community.

Annelida.

Members of the Enchytraeidae were numerous in the litter layers, but the difficulty of identification made it necessary to abandon attempts at classifying the specimens.

Acanthodriline earthworms were abundant in the Natural Forest at Witte-els-Bosch. Parachilota photodilus (Beddard) was found in the litter layers of the Pine plantations and Natural Forest in this area. The scarcity of Acanthodrilines in the Amatola Mountains was very striking, and appeared to be due to the presence of a predominantly Lumbricid earthworm fauna. Stephenson (1930, p.905) states that the introduction of Lumbricids into new territory frequently causes the disappearance of the endemic earthworm fauna. This appears to be what has happened in these forests. Many investigators have concluded that the deep and friable mull of deciduous forests is contingent on the activity of earthworms and associated species. Their importance in the working of the organic-matter cycle is thus very great.

Mollusca (Pulmonata).

Numerous large and small Pulmonates were found in the litter layers of the Natural Forests. Of these, Euonyma

/ platyacme....

platyacme (M and P) were abundant in the Amatola Mountain forests, but absent from the forests at Witte-els-Bosch. Trachycystis centrifuga (M and P) occurred in both areas. From an examination of the contents of their intestines, it was concluded that they were saprophagous. The majority of other specimens which were found could not be identified with certainty, but in view of their abundance in the litter layer, they must exercise a considerable influence on the soil community.

(c) Epedaphic Macrofauna.

Under this heading, all the macroarthropods may be placed that move over the forest floor, and for that reason can be caught in tins buried in the soil.

Representatives of the Diplopoda, Amphipoda, Arachnida, and Hemiptera were caught in this way. These have already been mentioned in dealing with the Edaphic and Hemiedaphic macrofauna.

The Opliones may be placed here, since the litter layer is but a part of their habitat. They were also found in the herbaceous layer and even in the tree layer. Their numbers were not great and thus their effects on the soil community is probably small.

Some specimens of the Family Gryllacridae were found within rotting stumps in the Natural Forest at Witte-els-Bosch.

/ The....

The microscopical analysis of the contents of their intestines revealed that they were omnivorous. Some unidentified Mycetophilidae of the Nematocera were caught in buried tins. Nothing is known of the bionomics of the specimens. According to Imms (1942, p.647), the adults are found in a variety or situations, where there is fungoid growth or decaying vegetation. The larvae feed upon fungi more often than any other substance.

Some vertebrate members of the soil community, of the Class Amphibia, were found within the Natural Forest in the Amatola Mountain area. They were identified as Anhydrophryne rattrayi (Hwtt). At Witte-els-Bosch, a specimen of Breviceps fuscus (Hwtt) was found in a Pine plantation.

(d) Hyperedaphic Macrofauna.

No collection was made from this biotope, but a few members of the Family Cyrtacanthacrinae were found during the course of collecting from litter in the Natural Forest. The importance of these, and other animals living in this biotope, is to be found in the faecal material which is added to the soil as a result of their activities.

Some Culicids and a number of Ortalids were caught in buried tins. They probably do not influence the soil community in any way.

/ The Fauna....

The Fauna.

Epedaphic Macrofauna.

The following fauna were caught, over a period of 24 hours, in tins, which were buried with their rims level with the forest floor:-

Natural Forest.

Amphipoda.	Talitridae.	Talitroides eastwoodae (Meth).
Diptera.	Culicidae.	Theobaldia sp.
	Mycetophilidae.	spp.
	Ortalidae.	sp.
Coleoptera.	Staphylinidae.	Philonthus sp.
Chilopoda.	Henicopidae.	Paralamyctes weberi (Silv).
Opliones.	Phlangodidae.	Metabiantes sp.
Annelida.	Acanthadrilinae.	Parachilota photodilus (Beddard)
		Total Catch 130.

Pine.

Diptera.	Culicidae.	Theobaldia sp.
	Mycetophilidae.	sp.
	Ortalidae.	sp.
Diplopoda.	Sphaerotheridae.	Sphaerotherium spinatum (Silv).
		Total Catch 49.

Bluegum.

Diptera.	Culicidae.	Theobaldia sp.
	Ortalidae.	sp.
Hemiptera.	Coreidae.	spp.
Araneida.	Drassidae.	spp.
	Zodariidae.	sp.
		Total Catch 45.

Hemiedaphic Macrofauna.

The following fauna were collected from the litter:-

Amatola Mountains.

Natural Forest. (Fig. 39).

Amphipoda.	Talitridae.	Talitroides eastwoodae (Meth).
Isopoda.	Oniscidae.	Philoscia fulva (Barnard).
	Armadillidiidae.	Diploexochus flavescens (Brdt).
		Bethalus nigrinus (Budde-Lund).
Thysanura.	Japygidae.	Japyx sp.
	Machilidae.	Machiloides sp.
Blattariae.	Blattidae.	Melanoblattia lampyroidea (Wlk).
Orthoptera.	Cyrtacanthacrinae.	Acanthacris sp.
Coleoptera.	Carabidae.	Dyoriche sp.
	Staphylinidae.	sp.
	Scydmaenidae.	Mastigus sp.
	Lagriidae.	Lagria sp.
Araneida.	Drassidae.	sp.
	Salticidae.	sp.
Opliones.	Biantinae.	Metabiantes pusulosus (Loman).
Diplopoda.	Sphaerotheridae.	Sphaerotherium sp.
		Sphaerotherium rotundatum (Brdt).
		Sphaerotherium subdorsale (Silv).
	Spirostreptidae.	Gymnostreptus pyrrhocephalus (L. Koch).
	Sphaerotrichopidae.	Gnomeskelus sp.
Chilopoda.	Henicopidae.	Paralamyctes spenceri (Poc).
	Cryptopidae.	Cryptops australis (Newp.)
	Geophilidae.	Amphilodon weberi (Silv).
Symphyla.	Scutigerellidae.	Hanseniella sp.
Mollusca.	Achatinidae.	Euonyma platyacme (M & P).
	Endodontidae.	Trachycystis centrifuga (M & P).
	Paraphantidae.	Natalina sp.

	Helicarionidae.	Sheldonia sp.
Oligochaeta.	Acanthodrilinae.	Parachilota spp.
	Enchytraeidae.	spp.
	Lumbricidae.	Eiseniella sp.
Anura.	Ranidae.	Anhydrophryne rattrayi (Hwtt).
Larvae.	Elateridae.	sp.
	Tenebrionidae.	sp.
	Scarabaeidae.	Cetoniinae sp. Melolonthinae sp.
	Phoridae.	sp.

Oak. (Fig. 40).

Amphipoda.	Talitridae.	Talitroides eastwoodae (Meth).
Thysanura.	Japygidae.	Japyx sp.
Orthoptera.	Cyrtacanthacrinae.	Acanthacris sp.
Coleoptera.	Carabidae.	Trechus sp.
	Staphylinidae.	sp.
Diplopoda.	Sphaerotheridae.	Sphaerotherium rotundatum (Brdt).
	Sphaerotrichopidae.	Gnomeskelus sp.
Chilopoda.	Henicopidae.	Paralamyctes spenceri (Poc).
	Geophilidae.	Amphilodon weberi (Silv).
Mollusca.	Achatinidae.	Euonyma platyacme (M & P).
Oligochaeta.	Enchytraeidae.	spp.
	Lumbricidae.	Bimastus sp.
Larvae.	Bibionidae.	sp.

Pine. (Fig. 41).

Blattariae.	Blattidae.	Aptera sp.
Coleoptera.	Carabidae.	Trechus sp.
	Staphylinidae.	sp.
Araneida.	Drassidae.	sp.
	Zodariidae.	sp.
Opliones.	Biantinae.	Metabiantes pusulosus (Loman).

Fig.39 - Hemiedaphic Macrofauna. Natural Forest.

Fig.40 - Hemiedaphic Macrofauna. Oak.

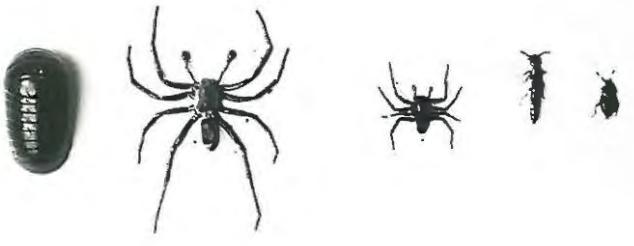

Fig.41 - Hemiedaphic Macrofauna. Pine.

L.- R. In order of decreasing abundance.

Diplopoda.	Sphaerotheridae.	Sphaerotherium rotundatum (Brdt).
	Spirostreptidae.	Gymnostreptus pyrrhocephalus (L. Koch).
Chilopoda.	Henicopidae.	Paralamyctes spenceri (Poc).
Oligochaeta.	Enchytraeidae.	spp.
	Lumbricidae.	Bimastus sp.
		Eiseniella sp.
Larvae.	Staphylinidae.	sp.

Witte-els-Bosch.

Natural Forest. (Fig. 42).

Amphipoda.	Talitridae.	Talitroides eastwoodae (Meth).
Isopoda.	Oniscidae.	Philoscia sp.
Thysanura.	Japygidae.	Japyx spp.
Orthoptera.	Tettigonidae.	Hoplolopha sp.
	Gryllacridae.	Henicus sp.
		Onosandrus spp.
Blattariae.	Blattidae.	Melanoblattia sp.
	Phyllodromiidae.	Phyllodromia sp.
Coleoptera.	Carabidae.	Dyoriche sp.
		Haplotrechus sp.
	Staphylinidae.	Philonthus sp.
		Quedius sp.
	Scydmaenidae.	Mastigus sp.
Hemiptera.	Coreidae.	spp.
Araneida.	Drassidae.	spp.
	Salticidae.	sp.
	Zodariidae.	sp.
Opliones.	Triaenonychidae.	Larifuga weberi (Loman).
Scorpionida.	Ischnuridae.	Opisthocanthus brownii (Hwtt).
Diplopoda.	Sphaerotheridae.	Sphaerotherium rotundatum (Brdt).
		Sphaerotherium sp.
	Spirostreptidae.	Gymnostreptus pyrrhocephalus (L.Koch).

	Sphaerotrichopidae.	Gnomeskelus repandus (Attems).
		Gnomeskelus sp.
	Trigoniulidae.	Chersastus sp.
Chilopoda.	Henicopidae.	Paralamyctes weberi (Silv).
	Cryptopidae.	Cryptops australis (Newp).
		Cryptops sp.
	Scolopendridae.	Scolopendra morsitans (L).
Mollusca.	Endodontidae.	Trachycystis centrifuga (M & P).
		Trachycystis sp.
	Paraphantidae.	Natalina sp.
	Achatinidae.	Achatina sp.
Oligochaeta.	Enchytraeidae.	spp.
	Acanthodrilinae.	Parachilota photodilus (Beddard).
		Parachilota excavatus (Beddard).
		Chilota sp.
		Eodrilus sp.
	Geoscolicidae.	Microchaetus sp.
Larvae.		
	Elateridae.	sp.
	Bibionidae.	sp.

Pine. (Fig. 43).

Amphipoda.	Talitridae.	Talitroides eastwoodae (Meth).
Orthoptera.	Acridiidae.	Catantops sp.
Blattariae.	Blattidae.	Melanoblattia sp.
		Pseudoderopeltis sp.
Coleoptera.	Carabidae.	sp.
	Staphylinidae.	sp.
Araneida.	Drassidae.	spp.
Diplopoda.	Sphaerotheridae.	Sphaerotherium spinatum (Silv).

	Sphaerotrichopidae.	Gnomeskelus sp.
Chilopoda.	Henicopidae.	Paralamyctes weberi (Silv).
	Cryptopidae.	Cryptops sp.
Mollusca.	Endodontidae.	Trachycystis sp.
Oligochaeta.	Acanthodrilinae.	Parachilota photodilus (Beddard).
Anura.	Engystomatidae.	Breviceps fuscus (Hwtt).
Larvae.	Elateridae.	sp.
	Asilidae.	Promachus sp.

Bluegum. (Fig. 44).

Isopoda.	Oniscidae.	Philoscia sp.
Blattariae.	Blattidae.	Melanoblattia sp.
		Pseudoderopeltis sp.
Hymenoptera.	Formicidae.	sp.
Hemiptera.	Coreidae.	spp.
Araneida.	Drassidae,	sp.
	Salticidae.	spp.
Scorpionida.	Ischnuridae.	Opisthocanthus brownii (Hwtt).
Larvae.	Elateridae.	spp.

Hemiedaphic Macro- and Mesofauna.

The following fauna were extracted from the Ao horizons of the Witte-els-Bosch soils:-

Natural Forest.

Thysanura.	Japygidae.	Japyx sp.
Collembola.	Entomobryidae.	spp.
	Poduromorpha.	spp.
Coleoptera.	Ptiliidae.	Ptiliolum sp.
Acarida.	Oribatidae.	Hoploderma spp.
		Oribata spp.
		Notaspis spp.

Fig.42 - Hemiedaphic Macrofauna. Natural Forest.

Fig.43 - Hemiedaphic Macrofauna. Pine.

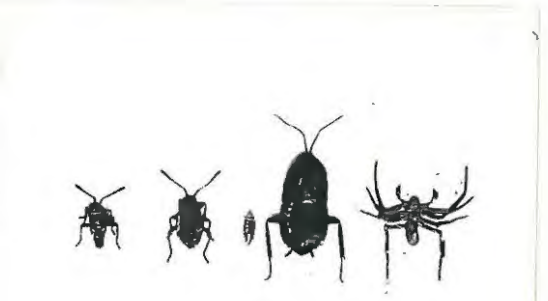

Fig.44 - Hemiedaphic Macrofauna. Bluegum.

L.- R. In order of decreasing abundance.

	Trombidiformes.	spp.
	Parasitiformes.	spp.
	Nymphs and Acaridiae.	spp.
Araneida.	Drassidae.	sp.
Opliones.	Triaenonychidae.	Ceratomontia sp.
Diplopoda.	Sphaerotheridae.	Sphaerotherium rotundatum (Brdt).
		Sphaerotherium sp.
	Sphaerotrichopidae.	Gnomeskelus sp.
Chilopoda.	Henicopidae.	Paralamyctes sp.
Symphyla.	Scutigerellidae.	Hanseniella sp.
Oligochaeta.	Enchytraeidae.	spp.
	Acanthodrilinae.	Parachilota photodilus (Beddard).
Larvae.	Scarabaeidae.	spp.
Pine.		
Protura.	Eosentomidae.	Eosentomon sp.
Collembola.	Entomobryidae.	spp.
	Poduromorpha.	spp.
Coleoptera.	Staphylinidae.	sp.
	Ptiliidae.	Ptiliolum sp.
Hymenoptera.	Formicidae.	Dorylus sp.
Acarida.	Oribatidae.	Hoploderma spp.
		Oribata spp.
		Notaspis spp.
	Trombidiformes.	spp.
	Parasitiformes,	spp.
	Nymphs and Acaridiae.	spp.
Araneida.	Drassidae.	sp.
Diplopoda.	Sphaerotheridae.	Sphaerotherium spinatum (Silv).
Chilopoda.	Henicopidae.	Paralamyctes sp.
Symphyla.	Scutigerellidae.	Hanseniella sp.

Bluegum.

Thysanura.	Japygidae.	Japyx sp.
Collembola.	Entomobryidae.	spp.
	Poduromorpha.	spp.
Coleoptera.	Staphylinidae.	sp.
	Ptiliidae.	Ptiliolum sp.
Acarida.	Oribatidae.	Hoploderma sp.
		Oribata sp.
		Notaspis spp.
	Trombidiformes.	spp.
	Parasitiformes.	spp.
	Nymphs and Acaridiae.	spp.
Chilopoda.	Henicopidae.	Paralamyctes sp.
Symphyla.	Scutigerellidae.	Hanseniella sp.

Eudaphic Macro- and Mesofauna.

The following fauna were found in the mineral soil after the organic layers had been removed:-

Natural Forest.

Protura.	Eosentomidae.	Eosentomon sp.
Thysanura.	Japygidae.	Japyx sp.
Collembola.	Entomobryidae.	spp.
	Poduromorpha.	spp.
Coleoptera.	Staphylinidae.	sp.
Acarida.	Oribatidae.	Oribata spp.
		Notaspis spp.
	Parasitiformes.	spp.
	Nymphs and Acaridiae.	spp.
Diplopoda.	Sphaerotrichopidae.	Gnomeskelus sp.
Oligochaeta.	Acanthodrilinae.	Parachilota photodilus (Beddard).
		Parachilota sp.

Larvae.	Staphylinidae.	sp.
	Elateridae.	sp.
	Scarabaeidae.	Cetoniinae sp.
	Asilidae.	Promachus sp.
Pine.		
Collembola.	Poduromorpha.	sp.
Coleoptera.	Staphylinidae.	sp.
Acarida.	Oribatidae.	Oribata spp.
	Nymphs and Acaridiae.	spp.
Bluegum.		
Collembola.	Entomobryidae.	sp.
	Poduromorpha.	sp.
Acarida.	Oribatidae.	Oribata sp.
		Notaspis spp.
	Parasitiformes. Nymphs.	spp.

The differences between the qualitative composition of the fauna in the three soils is striking. From Figure 45, it will be seen that of the three soil horizons, the Aoo horizon shows the largest qualitative difference. The fact that the foliage of the Pine and Bluegum tends to favour an acid type of decomposition, may inhibit the development of a rich fauna in their organic layers. The numbers of fauna in the Pine and Bluegum organic layers is however, much greater than in the Natural Forest. As would be expected, the fauna consists largely of small fungivorous animals. Eaton and

/ Chandler....

Chandler (1942) believed that the Acarine and Collembola population in mor humus layers was much greater than in mull. Figure 46 shows that this is so for the organic layers, but not for the entire core (Fig. 47).

Figure 48 shows the faunal composition of the cores obtained during the investigation. It will be seen that there are, with two exceptions, higher values for the Natural Forest soils. The fact that the distribution of the organic material within the soil determines the quantitative faunal composition, does not imply that the qualitative composition is in any way related. The differences in the qualitative faunal composition are a reflection of the nature of the tree foliage and its mode of decomposition.

It is now possible to account in part for the differences in the soil profiles. Dependant upon the kind of decomposition of the organic matter falling on the soils, there arises greatly different soil profiles. In consequence of a relatively rapid decomposition of the litter, chiefly under the influence of bacteria and a rich macrofauna, there arises a " Mull-type ", in which the pH is rather high, and the humus mixed with the mineral soil, the latter having a crumby structure. On the other hand in consequence of a slow decomposition, the litter accumulates on the mineral soil, and fungi attack the cellulose and form acids. With the low pH,

/ bacteria....

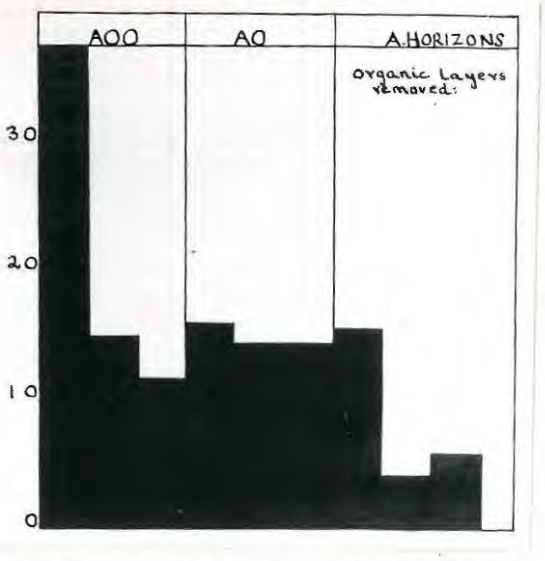

Fig.45 - Numbers of Faunal Groups in the various Horizons of the Witte-els-Bosch soils.

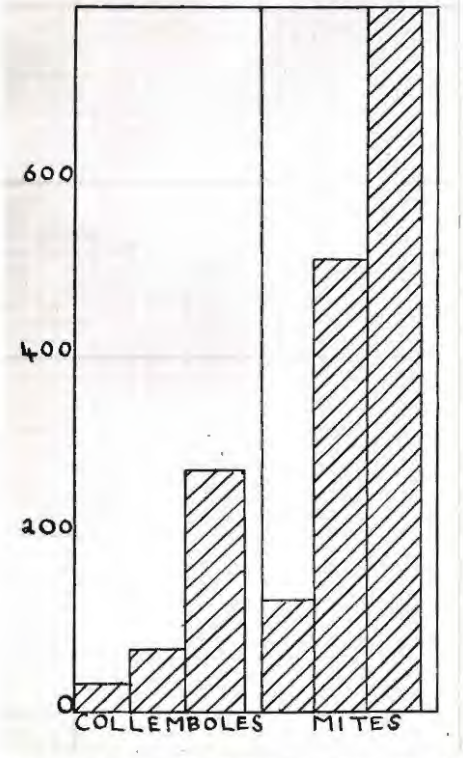

Fig.46 - Collembola and Acarine populations in the Ao Horizons of the Witte-els- Bosch soils.

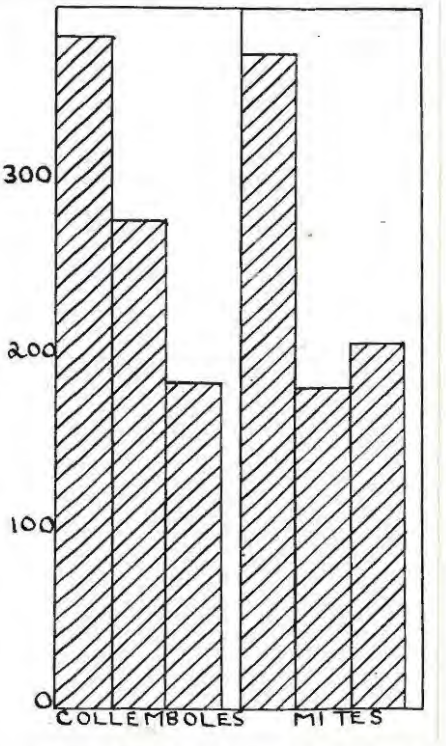

Fig.47 - Collembola and Acarine populations in the A Horizons of the Witte-els- Bosch soils.

Histograms read from left to right, Natural Forest, Pine, and Bluegum.

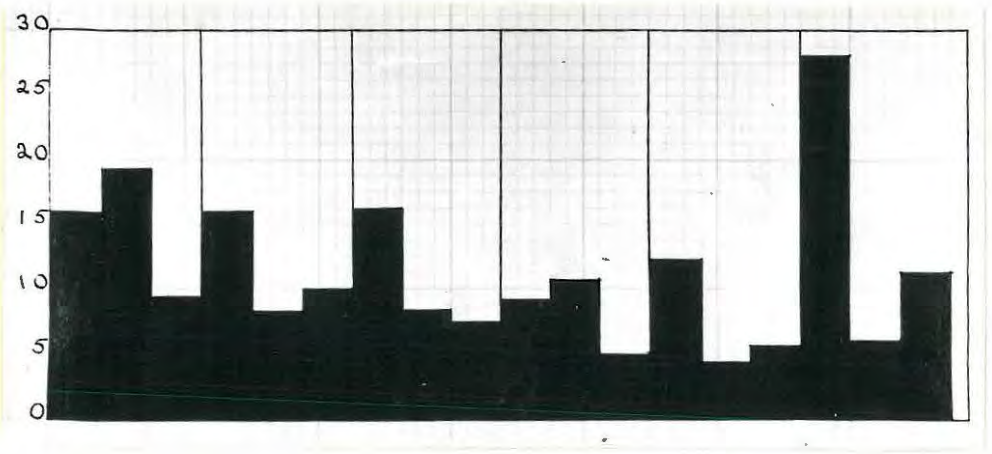

Fig.48 - Numbers of Faunal Groups in the Cores.
L.- R. A, B, C1-2, C4-6, D, FG Series.

Histogram reads from left to right, Natural Forest, Pine, and Bluegum.

bacteria play a subordinate part and the fauna is chiefly represented by the mesofauna, which are confined to the organic layers, and so are not capable of mixing the organic material with the mineral soil. The small number of macrofauna that do occur however, are also restricted to the organic layers and therefore cannot influence the mixing process. This " Mor type " of humus layer is characterised in the field by a layer of unincorporated organic material resting upon a leached mineral soil, since the organic acids and humus substances, washed away from the humus layers, cause leaching of the upper layers of the soil.

CHAPTER 6.

DIFFERENCES IN THE QUALITATIVE COMPOSITION OF THE SOIL MICRO-FAUNA (PROTOZOA), AND SOME METHODS FOR THEIR CULTURE.

Although the occurrence of Protozoa in the soil was well known since the work of Ehrenberg (1837), serious interest in them as a factor playing a part in the general economy of the soil can only be regarded as having started with the publication by Russell and Hutchinson in 1909 of their theory of " Partial Sterilisation ". A great deal of work has been since then to test this theory. Kopeloff and Coleman (1917) cite over 121 papers published by various authors on the subject of soil sterilisation in their exhaustive review of the literature accumulated prior to the year 1917. It was in order to reconcile the conflicting views held in the past on the part that Protozoa play in the general economy of the soil, that led Sandon (1928) to make a detailed investigation of various American soils. He found that the protozoan population was roughly related to the bacterial population. But in spite of recent investigations into the problem, considerable differences of opinion still exist on the fundamental question of the significance of the protozoan fauna in the soil.

Fantham and Taylor (1921, 1922), and Fantham and Paterson (1923, 1924) made the first investigation of the

/ protozoan....

protozoan fauna of South African soils. Their work was necessarily of a preliminary character, and did not embrace a detailed examination of forest soils. The present investigation is the first to compare the protozoan fauna of South African forest soils.

Culture Media.

An essential requisite to the study of Protozoa is their efficient culture in artificial media. It is a matter of great difficulty to obtain an artificial environment comparable to their natural habitat. Many methods have been devised to overcome the problem, none of which have however, been entirely successful. Koch (1915) found that the development of soil protozoa in artificial cultures varied with the kind of media employed, the quantity of soil used as an inoculum, and the temperature of incubation. A standard technique is therefore essential for a comparative investigation.

A widely used medium amongst the earlier workers was a 10% Hay Infusion. Russell and Hutchinson (1909, 1913), and Goodey (1913), made slightly alkaline infusions and added egg albumen and 0.75% NaCl. Bacteriological solutions have been used by many German workers. Cunningham and Löhnis (1914) made a survey of some commonly used bacteriological solutions. These were:-

(a) Ammonifying solutions. (1) 1% Bloodmeal, 0.05% K_2HPO_4, and water.

(2) Cornmeal and Fleshmeal solutions.
(3) 1% solution and a 0.50% solution of K_2HPO_4.

(b) Nitrifying solution of Windgradsky-Omelianski, using a 0.10% solution of $(NH_4)_2SO_4$.

(c) Denitrifying solution of Giltag.

(d) Azotobacter media.
(1) 1% Mannite, 0.050% K_2HPO_4 in soil extract.
(2) 2% Calcium Malate, 0.050% K_2HPO_4 in water.
(3) A number of Mannite solutions, whose Butyric acid bacteria replaced Azotobacter.

(e) 5% Urea solution, and 0.050% K_2HPO_4 in soil extract.

(f) 0.2 grms Cyanamide, 0.05 grms K_2HPO_4, 0.01 grms Asparagin and 0.01 grms glucose.

(g) Omelianski's solution for cellulose decomposing bacteria.

(h) (1) 1% Mannite, 0.050% K_2HPO_4, Chalk and Bacillus fluorescens.
(2) Soil extract and K_2HPO_4 agar plates.

A feature, which was brought out by the survey, was the relationship between the development of the Protozoa and that of the bacteria. The most satisfactory media proved to be the soil extract and K_2HPO_4.

Martin and Lewin (1914) recommend Horse-dung agar, prepared by boiling three lumps of horse dung in 500 ccs of

/ water....

water for 1½ hours. The liquor was filtered and 6 grams of agar added. The plates were moistened with small amounts of water from time to time. Dixon (1937) undertook an investigation into the merits of peptone agars and soil extract agars for quantitative and qualitative estimations. She used 200 grams of soil to 400 ccs of water. After filtering, the extract was made up to 500 ccs, and 5 grams of agar added. She found that a big increase in the numbers of all classes of Protozoa resulted when soil agar was used. It was most noticeable in the case of Amoebae and to a lesser degree the Ciliates. The appearance of the peptone and soil agars was quite distinct. The peptone media encouraged the growth of specialised species of bacteria, while the soil extract agars allowed the growth of many species in small numbers. Fantham and Taylor (Loc. cit.) and Fantham and Paterson (Loc. cit.), in their investigation on South African soils, used water. They believed that as water was the natural medium for moistening soils, such cultures would reveal a content of Protozoa approximately normal to the soil. They point out that their cultures gave however, an incomplete representation of the faunal composition.

The properties of some media were compared with the following results, given in Table 17.

On comparing the water cultures, soil extract agars, and agars made from a mixture of Hay Infusion and Lockes solution,

/ the....

TABLE 17.

Agar Media (Dil. 1:100).

Media	Nos: Cultures	Numbers of Species: Flagellates	Rhizopods	Ciliates	Total
Hay Infusion and Lockes Soln	4	21	10	23	54
Soil Extract	4	22	8	23	53
Hay Infusion	4	14	5	14	33
Peptone	4	5	2	1	8
Peptone-glucose	4	2	4	2	8
Peptone and Hay Infusion	4	4	2	4	10

Liquid Media (Dil. 1:100).

Media	Nos: Cultures	Numbers of Species: Flagellates	Rhizopods	Ciliates	Total
Oatmeal	4	8	0	2	10
Wheat	4	5	1	1	7
Bread	4	5	0	1	6
Soil	4	3	1	0	4

Natural Forest soil used as an inoculum.

TABLE 18.

(Dil. 1:20).

Media		Nos: Cultures	Numbers of Species: Flagellates	Rhizopods	Cilates	Total
Water	a	1	7	2	4	13
	b	1	5	3	4	12
	c	1	3	0	10	13
	d	1	5	2	5	12
	e	1	3	0	13	16
	f	1	3	1	3	7
	Total	6	26	8	39	73
			Mean 4	1	6	12
Soil	a	1	4	2	8	14
Extract	b	1	12	7	8	27
Agar	c	1	7	4	7	18
	d	1	10	4	3	17
	e	1	13	4	17	34
	f	1	9	4	11	24
	Total	6	55	25	54	134
			Mean 9	4	9	22
Hay	a	1	7	2	6	15
Infusion	b	1	9	2	8	19
and	c	1	5	5	8	18
Lockes	d	1	7	2	4	13
Solution	e	1	11	4	12	27
Agar	f	1	9	1	5	15
	Total	6	48	16	43	107
			Mean 8	2	7	17

Natural Forest soil used as an inoculum.

the results given in Table 18 were obtained on using a lower dilution. It will be seen that the soil extract and Hay Infusion-Lockes solution agars gave better results than when water and soil was used. The inoculum dilution of 1:20, when compared with the higher dilution of 1:100, favoured the development of more species in the soil extract agar than in the Hay Infusion-Lockes solution agar. On comparing these two media, and using an inoculum dilution of 1:10, the results given in Table 19 were obtained. A more satisfactory representation of the protozoan fauna is thus obtained from a soil extract agar with an inoculum dilution of 1:20 or 1:10. Both media appear however, to be equally efficient with a dilution of 1:100. For qualitative estimations, when higher inoculum dilutions are necessary, and the medium requires to be standardised, the Hay Infusion-Lockes solution agar may prove to be useful.

In this investigation, the soil extract agars were prepared from the soils, which were to be examined, using an inoculum dilution of 1:10. Lower dilutions than this were found to be impracticable due to the difficulty of examination with the excessive debris in the culture fluid.

Microfaunal Composition of the Mineral Soil.

In recording the Protozoa found in the different soils, only those forms which could be identified were included.

/ The....

TABLE 19.

(Dil. 1:10) Media		Nos: Cultures	Numbers of Species: Flagellates	Rhizopods	Ciliates	Total
Soil	a	1	8	2	9	19
Extract	b	1	9	4	10	23
	c	1	10	3	7	20
	d	1	7	2	11	20
	Total	4	34	11	37	82
			Mean 8	2	9	20

(Dil. 1:10) Media		Nos: Cultures	Numbers of Species: Flagellates	Rhizopods	Ciliates	Total
Hay	a	1	4	3	7	14
Infusion	b	1	6	1	6	13
and	c	1	7	3	4	14
Lockes	d	1	4	1	6	11
Solution	Total	4	21	8	23	52
			Mean 5	2	5	13

Natural Forest soil used as an inoculum.

The following species were identified from the mineral soil:-

Flagellates.

Bodo sp.	Grahamstown. Natural Forest, Pine, Mixed Pine, (Coastal Scrub).
Cercomonas crassicauda. Alex.	Grahamstown. Natural Forest, Pine, Mixed Pine, (Coastal Scrub).
	Amatola. Oak.
	Witte-els-Bosch. Natural Forest, Bluegum.
Entosiphon sulcatum (Duj).	Grahamstown. Natural Forest, Pine, Mixed Pine, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest.
Euglena sp.	Grahamstown. Mixed Pine.
Heteromita globosa Stein.	Grahamstown. Natural Forest, Pine, Bluegum, Mixed Pine, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Oak, Bluegum, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Heteromita ovata Duj.	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub, Trampled soil).
Phalansterium sp.	Grahamstown. Natural Forest.
Peranema trichophorum (Ehrbg).	Grahamstown. Natural Forest, Pine, Bluegum, (Coastal Scrub, Trampled soil).

	Amatola. Natural Forest, Oak, Bluegum, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Petalomonas sp.	Grahamstown. Natural Forest, (Coastal Scrub).
Pleuromonas jaculans Perty.	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum,
	Amatola. Oak, Pine, Bluegum, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Oikomonas termo (Ehrbg).	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Pine, Bluegum, Oak, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine.
Flagellate (a).	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Oak.
Flagellate (b).	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub).
	Amatola. Natural Forest, Oak, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine.
Flagellate (c).	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum, (Trampled soil).
	Amatola. Natural Forest, Pine.
Flagellate (d).	Grahamstown. (Coastal Bush).

	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Flagellate (e).	Grahamstown. (Coastal Bush).
Flagellate (f).	Grahamstown. (Coastal Bush, Trampled soil).
Rhizopods.	
Actinophrys sol Ehrbg.	Grahamstown. Natural Forest, Pine, Mixed Pine, (Trampled soil).
	Amatola. Natural Forest, Bluegum.
	Witte-els-Bosch. Pine.
Amoeba glebae Dobell.	Grahamstown. Natural Forest.
Amoeba (Proteus group).	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub).
	Amatola. Natural Forest, Oak, Pine, Bluegum.
	Witte-els-Bosch. Natural Forest, Pine.
Amoeba radiosa Ehrbg.	Grahamstown. Pine, Bluegum, (Coastal Scrub).
	Amatola. Natural Forest, Oak, Pine.
Amoeba verrucosa Ehrbg.	Grahamstown. Natural Forest,(Trampled soil).
Difflugia sp.	Grahamstown. Bluegum.
Euglypha sp.	Grahamstown. Natural Forest, Pine,Bluegum, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Oak, Pine.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Hartmanella sp.	Grahamstown. Natural Forest, Pine.
	Amatola. Natural Forest, Oak, Pine, Bluegum.

Naegleria gruberi (Schardinger).	Grahamstown. Natural Forest, Mixed Pine, (Coastal Scrub, Trampled soil).
Nuclearia sp.	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum, (Coastal Scrub).
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Ciliates.	
Amphileptus cygnus Clap. & Lach.	Grahamstown. (Coastal Bush).
Colpidium sp.	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum.
	Amatola. Sclerophyll Bush.
Colpidium colpoda Stein.	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Oak, Pine, Bluegum, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Colpidium striatum Stokes.	Grahamstown. Natural Forest, Pine, Mixed Pine, (Trampled soil).
	Amatola. Natural Forest, Pine, Bluegum, Oak.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Colpoda (a).	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum.
	Amatola. Pine, Bluegum, Sclerophyll Bush.

	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Colpoda (b).	Grahamstown. (Coastal Scrub, Trampled soil).
	Witte-els-Bosch. Natural Forest.
Colpoda cucullus (Müller).	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest, Bluegum, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Colpoda maupasii Enriques.	Grahamstown. Natural Forest, Pine, Mixed Pine, (Coastal Scrub).
	Amatola. Natural Forest, Oak, Pine, Bluegum, Sclerophyll Bush.
Chilodon cucullulus (O. F. M.).	Amatola. Natural Forest, Bluegum.
Cyclidium glaucoma (O. F. M.).	Grahamstown. Pine, Mixed Pine, Bluegum.
	Amatola. Natural Forest, Pine, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Enchelys sp.	Grahamstown, Natural Forest, (Coastal Scrub).
Halteria sp.	Witte-els-Bosch. Natural Forest.
Halteria grandinella (O. F. M.).	Grahamstown. Natural Forest, Mixed Pine.
	Amatola. Pine, Bluegum.
Holophrya ovum Ehrbg.	Grahamstown. (Coastal Scrub).

Holosticha sp.	Grahamstown. (Coastal Scrub).
Lionotus fasciola (Ehrbg).	Grahamstown. Natural Forest, Pine, Mixed Pine, Bluegum.
Lacrymaria olor (Müller).	Grahamstown. Pine, (Coastal Scrub).
Oxytricha sp.	Grahamstown. Natural Forest, Mixed Pine, Bluegum, (Coastal Scrub).
	Amatola. Natural Forest, Pine, Oak, Bluegum.
Oxytricha pellionella (Müller).	Grahamstown. Natural Forest, Pine, Bluegum, (Coastal Scrub).
	Amatola. Natural Forest, Pine.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Paramoecium aurelia Müller.	Grahamstown. Natural Forest, (Coastal Scrub, Trampled soil).
Paramoecium putrinum Clap.& Lach.	Grahamstown. Pine.
Pleurotricha lanceolata (Ehrbg).	Grahamstown. Mixed Pine, Bluegum, (Coastal Scrub).
	Amatola. Pine.
	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Pleuronema chrysalis Ehrbg.	Grahamstown. Mixed Pine, (Coastal Scrub).
Phacodinium muscorum Prowazek.	Grahamstown. Pine.
Prorodon ovum Ehrbg.	Grahamstown. (Coastal Scrub).
Stylonychia sp.	Grahamstown. Natural Forest, Pine, (Coastal Scrub, Trampled soil).
	Amatola. Natural Forest.

Uroleptus piscis Ehrbg.	Grahamstown. Mixed Pine, (Coastal Scrub).
	Amatola. Natural Forest, Pine, Bluegum.
	Witte-els-Bosch. Natural Forest, Bluegum.
Urostyla sp.	Grahamstown. (Coastal Scrub).
Vorticella sp.	Grahamstown. Natural Forest, Pine, (Coastal Scrub).
	Amatola. Pine, Oak, Sclerophyll Bush.
	Witte-els-Bosch. Natural Forest.

Microfaunal Composition of the Humus Layers.

Cultures of the organic horizons showed a wider distribution for many of the species than is indicated above. This is to be expected in view of the higher organic content of the surface layers as compared with the mineral soil below.

The following species were identified from the organic layers:-

Rhizopods.

Amoeba (Limax group).	Grahamstown. Pine.
Amoeba proteus (Pallas).	Witte-els-Bosch. Natural Forest.
Difflugia globulosa (Duj).	Grahamstown. Natural Forest.
	Amatola. Oak.
	Witte-els-Bosch. Bluegum.
Difflugia pyriformis Perty.	Witte-els-Bosch. Natural Forest, Bluegum.
Pelomyxa palustris Greef.	Grahamstown. Pine.
	Witte-els-Bosch. Natural Forest, Pine.

Ciliates.

Colpoda (c).	Witte-els-Bosch. Natural Forest.
Chilodon sp.	Grahamstown. Natural Forest.
	Amatola. Oak.
Gastrostyla sp.	Witte-els-Bosch. Natural Forest, Pine, Bluegum.
Loxophyllum rostratum Duj.	Grahamstown. Natural Forest.
Uroleptus dispar Stokes.	Amatola. Oak.
	Witte-els-Bosch. Natural Forest.

Figures 49 and 50 show the qualitative microfaunal composition of the organic layers at Witte-els-Bosch. The values for the Aoo horizons are probably related to differences in foliage composition, and the values for the A horizons to differences in organic content. The differences shown however, by the microfaunal composition of the Ao horizons is unexpected.

Sandon (1927, p.38) states that the similarity between the vertical distribution of the soil protozoa and bacteria, supports the idea that the protozoal population is determined mainly by the quantity of bacteria available for food. Fellers and Allison (1920) have commented upon the close connection the numbers of protozoal species and of bacteria in the soil. It seems then, that the bacterial population in the Ao horizons of the Pine and Bluegum soils is relatively higher than the Natural Forest. This is contrary to what would be expected in view of the acid decomposition taking place, which tends to

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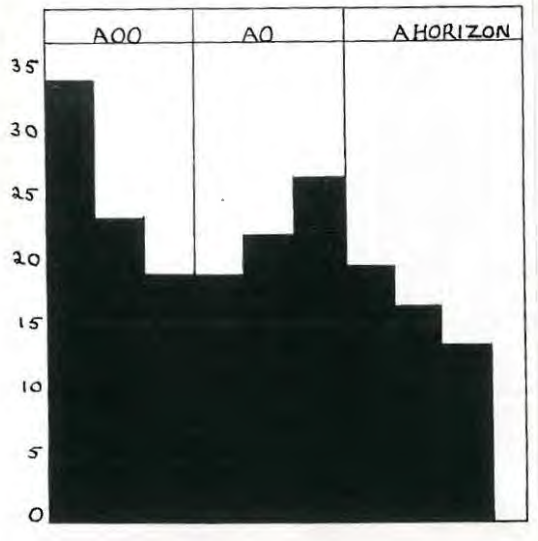

Fig.49 - Numbers of Protozoan species in the various Horizons of the Witte-els-Bosch soils.

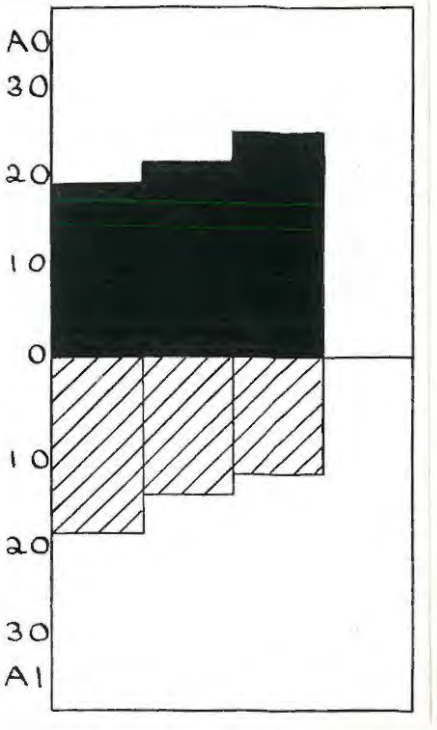

Fig.50 - Numbers of Protozoan species in the Ao and A1 Horizons of the Witte-els-Bosch soils.

Histograms read from left to right, Natural Forest, Pine, and Bluegum.

inhibit bacterial growth. The cause of the higher values is not known, but it is possible that other factors, besides bacteriological, are acting as determinants.

Figure 51 shows the qualitative microfaunal composition of the mineral soil. The differences between the values appear to be a reflection of the differences in the soil profiles. The protozoan fauna of Coastal Scrub, Mixed Pine, Trampled soil, Oak, and Sclerophyll Bush is given in Figure 52. Reference to Table 40 (Appendix) will show that the values are partly an expression of the organic content of the soil. It is interesting to note that, in spite of the low organic content (2.20%), the Trampled soil is able to support a number of Protozoa.

The soil reaction appears to have no appreciable effect on the microfaunal composition of these soils.

It is noticeable that investigators, who have devoted most attention to the distribution of the soil protozoa, avoid detailed generalisations of any kind. Thus Fellers and Allison (Loc. cit.) content themselves with a statement that " in general fertile soils are richer in Protozoa than unfertile ones ". This is probably as much as our present knowledge allows us to assert with any degree of certainty. If the relative abundance of organic matter in the soil is an expression of fertility, then the results of the present investigation are in agreement with Fellers and Allison's assertion.

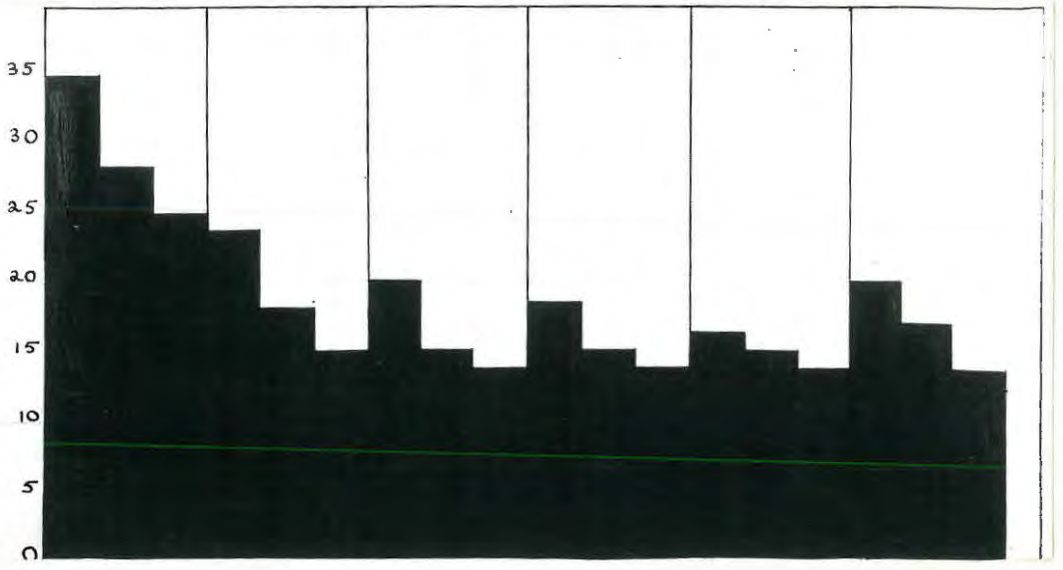

Fig.51 - Numbers of Protozoan species in the mineral soil. L.- R. A, B, C, D, E, FG Series.

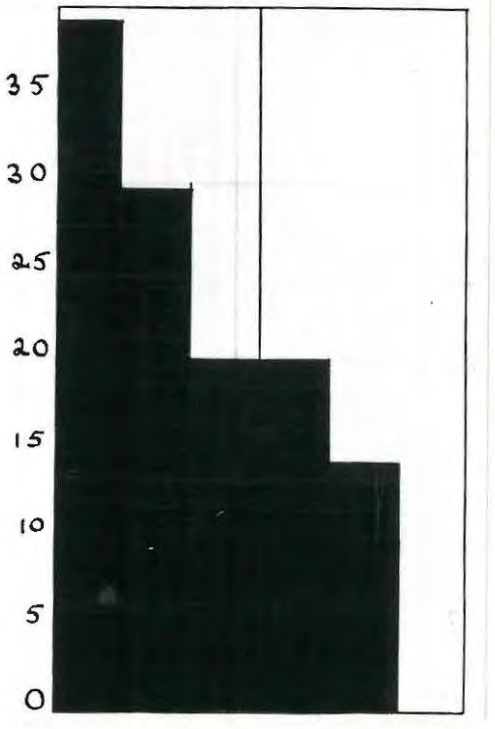

Fig.52 - Numbers of Protozoan species in the mineral soil of (L.- R.) Coastal Scrub, Mixed Pine, Trampled soil, Oak, and Sclerophyll Bush.

Histograms read from left to right, Natural Forest, Pine, and Bluegum.

CHAPTER 7.

MODIFICATION OF SOIL CONDITIONS BY THE SOIL FAUNA.

The elements of the fauna of the three soils having been considered, certain general relationships between the animal population and soil conditions will now be discussed.

The multiform composition of the soil fauna implies that the part played by it in the organic-matter cycle is very complex. Unfortunately the bionomics of the soil community is still insufficiently known, but what is known of some groups such as the earthworms and millepedes, gives some notion of the importance of these in the economy of the soil.

Müller (1887) was probably one of the first to regard the humus layers of the forest as natural biological units. He believed that the nature of the humus layer was influenced by the kind of fresh organic debris, the locality or site, and the living organisms present. Romell (1935) regarded decomposition in mor types of humus layers as primarily due to fungi, and in mull types as primarily due to bacteria and animals. The soil fauna was visualised by Romell as important in holding in check acid-producing fungi. He referred to the soil animals as " guardians against biologically produced acidity ".

The influence of the fauna on the substrate is largely

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to be attributed to processes related to locomotion and metabolism. The movements of the fauna in the mineral soil bring about mixing of the organic and inorganic material. The size of the animals largely determines the effect of their mobility, since it is only when their sizes exceed those of the interstices in the litter layer, do their movements influence the mixing process. Thus the movements of the mesofauna will be of little importance in raw humus, and those of the macrofauna will be most important in layers with the densest structure. The abundance of the smaller animals in the mor humus layers of the Pine and Bluegum stands, has already been demonstrated. The great majority of the animals in these soils were fungivorous forms. In distinction to this, the mull soils of the Natural Forest contained the greater number of macrofauna. Bornebusch (1930) has shown that the weight of animals in the poorest mor soil was only one-fifth of that in the best mull soil. The present study has shown a similar general relationship. The mor humus layers contained the larger number of animals, but the mull humus layers, the greater weight of fauna, because of the presence of earthworms and larger arthropods. The absence of a well defined humus layer in the mull soils is due to the activities of their macrofaunal population.

Influence of Locomotion.

Figure 53 shows the differences in the appearance of

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the mull and mor organic layers, and Figure 54, the differences in the appearance of the mineral soil. The poor soil structure of the humus fraction of the Pine and Bluegum soils, as shown in the latter figure, results from podzolisation. This is related to the presence of an unincorporated layer of organic material resting upon the soil surface. That the absence of this layer in the Natural Forest is due to the mixing of the organic layers within the soil body, is apparent from Figure 55. The partly decayed organic material, which is illustrated, is in greater abundance in the Natural Forest soil. There can be little doubt that the movements of the macrofauna are responsible for the incorporation of this material within the soil body.

An experiment was designed to illustrate the effects of faunal movements upon soil structure. Six cells were used, fitted with glass sides. These were filled with organic material and sand, so as to represent the organic and inorganic layers of a mor soil profile (Fig. 56). The organic material was obtained from the three forest soils, and their fauna extracted with the aid of the Berlese funnel. Two cells were used for each soil type. The Natural Forest cells were inoculated with a bulked mesofaunal extract, and the Pine and Bluegum cells with the following macrofauna:-

3. Poratophilus punctatum (Silv).
3. Sphaerotherium spinatum (Silv).
2. Microchaetus sp.

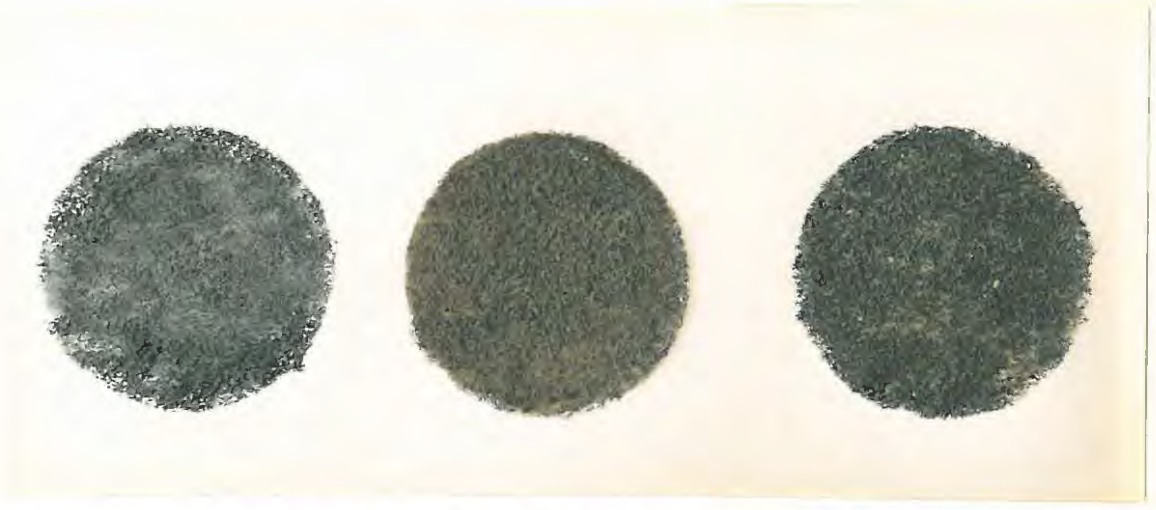

Fig.53 - Partly Decayed Fractions of the Ao Horizons of (L.- R.) Natural Forest, Pine, and Bluegum.

Humus Fractions.

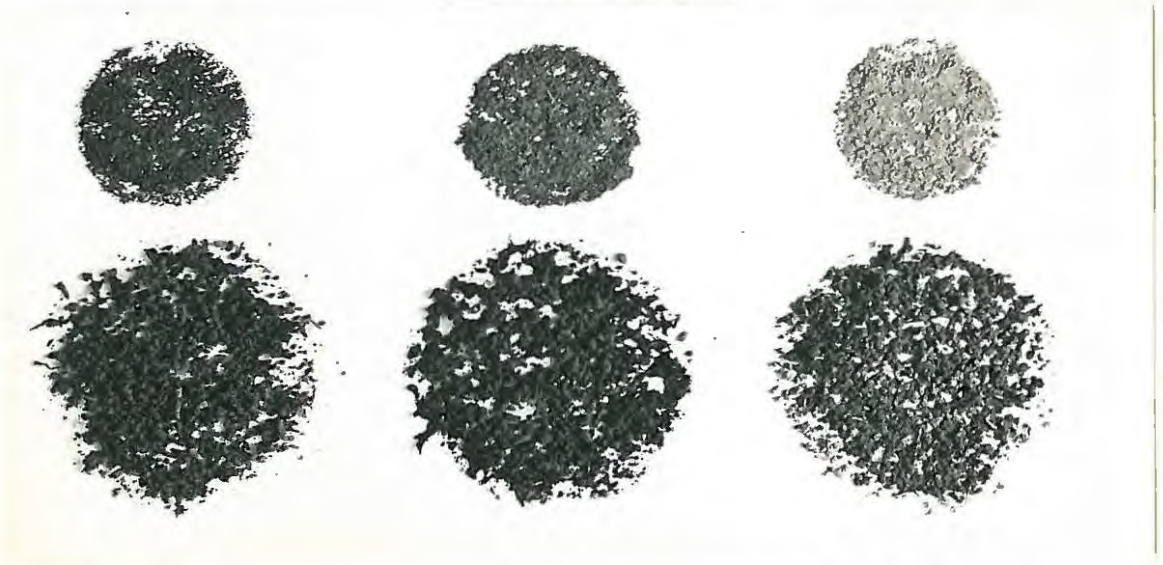

Fig.54 - The Mineral soil of (L.- R.) Natural Forest, Pine, and Bluegum. Lower series shows the Total Organic Fractions.

Fig.55 - Partly Decayed Organic Material from the Mineral soil, sampled 5 ins below the soil surface. L.- R. Natural Forest, Pine, and Bluegum.

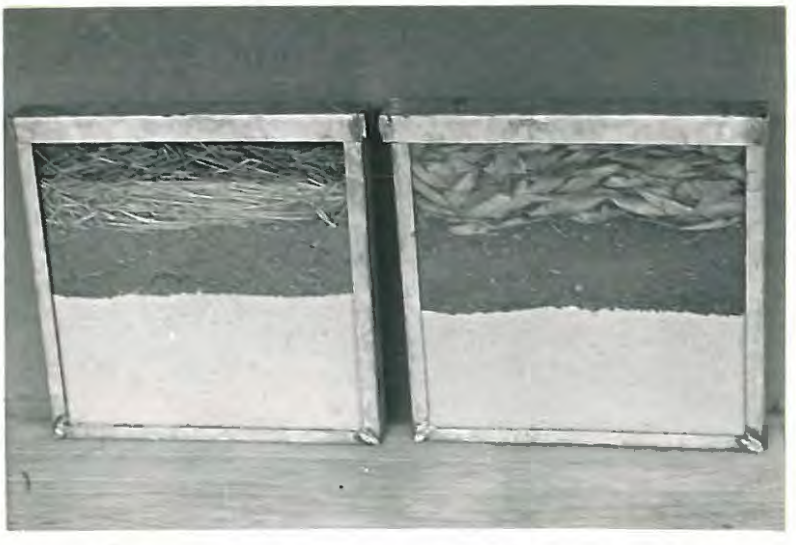

Fig.56 - Appearance of Cells before experiment, filled with sand and organic material from the Pine and Bluegum stands, so as to represent a Mor Soil Profile.

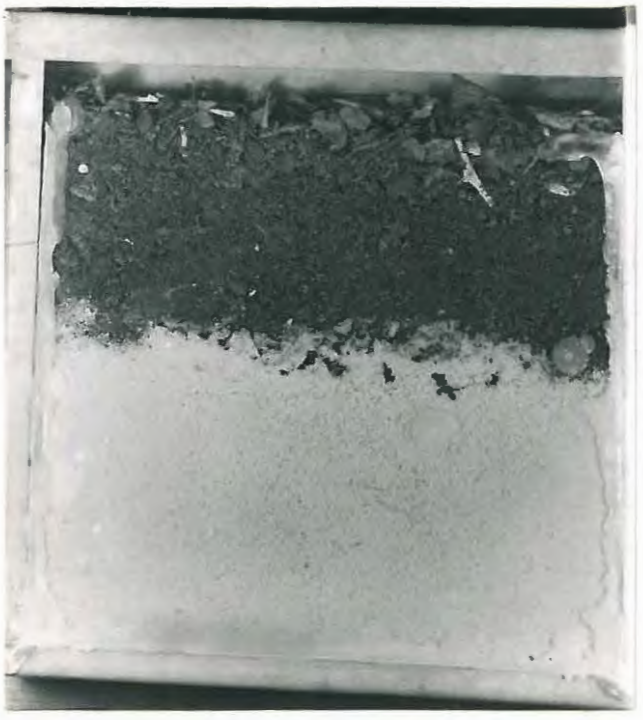

Fig.57a - Appearance of Cell before experiment, filled with organic material from the Natural Forest floor.

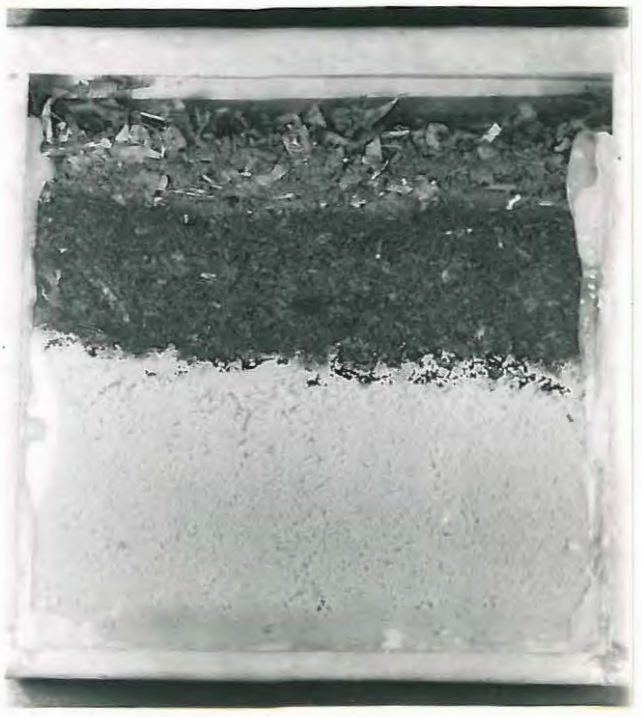

Fig.57b - Appearance of the same Cell after 2 months.

4. Scarabid Larvae.
2. Tenebrionid Larvae.

The cells were incubated at 60 degrees Fahrenheit for two months. Figures 57a,57b. 58a,58b. 59a,59b clearly show that the macrofauna,and not the mesofauna, are responsible for the mixing of the organic matter with the sand in the cells. The destruction of the litter (Aoo Horizon) is very striking, and suggests that the role of the macrofauna is important in the breakdown of such material.

Mechanical Breakdown of the Litter.

The breakdown of the litter by the macrofauna, and its incorporation within the soil body, is illustrated in the following experiment.

Four flasks were filled, without mixing, with equal quantities of ignited soil and pine needles. The following macrofauna were added to each flask:-

6. Poratophilus punctatum (Silv).
3. Sphaerotherium spinatum (Silv).
2. Scarabid Larvae.
1. Tenebrionid Larva.

The results obtained on analysing the material adhering to the bottom of the flasks, are given in Table 20. The increase in the organic content is a direct result of the breakdown of the litter, and its incorporation within the soil by the activities of the animals. Figures 60 and 61 show the macroscopic appearance of the soil before and after the

/ experiment....

Fig.58a - Pine cell after 2 months.

Fig.58b - Pine cell after 2 months

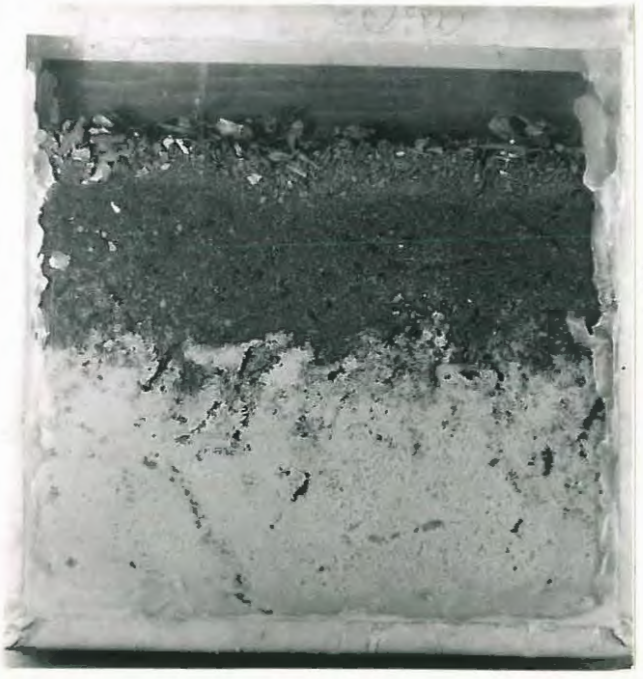

Fig.59a - Bluegum cell after 2 months.

Fig.59b - Bluegum cell after 2 months.

Fig.60 - Macroscopic appearance of ignited soil before experiment. (X 10)

Fig.61 - Macroscopic appearance of the same soil after the experiment. (X 10)

experiment. The faecal material has formed a nucleus for the aggregation of the quartz grains. The similarity in the appearance of the ignited soil and a podzolised soil is very striking (Fig. 62).

The average consumption by 5 mature and 5 immature P. punctatum of equal quantities of leaf-litter from Natural Forest, Pine, and Blue gum was found to be 74%, 11%, and 6% respectively, over a period of four days. On extracting the Natural Forest, Pine and Bluegum litters with hot water and ether, and then treating the Natural Forest litter with the Pine and Bluegum water-soluble extracts, and these with the Natural Forest water-soluble extracts, the same number of animals consumed an average of 54% of the Bluegum, 50% of the Pine, and 32% of the Natural Forest litter. This suggests that unpalatable substances are present in the Pine and Bluegum litter, which results in reduction in the litter consumption (Table 21). Since the presence of suitable food is one of the most important determinants in the environment, differences in the palatability of the litters may well be responsible for the qualitative differences in the faunal contents of the three soils. In addition, the greater variety of trees in the Natural Forest provides a wider selection of food material, which in turn favours a wider variety of animal life. Tree leaves showing the effect of feeding by members of the Hemiedaphic macrofauna are presented in Figures 63 and 64.

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TABLE 20.

Organic Matter Increase in Ignited Soil due to Admixture of Faecal Material.

	Percentages		
Months	Humus Fraction	Partly Decayed Fraction	Total Organic
1	0.20	1.73	1.93
2	4.59	22.46	27.05
3	14.99	12.17	27.16
4	15.63	11.15	27.56

TABLE 21.

Ether and Chloroform-soluble extracts from litter.

	Percentages.
Natural Forest	4.23
Pine	5.59
Bluegum	6.43

Expressed as a percentage of the dry weight of soil.

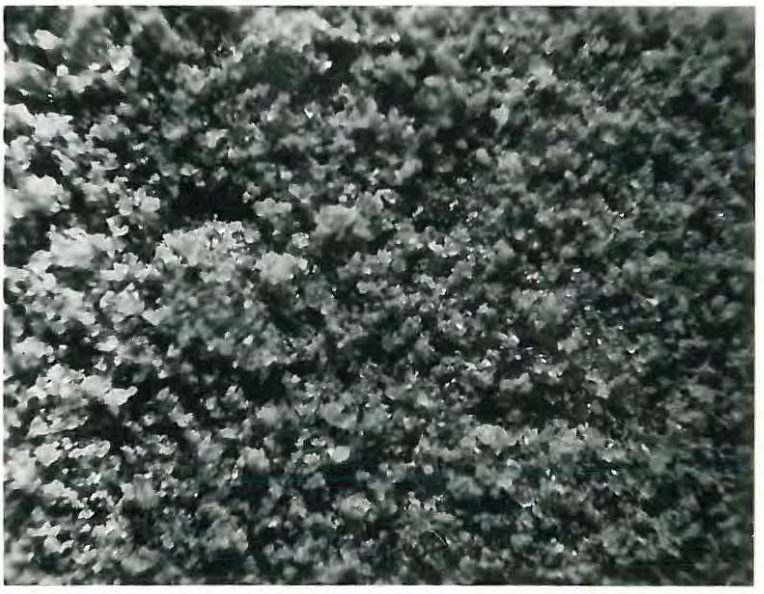

Fig.62 - Macroscopic appearance of a podzolised Pine soil.(X 10)

Fig.63 - Poplar leaves showing the effect of feeding by Poratophilus punctatum.

Cassine papillosa. P. pinaster. E. diversicolor.

Fig.64 - Forest leaves from Witte-els-Bosch, partly consumed by members of the Hemiedaphic Macrofauna.

The small quantities of food stuffs taken from ingested litter are the cause of a great amount of litter having to be consumed for the fulfilment of the food requirements. The large quantities of excreta resulting from this, are probably attacked much more easily by micro-organisms than uneaten litter. Microscopical examination of the excreta obtained from cultures of P. punctatum and S. spinatum, still clearly showed reactions of cellulose and lignin. It therefore seems probable that the degree of decomposition is not appreciably increased during passage through the intestinal tract. Mechanical breakdown of the litter is however, important in promoting decomposition by providing a larger surface area for attack by micro-organisms, but it is not necessarily followed by mull formation (Figs. 65, 66).

The abundance of millepedes and earthworms in the mull soils of Natural Forest was associated with accumulations of faecal material, and prompt incorporation of the litter within the soil (Figs. 67, 68). Similar accumulations of millepede excreta were formed under Pine at Witte-els-Bosch (Figs. 69, 70). Prompt incorporation of the litter within the mineral soil was not evident. It appears that although millepedes assume considerable importance in breaking down the litter, they are not nearly as important in mull formation as earthworms. The necessary adjunct to the formation of a mull soil is thus an

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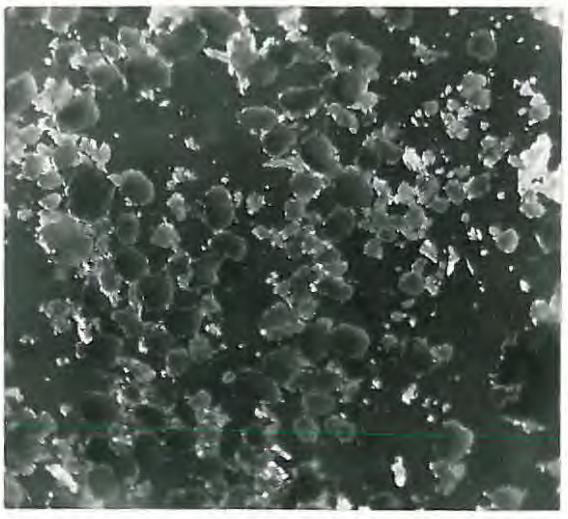

Fig.65 - Faecal material from a rotting tree-stump. (X 50)

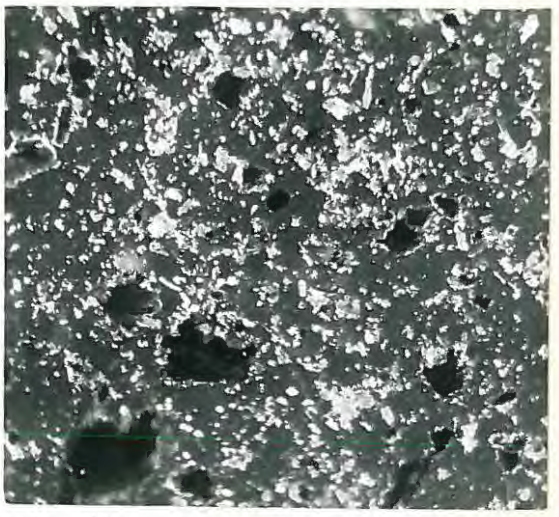

Fig.66 - Intestinal contents of Sphaerotherium rotundatum. (approx. X 100)

Fig.67 - Faecal material mixed with rotting wood from Natural Forest litter.

Fig.68 - Sphaerotherium rotundatum and food material from Natural Forest litter.

Fig.69 - Excrement of Sphaerotherium spinatum from the Ao Horizon of Pine at Witte-els-Bosch.

Fig.70 - Sphaerotherium spinatum and food material from Pine litter at Witte-els-Bosch.

abundant and active earthworm, and macroarthropod population. Burrowing geophiles (larval forms) may also assist in the mixing process, but they are of subsidary importance due to their relatively smaller size.

If organic debris builds up more rapidly than it decomposes, nutrient material is taken out of circulation. This fact has led some soil workers to designate the material of mor humus layers as, " capital which bears no interest ". Highly acid mor layers result in the leaching of nutrients from the mineral soil, and the development of undesirable biological conditions and physical properties. Whenever possible therefore, the silviculturist should give consideration to the creation and maintenance of forest conditions favourable to an active soil fauna.

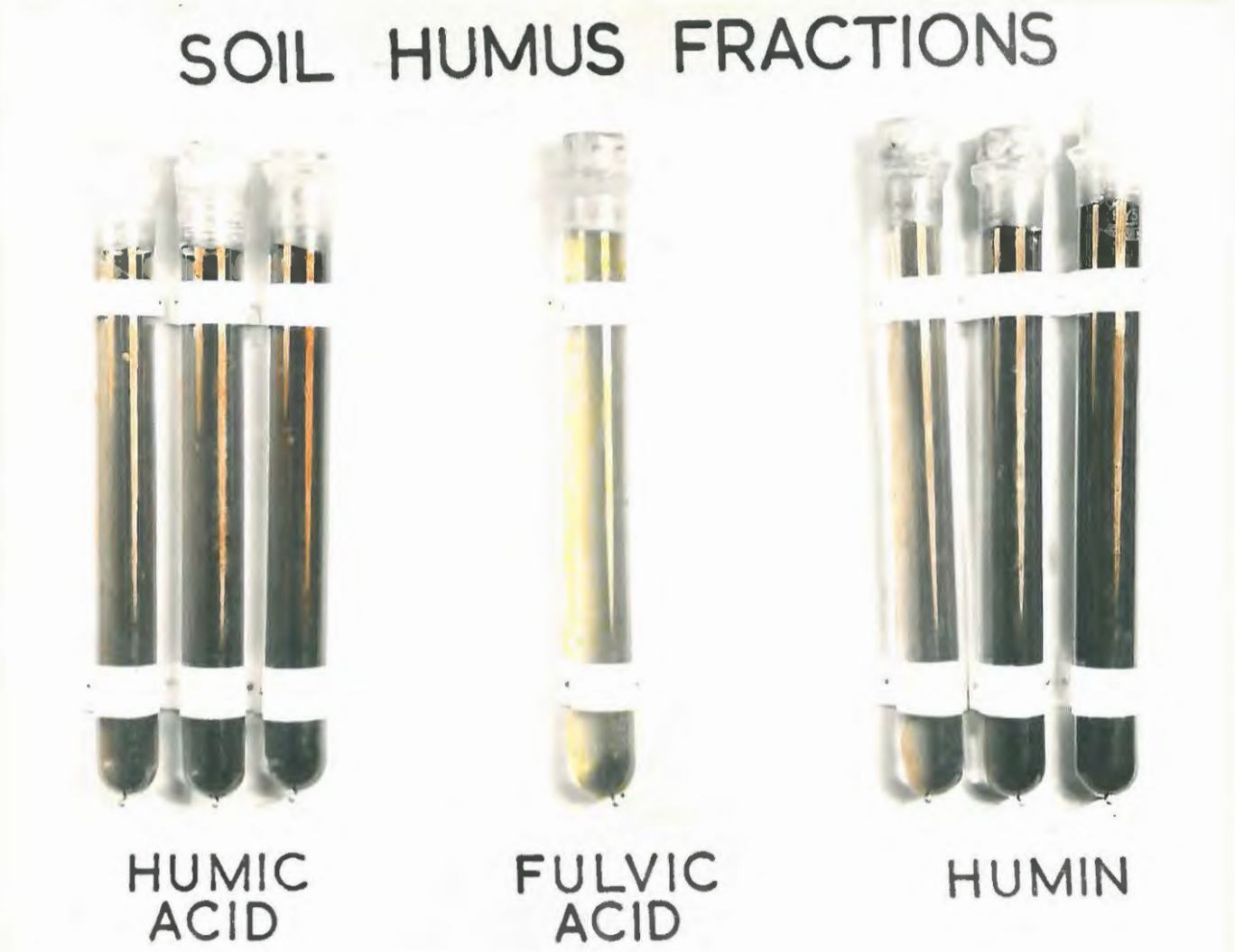

Fig.71 - Sodium Hydroxide soluble fractions of Humus. L.- R: Bluegum, Pine, and Natural Forest.

APPENDIX 1.

STATISTICAL ANALYSIS.

As an example of the two statistical methods employed, the numbers of macro- and mesofauna have been taken.

The faunal contents of the three soils to be compared may be denoted as aA(1-6), aB(1-6), aC(1-6), where the subscripts A and B refer to the soil types, and 1-6 to locality. In the first method, one comparison was made, in the second, two comparisons were made.

Considering the first method. There are two soil types sampled six times, hence the degrees of freedom (N) number 11 in all. These are subdivisible into three groups:-

(a) One for comparison between soil types (varieties).

(b) 5 for differences between localities.

(c) 5 for variation of the varietal differences in the 6 localities.

The comparison of the faunal contents of two soil types will be:-

$(aA_1 + aA_2 + aA_3 \ldots\ldots aA_6) - (aB_1 + aB_2 + aB_3 \ldots\ldots)$.

$S(K^2)=12$, where K equals the coefficient by which the a values are multiplied to give the comparisons used. The sum of its square gives the total number of observations, viz. 12.

Putting $aA_1 + aA_2 + aA_3 \ldots\ldots aA_6 = aA$

/ and....

and $aB_1 + aB_2 + aB_3 \ldots\ldots aB_6 = aB$. Then the sum of squares (S.S.) for

$$\frac{1}{12}(aA - aB)^2 = \frac{1}{12}(aA^2 - 2a_A a_B + aB^2) = \frac{1}{12}(2aA^2 + 2aB^2) -$$

$$(aA + aB)^2 = \frac{1}{6}(a^2A^2 + aB^2) - \frac{1}{12}(aA + aB)^2.$$

The latter term is the correction term, which is deducted. The correction term, $\frac{1}{n} S^2(a)$, is employed as a correction for the use of $\underline{0}$ as a working mean. In the present case, there are 12 observations, hence n = 12. This agrees with the general rule about divisors, viz. that any square is divided by the number of observations, which have been summed to give the item squared.

The former term consists of the S.S. of the 2 varietal totals, divided by the number of samples on which each total is based.

The S.S. for locality is found from the summed values of the faunal contents for each locality. These numbers are squared and their squares summed. Each is based on the contents of 2 soils, so the S.S. will be divided by 2. The correction term is the same as that used in the calculation of the faunal contents. Hence,

$$\frac{1}{2}(aA_1 + aB_1)^2 + (aA_2 + aB_2)^2 + (aA_3 + aB_3)^2 + (aA_4 +$$

$$aB_4)^2 + (aA_5 + aB_5)^2 + (aA_6 + aB_6)^2 - \frac{1}{12}(a_A - a_B)^2.$$

/ gives....

gives the locality S.S.

The calculation of the S.S. due to the type-locality interaction is about the same as that for locality, but the difference between the faunal contents of the two soils is used instead of their sums. Hence,

$\frac{1}{2}(aA_1 - aB_1)^2 + (aA_2 - aB_2)^2 + (aA_3 - aB_3)^2 + (aA_4 - aB_4)^2 + (aA_5 - aB_5)^2 + (aA_6 - aB_6)^2 - \frac{1}{12}(aA_1 - aB_1 + aA_2 - aB_2 + aA_3 - aB_3 + aA_4 - aB_4 + aA_5 - aB_5 + aA_6 - aB_6)^2$ gives the type-place interaction.

The Table of Analysis of the Variance Ratio gives the S.S. in the second column, and the number of degrees of freedom in the third column. The ratio of the S.S. to its corresponding number of degrees of freedom, gives the mean square as shown in the fourth column.

As the interest lies in the varietal difference, whose mean square is based upon one comparison, a " t " Test is suitable for the purpose.

$$t = \frac{\text{S.S./N (Soil Type)}}{\text{S.S./N (Interaction}} =$$

t_1 = Ratio

where the denominator of t is found by taking the square root of the error mean square.

In the second method, where three sets of data are

/ compared....

compared, the degrees of freedom for type and locality are found in the same manner as when two sets of data are compared. The degrees of freedom appertaining to any interaction may be however, determined by multiplying together the degrees of freedom allocated to the type and locality positions.

The varietal S.S. is found by summation over locality. The term correcting for the use of $\underline{0}$ as a working mean, is found as before, by dividing the square of the grand total by the total number of observations, viz. 18.

$$\frac{1}{6}(aA_{1-6})^2 + (aB_{1-6})^2 + (aC_{1-6})^2 - \frac{1}{18}(aA_{1-6} + aB_{1-6} + aC_{1-6})^2.$$

The locality S.S. is obtained by summation over types. Each total comprises 3 values, hence the divisor of the squared values will be 3. The correction term is as before.

$$\frac{1}{3}(aA_1 + aB_1 + aC_1)^2 + (aA_2 + aB_2 + aC_2)^2 + (aA_3 + aB_3 + aC_3)^2 + (aA_4 + aB_4 + aC_4)^2 + (aA_5 + aB_5 + aC_5)^2 + (aA_6 + aB_6 + aC_6)^2 - \frac{1}{18}(aA_{1-6} + aB_{1-6} + aC_{1-6})^2.$$

The first order interactions between varietes, or types, and localities, is found by summing over localities and types.

Since each value for the faunal content of any one soil is composed of only one observation, the divisor will be 1.

/ The....

The correction term is as before.

$$(aA_1^2 + aA_2^2 + aA_3^2 \ldots\ldots aA_6^2) + (aB_1^2 + aB_2^2 + aB_3^2 \ldots aB_6^2) + (aC_1^2 + aC_2^2 + aC_3^2 \ldots\ldots aC_6^2) - \frac{1}{18}(aA_{1-6} + aB_{1-6} + aC_{1-6})^2 .$$

This includes the type and locality main effects as well as their interactions. Deducting the main effect sums of squares as already found, the type-locality interaction is found.

Since the interest lies in the varietal difference, whose mean square is based upon two comparisons, the " t " Test is not applicable, but the significance of the data is tested by means of the " Z " or variance ratio.

The probability value " P ", involving the question of significance, frequently causes confusion. The level of probability, which is considered to indicate a significant departure from the normal, is really the level of admissible error, since the rejection of a hypothesis, when it shows the data to have a probability of one in n times, means that it will be wrongly rejected once in n times. According to Mather (1946, p.21), a probability of 0.05 indicates a suspiciously large departure from expectation, and 0.01 shows a real discrepancy between the data and expectation. He goes on to say, " that these are not however rules and the decision must always be dependant to some extent on the circumstances of the case ".

TABLE 22.

Numbers of Macro- and Mesofauna.

Locality	Natural Forest	Pine	Differences	Type Sums
A	181	51	130	232
B	46	60	-14	106
C (1-3)	112	70	42	182
C (4-6)	130	96	34	226
D	150	19	131	169
FG	332	180	152	512
Total.	951	476	475	1427

Analysis of Variance of Macro- and Mesofauna.

	S.S.	N.	SS/N.	t_5.	P.
Type -	18802	1	18802	2.88	0.05-0.02
Locality	50288	5	10058		
Type-Locality Interaction	11338	5	2268		

TABLE 23.

Numbers of Macro- and Mesofauna.

Locality	Natural Forest	Bluegum	Differences	Type Sums
A	181	57	124	238
B	46	47	-1	93
C (1-3)	112	24	88	136
C (4-6)	130	91	39	221
D	150	68	82	218
FG	332	124	208	456
Total.	951	411	540	1362

Analysis of Variance of Macro- and Mesofauna.

	S.S.	N.	SS/N.	t_5.	P.
Type	24300	1	24300	3.05	0.05-0.02
Locality	39458	5	78916		
Type-Locality Interaction	13015	5	2603		

TABLE 24.

Numbers of Microfaunal Species.

Locality	Natural Forest	Pine	Differences	Type Sums
A	35	29	6	64
B	23	18	5	41
C	19	15	4	34
D	16	14	2	30
FG	20	17	3	37
Total	113	93	20	206

Analysis of Variance of Microfaunal Species.

	S.S.	N.	SS/N.	t_4	P.
Type	40	1	40	5.66	0.01-0.001
Locality	357.4	4	89.35		
Type-Locality Interaction	5.0	4	1.25		

TABLE 25.

Numbers of Microfaunal Species.

Locality	Natural Forest	Bluegum	Differences	Type Sums
A	35	25	10	60
B	23	15	8	38
C	19	13	6	32
D	16	13	3	29
FG	20	13	7	33
Total.	113	79	34	194

Analysis of Variance of Microfaunal Species.

	S.S.	N.	SS/N.	t_4.	P.
Type	115.6	1	115.6	5.87	0.01-0.001
Locality	312.6	4	78.15		
Type-Locality Interaction	13.4	4	3.35		

TABLE 26.

Percentage of Soil Organic Content.

Locality	Natural Forest	Pine	Differences	Type Sums
B	17.23	14.75	2.48	31.98
C (1-3)	23.73	11.19	12.54	34.92
C (4-6)	18.95	15.0	3.95	33.95
D	19.7	8.17	11.53	27.87
FG	26.6	19.36	7.24	45.96
Total.	106.21	68.47	37.74	174.68

Analysis of Variance of Soil Organic Content.

	S.S.	N.	SS/N.	t_4.	P.
Type	142.43	1	142.43	3.78	0.02-0.01
Locality	90.58	4	22.65		
Type-Locality Interaction	39.75	4	9.94		

TABLE 27.

Percentage of Soil Organic Content.

Locality	Natural Forest	Bluegum	Differences	Type Sums
B	17.23	9.60	7.63	26.83
C (1-3)	23.73	11.83	11.90	35.56
C (4-6)	18.95	12.29	6.66	31.24
D	19.7	9.73	9.97	29.43
FG	26.6	9.29	17.31	35.89
Total.	106.21	52.74	53.47	158.95

Analysis of Variance of Soil Organic Content.

	S.S.	N.	SS/N.	t_4.	P.
Type	285.9	1	285.9	5.66	0.01-0.001
Locality	30.75	4	7.687		
Type-Locality Interaction	35.71	4	8.927		

TABLE 28.

Percentage of Partly Decayed and Humus Organic Fraction.

Locality	Natural Forest	Pine	Differences	Type Sums
A	13.72	4.84	8.88	18.56
B	15.37	13.86	1.51	29.23
C (1-3)	19.44	10.5	8.94	29.94
C (4-6)	13.54	12.23	1.31	25.77
D	16.9	8.17	8.87	25.07
FG	24.71	17.35	7.36	42.06
Total.	103.68	66.95	36.87	170.63

Analysis of Variance of Partly Decayed and Humus Fraction.

	S.S.	N.	SS/N.	t_5.	P.
Type	112.42	1	112.42	4.034	0.01-0.001
Locality	152.24	5	30.45		
Type-Locality Interaction	34.53	5	6.91		

TABLE 29.

Percentage of Partly Decayed and Humus Organic Fraction.

Locality	Natural Forest	Bluegum	Differences	Type Sums
A	13.72	4.50	9.22	18.22
B	15.37	8.68	6.69	24.05
C (1-3)	19.44	9.97	9.47	29.41
C (4-6)	13.54	10.43	3.11	23.97
D	16.9	6.03	10.93	22.93
FG	24.71	7.52	17.19	32.23
Total.	103.68	47.13	56.61	150.81

Analysis of Variance of Partly Decayed and Humus Fraction.

	S.S.	N.	SS/N.	t_5.	P.
Type	266.5	1	266.5	4.822	0.01-0.001
Locality	61.92	5	12.38		
Type-Locality Interaction	54.98	5	11.0		

TABLE 30.

Percentage of Soil Moisture.

Locality	Natural Forest	Pine	Differences	Type Sums
A	15.02	13.26	1.76	28.28
B	13.59	18.31	-5.28	31.90
C (1-3)	44.03	16.23	27.80	60.26
C (4-6)	25.12	18.79	6.33	43.91
D	41.23	22.06	29.17	63.29
E	35.02	20.14	14.88	55.16
FG	32.21	25.50	6.71	57.71
Total.	206.22	134.29	81.37	340.51

Analysis of Variance of Soil Moisture.

	S.S.	N.	SS/N.	t_6.	P.
Type	369.57	1	369.57	2.09	0.1-0.05
Locality	595.78	6	99.30		
Type-Locality Interaction	507.68	6	84.61		

TABLE 31.

Percentage of Soil Moisture.

Locality	Natural Forest	Bluegum	Differences	Type Sums
A	15.02	10.08	4.94	25.10
B	13.59	14.36	-0.77	27.95
C (1-3)	44.03	14.26	29.77	58.29
C (4-6)	25.12	17.10	8.02	42.22
D	41.23	14.33	26.90	55.56
E	35.02	15.63	19.39	50.65
FG	32.21	16.28	15.93	48.49
Total.	206.22	102.04	104.18	308.26

Analysis of Variance of Soil Moisture.

	S.S.	N.	SS/N.	t_6.	P.
Type	775.25	1	775.25	3.357	0.02-0.01
Locality	510.10	6	85.02		
Type-Locality Interaction	389.2	6	64.87		

TABLE 32.

Numbers of Macro- and Mesofauna.

Locality	Natural Forest	Pine	Bluegum	Type Sums
A	181	51	57	289
B	46	60	47	153
C (1-3)	112	70	24	206
C (4-6)	130	96	91	317
D	150	19	68	237
FG	332	180	124	636
Total.	951	476	411	1838

Analysis of Variance of Macro- and Mesofauna.

	S.S.	N.	SS/N.	Variance Ratio	P.
Types	28969.5	2	14484.75	7.769	0.01-0.001
Localities	49144.1	5	9828.82		
Types-Localities, First Order Interaction	18644.2	10	1864.42		

TABLE 33.

Numbers of Microfaunal Species.

Locality	Natural Forest	Pine	Bluegum	Type Sums
A	35	29	25	89
B	23	18	15	56
C	19	15	13	47
D	16	14	13	43
FG	20	17	13	50
Total.	113	93	79	285

Analysis of Variance of Microfaunal Species.

	S.S.	N.	SS/N	Variance Ratio	P.
Types	117	2	58.5	33.43	0.001
Localities	457	4	114.25		
Types- Localities First Order Interaction	14	8	1.75		

TABLE 34.

Percentage of Soil Organic Content.

Locality	Natural Forest	Pine	Bluegum	Type Sums
B	17.23	14.75	9.60	41.58
C (1-3)	23.73	11.19	11.83	46.75
C (4-6)	18.95	15.00	12.29	46.24
D	19.70	8.17	9.73	37.60
FG	26.60	19.36	9.29	55.25
Total.	106.21	68.47	52.74	227.42

Analysis of Variance of Soil Organic Content.

	S.S.	N.	SS/N.	Variance Ratio,	P.
Types	302.05	2	151.27	15.16	0.001
Localities	58.32	4	14.58		
Types-Localities First Order Interactions	79.85	8	9.98		

TABLE 35.

Percentage of Partly Decayed and Humus Organic Fraction.

Locality	Natural Forest	Pine	Bluegum	Type Sums
A	13.72	4.84	4.50	23.06
B	15.37	13.86	8.68	37.91
C (1-3)	19.44	10.50	9.97	39.91
C (4-6)	13.54	12.23	10.43	36.20
D	16.90	8.17	6.03	31.10
FG	24.71	17.35	7.52	49.58
Total.	103.68	66.95	47.13	217.76

Analysis of Variance of Partly Decayed and Humus Fraction.

	S.S.	N.	SS/N.	Variance Ratio	P.
Types	274.44	2	137.22	16.85	0.001
Localities	131.45	5	26.29		
Types-Localities First Order Interactions	81.42	10	8.142		

TABLE.36.

Percentage of Soil Moisture.

Locality	Natural Forest	Pine	Bluegum	Type Sums
A	15.02	13.26	10.08	38.36
B	13.59	18.21	14.36	46.26
C (1-3)	44.03	16.23	14.26	74.52
C (4-6)	25.12	18.79	17.10	61.01
D	41.23	22.06	14.33	77.62
E	35.02	20.14	15.63	70.82
FG	32.21	25.50	16.28	73.99
Total.	206.22	134.29	102.04	442.58

Analysis of Variance of Soil Moisture.

	S.S.	N.	SS/N.	Variance Ratio	P.
Types	811.48	2	405.74	9.436	0.01-0.001
Localities	473.11	6	78.85		
Types-Localities First Order Interactions	516.04	12	43.00		

APPENDIX 2.

TABLE 37.

Summary of Methods of Investigation employed by some Authors.

Author	Size of each unit	No. of Units	Method	Frequency	Type of soil
Cameron (1913)	12-20 ins deep	-	Sifted	-	Grass
Morris (1920)	10X10 ins X2ft	-	Hand	29 samples	Pasture
(1927)	9X9X9 ins	5-7	Washing	-	Arable Land
Thompson (1924)	"	1	Sifted & Washed	1/14days	-
Dammerman (1925)	Sq. metre	-	Sifted	-	Tropical soil
Grimmett (1926)	9X9X9 ins	10	-	1/month	Forest
Bornebusch (1930)	$\frac{1}{10}$ metre sq.	-	Tullgren's apparatus	-	Forest
Ford (1935)	3X3X9 ins	-	Flotation	-	Meadow
Jacot (1936)	6X6X1 ins	1	Berlese funnel	1/site	Various
Fleming & Baker (1936)	1 sq. ft	25	-	-	Corn plot & Grass
Heyward & Tissot (1936)	$\frac{1}{4}$ sq.ftX2 ins	80 Total	Berlese funnel	1	Pine
Jones (1937)	1 sq. ft	50	Soil Sifter	Annual	Field
Frenzel (1936)	25cm.sq. 10cm.sq.	-	Berlese funnel	-	Meadow
Ghilarov (1937)	50X50X40 cms	18-40	-	-	-

/ Baweja....

TABLE 37 (Contd).

Summary of Methods of Investigation employed by some Authors.

Author	Size of each unit	No. of Units	Method	Frequency	Type of Soil
Baweja (1939)	3X4X9 ins	1	Ladell's apparatus	2/week	Grass
Glasgow (1939)	3 ins diam X13½ ins	9	"	1-2/month	Grass
Williams (1941)	1 sq. metre	11	Hand and Berlese f.	-	Panama Rain Forest
Yates & Finney (1942)	6X6X9 ins	20	-	-	Grass
Eaton & Chandler (1942)	2 sq. ft X1 inch deep	3	Berlese Funnel	4/month	Forest Humus
Salt & Hollick (1944)	1 sq. yd, 1 sq. ft, 4 ins diam	16, 20	Flotation	1-2/month	Fields
Dowdy (1944)	1 cubic ft	-	Hand	3/month	Grass
Strickland (1945)	3.6 diam X 9 ins	5	Flotation	Twice	Forest & Cocoa Res.
Cockbill, etc. (1945)	4 ins diam X 6 ins	-	"	-	Fields
Jones (1945)	2 ins diam X 8 ins	50	"	2/field	"
Haarlov (1947)	0.001 sq.m. X 6-7 cms	-	Tullgrens apparatus	-	-
V.d. Drift (1951)	40 cubic cms, 4 cubic dms	-	"	-	Beech Forest

TABLE 38.

Extraction from Berlese Funnel.

Hours	Extraction	Hours	Extraction
1	4	17	9
2	1	18	7
3	2	19	12
4	1	20	15
5	2	21	11
6	3	22	12
7	4	23	11
8	3	24	10
9	5	25	1
10	8	26	3
11	6	27	2
12	3	28	1
13	5	29	0
14	6	30	0
15	8	31	0
16	6	32	0

TABLE 39.

C/N Ratios.

Ao Horizon.

	Percentages			
	Organic Carbon	Total Organic	Nitrogen	C/N Ratio
Natural Forest	18.33	31.60	0.36	50.9:1
Pine	45.47	78.40	0.28	162.4:1
Bluegum	46.56	80.32	0.28	166.3:1

	Organic Carbon	P.Decayed Fraction	Nitrogen	C/N Ratio
Natural Forest	17.40	30.00	0.34	51.1:1
Pine	34.57	59.62	0.24	144.1:1
Bluegum	30.65	52.84	0.24	127.1:1

Organic determined by ignition. Expressed as a percentage of the dry weight of organic material.

A Horizon.

	Organic Carbon	P.Decayed Fraction	Nitrogen	C/N Ratio
Natural Forest	9.80	16.90	0.34	22.9:1
Pine	4.74	8.17	0.12	39.4:1
Bluegum	3.50	6.03	0.10	35.0:1

	Organic Carbon	Humus	Nitrogen	C/N Ratio
Natural Forest	8.00	13.79	0.22	36.7:1
Pine	3.80	6.55	0.077	49.3:1
Bluegum	2.60	4.48	0.068	38.2:1

Walkley and Blacks Values for Organic Carbon. Expressed as a percentage of the dry weight of soil.

TABLE 40.

Soil Analysis.

Ao Horizon.

D.Series	Nos. of Fauna	Percentages Moisture	Total Organic	pH
Natural Forest	70	41.68	31.60	5.8
Pine	145	57.27	78.40	5.3
Bluegum	730	62.26	80.32	5.2

E.Series	Nos. of Fauna	Moisture	P.Decayed Fraction	pH
Natural Forest	126	40.85	30.00	5.8
Pine	470	46.27	59.62	5.3
Bluegum	738	49.80	52.84	5.2

Cores.

A.Series	Nos. of Fauna	Moisture	Mineral	P.Decayed & Humus Fraction	pH
Natural Forest	181	15.02	0.13	13.72	6.4
Pine	51	13.26	0.11	4.84	5.4
Bluegum	57	11.06	0.10	4.50	5.0

B.Series	Nos. of Fauna	Moisture	Mineral	P.Decayed & Humus Fraction	Undecayed F.tion	Total Organic	pH
Natural Forest	46	13.59	0.34	15.37	1.86	17.23	6.2
Pine	60	18.31	0.33	13.86	0.89	14.72	5.6
Bluegum	47	14.36	0.31	8.68	0.92	9.60	5.8

TABLE 40 (Contd.)

C.Series	Nos. of Fauna	Moisture	Mineral	P.Decayed & Humus Fraction	Undecayed F.tion	Total Organic	pH
Natural Forest (C1-3)	112	44.03	0.45	19.44	4.29	23.73	5.0
(C4-6)	130	25.12	0.47	13.54	5.41	18.95	5.0
Pine (C1-3)	70	16.23	0.43	10.50	0.69	11.19	4.8
(C4-6)	96	18.79	0.40	12.23	0.77	15.00	4.8
Bluegum (C1-3)	24	14.26	0.43	9.97	1.86	11.83	4.4
(C4-6)	91	17.10	0.42	10.43	1.86	12.29	4.8
D.Series							
Natural Forest	150	41.23	0.43	22.20	2.80	25.00	5.0
Pine	19	22.06	0.75	8.71	-	8.71	4.8
Bluegum	68	14.33	0.75	6.03	-	6.03	4.8
FG.Series							
Natural Forest	332	32.21	0.44	24.71	1.95	26.66	5.0
Pine	180	25.50	0.41	17.35	2.01	19.36	4.8
Bluegum	124	16.28	0.42	7.52	1.77	9.29	4.6
B.Series							
Oak	213	27.48	0.36	16.00	-	16.0	6.8
Sclerophyll Bush	52	15.41	0.33	13.30	1.62	14.92	6.6

A.Series	Nos. of Fauna	Moisture	Mineral	P.Decayed & Humus Fraction	pH
Coastal Scrub	194	12.78	0.19	13.51	7.4
Mixed Pine	34	11.05	0.10	4.64	6.8
Trampled Soil	10	3.82	0.02	2.20	7.0

TABLE 40 (Contd).

(Mineral Soil)

E.Series.	Nos. of Fauna	Moisture	Humus Fraction	pH
Natural Forest	146	35.02	13.79	5.0
Pine	12	20.14	6.55	4.8
Bluegum	30	15.63	4.88	4.8

Analysis on Cores at ± 4.5 inches depth.
Expressed as a percentage of the dry weight of soil.

APPENDIX 3.

TABLE 41.

Collembola.

Ao Horizon.

Series	Poduromorpha	Entomobryidae	Total
Natural Forest			
D	6	1	7
E	27	1	28
Pine			
D	17	-	17
E	56	5	61
Bluegum			
D	117	19	136
E	88	42	130

Cores.

Natural Forest			
A	40		40
B	7	2	9
C(1-3)	38	6	44
C(4-6)	46	12	58
D	74	9	83
FG	131	19	150
Pine			
A	42	1	43
B	36	11	47
C(1-3)	16	4	20
C(4-6)	54	1	55
D	2	-	2
FG	103	6	109
Bluegum			
A	5	-	5
B	11		11
C(1-3)	5		5
C(4-6)	25	6	31
D	33	13	46
FG	86	2	88

TABLE 42.

Acarida.

Ao Horizon.

	Oribatids	Trombidi formes	Parasiti formes	Nymphs, etc	Total
Natural Forest					
D	27	4	3	19	53
E	48	4	6	18	76
Pine					
D	41	5	11	62	119
E	110	13	40	231	394
Bluegum					
D	237	13	66	272	588
E	145	25	51	359	580

Cores.

Natural Forest					
A	26	1	-	21	48
B	12	1	6	5	24
C(1-3)	29	-	3	25	57
C(4-6)	14	-	6	47	67
D	6	-	6	47	59
FG	59	3	12	45	119
Pine					
A	2	1	-	-	3
B	3	-	2	4	9
C(1-3)	6	-	3	37	46
C(4-6)	6	-	10	22	38
D	7	-	1	9	17
FG	1	-	2	67	70
Bluegum					
A	6	1	2	38	47
B	16	6	1	8	31
C(1-3)	7	3	2	6	18
C(4-6)	-	-	8	52	60
D	8	-	4	10	22
FG	2	1	1	27	31

TABLE 43.

Qualitative Composition of Samples.

Aoo Horizon

	Numbers of Groups, etc.			
	Natural Forest	Oak	Pine	Blue gum
Witte-els-Bosch	42	-	15	12
Amatola	37	13	11	-
Ao Horizon				
E Series	16	-	14	14
Cores				
A Series	16	-	19	9
B Series	16	-	8	10
C Series (1-3)	15	-	8	7
C Series (4-6)	9	-	11	5
D Series	12	-	4	6
FG Series	28	-	6	11

TABLE 44.

Qualitative Composition of Samples (Microfauna).

Soil Extract Agars.
Inoculum Dil. 1:10.

Witte-els-Bosch	Nos. of Species
Aoo Horizon	
Natural Forest	34
Pine	23
Bluegum	20
Ao Horizon	
Natural Forest	19
Pine	22
Bluegum	26
A Horizon	
Natural Forest	20
Pine	15
Bluegum	13
A Horizon	
A. Series	
Natural Forest	35
Pine	27
Bluegum	25
B. Series	
Natural Forest	24
Pine	18
Bluegum	15
C. Series	
Natural Forest	20
Pine	15
Bluegum	13
D. Series	
Natural Forest	19
Pine	15
Bluegum	13

TABLE 44 (Contd).

	Nos. of Species
E. Series	
Natural Forest	16
Pine	15
Bluegum	13
FG. Series	
Natural Forest	20
Pine	17
Bluegum	13
Coastal Scrub	38
Mixed Pine	29
Trampled Soil	20
Oak	20
Sclerophyll Bush	14

APPENDIX 4.

LABORATORY TECHNIQUE.

Preparation and Separation of the Soil Organic Fractions.

Preliminary Treatment.

Ao Horizon. The sample was thoroughly mixed, quartered, and all living organic matter removed. A portion was set aside for analysis.

A Horizon. The sample was thoroughly mixed, quartered, and all living and dead gross organic matter removed with the aid of a 20 mesh sieve. Lumpy material was broken up by pounding, care being taken not to crush small stones. From the sieved material, a portion was set aside for pH determinations. The remaining material was stored in clean and stoppered containers, and set aside for analysis.

All samples were oven-dried at 105°C to constant weight.

Organic Content.

Ao Horizon. (1) Total Organic Fraction. The sample was passed through a 50 mesh sieve with pounding. The analysis on the sieved material was taken as the Total Organic Fraction.

(2) Partly Decayed Organic Fraction. The sample was passed through a 225 mesh sieve with pounding. The analysis on the sieved material was taken as

/ the....

the Partly Decayed Organic Fraction.

A Horizon. (1) Total Organic Fraction. The analysis was carried out on soil which was given the preliminary treatment only.

(2) Undecayed Organic Fraction. The sample was divided into two equal portions. One portion was passed through a 50 mesh sieve without pounding, the other portion was not sieved. The analysis was carried out on the sieved and unsieved portions, and the difference was taken as the Undecayed Organic Fraction.

(3) Partly Decayed and Humus Fraction. The sample was passed through a 50 mesh sieve without pounding. The analysis on the sieved material was taken as the Partly Decayed and Humus Fraction.

(4) Humus Fraction. The sample was passed through a 225 mesh sieve without pounding. The analysis on the sieved material was taken as the Humus Fraction.

Preparation for the estimation of Nitrogen.

The separation and preparation of the soil organic fractions were carried out in a similar manner to that already described. The samples were air-dried.

Preparation for the estimation of Organic Carbon.

The separation of the soil organic fractions was carried out in a similar manner to that already described. The soil

/ was....

was passed through a 225 mesh sieve before analysis and air-dried.

Sieves.

25/sq. cm.
50/sq. cm.
225/sq cm.

Determination of Moisture Content.

As soon as possible after sampling, 20 grms of soil, previously transported in stoppered tubes, were dried in an electric oven at 105°C to constant weight. The loss in weight was calculated as a percentage of the oven-dried soil.

Determination of the Volume Weight Ratio.

A known volume of soil was transported to the laboratory in a weighing-bottle with as little handling as possible, dried in an electric oven at 105°C, and weighed. The ratio was calculated on the basis of the weight of oven-dried soil.

Determination of Capillary Water.

Air-dried soil was passed through the 225 mesh sieve and placed in a container with a perforated bottom. The container was placed in a vessel of water. When the soil was saturated, the required quantity was weighed, and then oven-dried. The water retained was expressed as a percentage of the oven-dried soil.

Determination of pH.

The H.ion status was determined with the B.D.H. Capillator. The following technique was adopted.

A micropipette was filled to a given mark with the appropriate indicator solution, and transferred to a watch-glass. The pipette was refilled with the soil solution to be tested, and mixed with the indicator solution on the watch-glass.. Both solutions were then drawn up the pipette, and matched against the standard tubes of the same indicator. A compensation cell was used to determine the pH of dark coloured solutions. The soil-water ratio used was 1:2.

Determination of Nitrogen.

The Kjeldahl method was adopted, using 10 grms of air-dried soil. The digestion was carried out according to the methods of the Association of Official Agricultural Chemists, using the Gunning-Hibbard mixture.

On the completion of the digestion, the flasks were cooled, diluted, corked, and allowed to stand overnight. The contents were decanted and then transferred to a 1000 ml distillation flask, the sandy residue washed by decantation, and distilled after neutralisation, into 25 mls of 0.1N HCL.

Screened methyl red was used as the indicator. The ammonia was directly titrated with 0.1N NaOH.

/ Blank....

Blank determinations were carried out in the same manner, using 0.2 grms of sucrose, so as to correct for nitrogen in the reagents employed.

The percentage of nitrogen in the soil, on the basis of a 10 grm sample, is (B - T) X N X 0.14. Where:-

B = Blank titration, in mls of standard alkali.
T = Actual titration, in mls of standard alkali.
N = Normality of the standard alkali.

Determination of Organic Carbon (Walkley and Blacks method).

The soil was digested with chromic and sulphuric acids, making use of the heat of dilution. The excess of chromic acid, not reduced by the organic matter, was then determined by titration with standard Ferrous sulphate solution.

0.5 grms of soil were added to 10 mls of N.$K_2Cr_2O_7$, and 20 mls of concentrated sulphuric acid in an Erlenmeyer flask. After the reaction was complete (± 30 minutes), 200 mls of water, 10 mls of phosphoric acid, and 1 ml of Diphenylamine solution were added. This was titrated against a freshly prepared standard Ferrous sulphate solution.

Since 1 ml of N.$K_2Cr_2O_7$ is equivalent to 3 mg of carbon, the amount of carbon oxidised, expressed as a percentage of the air-dried soil, is therefore given by the expression:-

$$\frac{V1 - V2}{W} \times 0.003 \times 100$$

Where:-

V1 = Volume of N.$K_2Cr_2O_7$ (10.5mls).

/V2....

V2 = Volume of N.Ferrous sulphate, in mls.
W = Weight of soil taken.

Determination of Organic Content.

(a) Hydrogen Peroxide Method.

10 grms of soil were added to 10 mls of water, and 10 mls of 20 Vols. H_2O_2 in a 200 ml Erlenmeyer flask. Warmed over a water bath, and after the evolution of oxygen had ceased, a further 10 mls of H_2O_2 were added. If the soil contained a large amount of organic matter, further lots of 10 mls of H_2O_2 were run in until the oxidation was complete. The contents of the flask were then brought to the boil, cooled, and filtered. The residue was ignited to constant weight, the filtrate evaporated and then ignited to constant weight. The weight of the former gave the content of organic matter, and the latter, the content of water-soluble minerals expressed as a percentage of the oven-dried soil.

(b) Ignition.

10 grms of soil were moistened with a solution of NH_4CO_3, and heated gently. After the carbonates had been decomposed, the soil was strongly heated to constant weight. The loss in weight was then equal to the organic and combined water contents. The percentage was calculated on the basis of the weight of oven-dried soil.

(c) Estimation of the Organic Content using Von Bemmelens Factor.

The carbon content was determined by Walkley and Blacks

/ wet....

wet combustion method, and the organic content by the following expression:-

$$O = C \times 1.7240$$

Where O = Organic content
C = Organic carbon.

Correction for Carbonates.

10 grms of soil were placed in Schrötters apparatus, charged with dilute Hydrochloric and concentrated Sulphuric acids, and weighed. After the reaction was complete, the apparatus was warmed over a water bath and a current of air drawn through with the aid of an Aspirator. The apparatus was reweighed, the loss in weight being equal to the carbonate present in the sample.

Extraction of Ether and Chloroform soluble Humus Complexes.

10 grms of soil, previously passed through the 225 mesh sieve and air-dried, were extracted in a Soxhlet apparatus until the solvent came away clear. The weight of the residue was expressed as a percentage of the air-dried soil.

Extraction of Sodium Hydroxide soluble Humus Complexes.

10 grms of soil, previously passed through the 225 mesh sieve, were treated with hot 50% NaOH solution, filtered, and acidulated with dilute Sulphuric acid. The precipitate was caught on filter paper and washed with acidulated water. The precipitate was divided into two fractions, one soluble in absolute alcohol, the other in strong ammonia. Both fractions were diluted to the same volume and tubed.

Technique for Culturing the Protozoa.

Preparation of the Soil Inoculum.

The soil inoculum was prepared, as soon as possible after sampling, from soil stored in sterile stoppered tubes. A 25 mesh sieve, previously sterilised by prolonged immersion in 70% alcohol, and a final treatment in absolute alcohol, was used to separate all gross living and dead material from the sample.

Preparation of the Media.

All utensils used for the cultures and in the preparation of the media, were sterilised in the autoclave at 10 pounds pressure for one hour.

Nutrient agars were used with the following nutrient solutions, added in the ratio of 1 grm of dried Bacteriological agar to 100 mls of the nutrient solution.

(a) Hay Infusion.

(b) Equal parts of Hay Infusion and Lockes solution.

(c)

Peptone	2.0 grms
KH_2PO_4	0.2 grms
$MgSO_4$	0.2 grms
KCL	0.2 grms
$FeCL_3$	Trace
Sod. Acetate	2.0 grms
Water	1000 mls

(d)

Peptone	8.0 grms
Glucose	2.0 grms
Water	1000 mls

(e) 50 grms of soil were heated with 100 mls of sterile

/ distilled....

distilled water for one hour and then filtered. Agar was added and the medium autoclaved at 10 pounds pressure for 10 minutes, and allowed to cool immediately. Prolonged heating was found to have a detrimental effect on the soil extract.

The following non-agar media were used:-

(f) Wheat, Oatmeal, Bread. Equal weights of each.

(g) Soil. 50 grms of soil were autoclaved at 10 pounds pressure for 10 minutes in Erlenmeyer flasks plugged with cotton wool pledgets. 100 mls of sterile distilled water was then added.

(h) Soil and Water. A soil-water ratio of 1:20 was used.

Cultures.

The cultures with a liquid media were set in Erlenmeyer flasks plugged with cotton wool pledgets, those with a nutrient agar media in petri dishes. All the cultures were incubated at 25°C for one month.

Slides and cover-slips used in the microscopical examination of the cultures were given an initial wash in concentrated Hydrochloric acid, rinsed in distilled water, and stored in absolute alcohol until required. The cultures were examined every second day with the usual bacteriological precautions.

Dilutions.

1:100. 1 grm of soil was shaken up with 100 mls of sterile

/ distilled....

distilled water. 1 ml of the suspension was used as the inoculum.

1:20. 1 grm of soil was added to 20 mls of sterile distilled water.

1:10. 1 grm of soil was added to 10 mls of sterile distilled water.

Fixatives and Stains.

Fixatives.

Schaudins (Sat. Aq. soln $HgCL_2$, 5% Acetic acid, 95% Alcohol).
Sat. Aq. soln $HgCL_2$.
1% Copper sulphate solution.

Fixative-Stains.

Aceto-carmine.
Aceto-orcein.

Nuclear Stains.

Delafield's haematoxylin.
Ehrlichs acid haematoxylin.
Aceto-carmine.

Flagella and Cilia Stains.

30% Tannic acid solution.
Nolands Stain (Sat. Aq. soln Phenol, Gentian Violet).
Lugols Iodine (1.5 grms KI, 1 grm Iodine, 25 mls water).

Vital Stains.

Neutral Red (1:1500).
Methylene Blue (1:5000).

General Stains.

Acetic-methylene Blue.
Borax Carmine.
Methyl Green.

Narcotics.

Cocaine hydrochloride (1% solution).
Procaine hydrochloride (1% solution).

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* Indicates papers seen in abstract.

** Indicates papers used in the identification of the soil fauna.

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