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Titel Litter consumption and soil translocation by termites under maize and banana near Chuka, KENYA

Scriptie/Verslag

Behorende bij OWEL No.

Het onderzoek maakt deel uit van het project ...Chuka...

....

Begeleider(s) ...Ir. J.C.Y. Marinissen...

Goedgekeurd d.d. 1987

Hoogleraar ....

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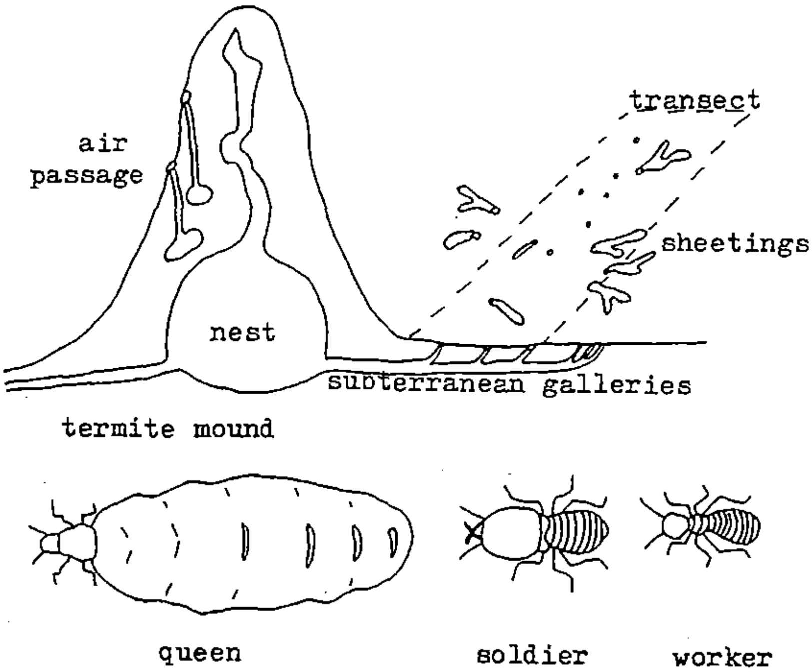

J.P. Kools

1987

Preface

In this report a preliminary research on the influence of termites on soils under agricultural practices is described.
A close connection with the findings of Wielemaker (1984) concerning the importance of termites in soil formation and the work of Kooyman and Onck (1987) concerning significance of termites for soils and land-use both in the Kisii-district exists. Experimental plots were chosen near Chuka, on the footslope of Mount Kenya,in the project area of the Training Project in Pedology. A project was planned in which two post-graduate students of the Agricultural University Wageningen, the Netherlands and two disciplines should cooperate: soil science (Nicole Bongers) and soil biology (Jeanine Kools). Fieldwork was done partly together from November 1985 untill April 1986.
This report contains the description and findings of the biological part. In another report the soil science aspects will be described, including both a comparative study to different soils on the footslope of Mount Kenya as the results of chemical analyses on soil sheetings and litter (Bongers, 1987).

Doing this research and writing this report would not have been possible without help of the following persons:
Mrs Joke Marinissen, Mr W. Wielemaker, Mr T. de Meester and Mr D. Legger of the Agricultural University of Wageningen, Mr R. Bagine of the National Museum of Kenya and Alfred Odupa, laboratory technician of the project. On this place I like to thank all these people once again.

June 1987,

Jeanine Kools

Abstract

In the sample area of the Training Project in Pedology (T.P.I.P., of the Agricultural University Wageningen) near Chuka in Kenya a project was planned in which both soil biology and soil science cooperated. Fieldwork was done from November 1985 till April 1986, thus including the short dry season.

In the project area termites (order Isoptera) seem to be the dominant soil fauna and especially the family Macrotermitinae. Termites have impact on both vegetation and soil:

* By feeding activities and subsequent decomposition termites affect the cycling of organic matter and nutrients.
* By building nests, mounds, subterranean galleries and covered runways or sheetings termites cause a redistribution of soil particles, resulting in altered soil physical and chemical properties.

When soil is used for agricultural practices underground galleries are destroyed at certain intervals by soil tillage and the habitat becomes less attractive for some termites.

In a preliminary study we tried to make an estimation of the amount of soil translocated under agriculture and made some chemical analyses on this soil material to get some idea of the influence of termite saliva (for cementing the soil particles) on soil fertility. Also we were interested in the amount of litter consumption by termites in the field situation.

This research was done on the footslope of Mount Kenya in two zones, representing different climatological conditions and related land-use types:

* the tea zone, close to Mount Kenya Forest, at ± 1800 metre (average temperature 16-18 °C, 1800-2000 mm rain annually)
* the cotton zone, at ± 1100 metre (average temperature 21-22 °C, 900-1100 mm rain annually).

In both zones a maize field was chosen as experimental site; in the cotton zone also a nearby banana plot was sampled for comparison of an annual crop and a standing vegetation. A higher termite activity is expected under banana because of the higher biomass production, the less extreme microclimate and the absence of destroyment of subterranean galleries when compared with the maize field.

Observations on termite activity were done in the early morning when the newly build sheetings were still wet with termite saliva. Foraging activity was measured by noting the dimensions (cm^2) of the freshly formed sheetings. With a conversion factor the amount of soil transported could be calculated. For litter consumption estimations litter bags were installed both aboveground and underground. These litter bags consisted of coated iron gauze (mesh width 0.5 x 0.5 cm). Aboveground litter bags contained the litter collected from 1 m^2 (maize field) or 0.25 m^2 (banana bush) and were replaced whenever they were attacked by termites. Underground litter bags contained 25 gr fresh litter, were dug in at a depth of 10-15 cm and renewed after 1, 2 or 4 weeks. Litter production for the maize plots was measured by collecting all litter from a certain m^2 and amounted 400 ± 67 gramme/m^2/24 experimental weeks for the cotton zone and 210 ± 74 gramme/m^2/24 experimental weeks for the tea zone. Estimating biomass in a banana bush requires the use of an alternative method. By counting the number of harvested plants per unit of time and per unit of acreage and weighing these cut materials the very rough estimation of 5000 (500-11,000) gramme/m^2/year is acquired.

A low termite activity in the tea zone compared to the cotton zone became clear from the different observations (both on litter consumption as on

termite activity). Termites seemed relatively unimportant in soil translocation and litter consumption in the tea zone.
It was not possible to quantify termite activity under banana by direct observations on a transect. This activity is still expected to be high, according to the incidental presence of great numbers of termites foraging on an area of a few square metres.
In the maize field in the cotton zone the termite activity was related to the presence of a termite nest: beyond a radius of about 20 metres from a Macrotermes mound a high activity was observed. On the experimental field also a zone of activity by Odontotermes exists, resulting in the overall estimation of 491 gr/m^2 for Macrotermes and 25 gr/m^2 for Odontotermes for the 24 weeks the experiment lasted. Because of the dependence of termite activity to distance from the mound and the big heterogeneity in distribution of the sheetings some caution must be practiced with extrapolation of these results to bigger areas.
Underground litter consumption experiments showed that besides bigger termites (as Macrotermes and Odontotermes) the smaller termite Microtermes is very numerous in the whole maize field. Only 1-5 gramme per week is foraged by Microtermes, but together with the high probability of presence (in 5 weeks 9 of the 10 underground litter bags were inhabited by Microtermes) these termites seemed to be important in underground litter consumption.
The amount of litter eaten by termites from aboveground litter bags was not constant: sometimes quite a lot and sometimes only a few gramme was eaten.
With data following from this research together with some rather crude hypotheses concerning foraging rate, the amount of litter eaten by termites and the amount of litter present, a very coarse estimation of the amount of litter left after the 24 experimental weeks can be made. Very generally 3/4 part of the available litter of the maize field has been consumed by termites during the 24 week experimental period.
Calculations showed that 35-66% of the banana litter is eaten in the same period, but it seemed likely that more litter disappeared because of the higher activity of other soil organisms (both soil fauna and fungi were observed at the experimental site).
Sheeting analyses showed that these have a higher C/N ratio and a lower Cation Exchange Capacity (CEC) than the top soil (Bongers, 1987). Termite sheetings thus did not contribute to an increased soil fertility. Combined with the high litter consumption it seemed that termite presence did not lead to more favourable agricultural conditions.
However data about physical influence on the soil of this site are not yet available, but from other research it seems very likely that termite presence has a favourable effect on soil physical properties (Wielemaker, 1984).

Contents

1 Introduction

1.1 Background of the T.P.I.P.

The Chuka project (April 1985 - July 1986) is the third phase of the Training Project in Pedology (T.P.I.P.) in Kenya of the Agricultural University of Wageningen (the Netherlands). Previous phases were the Kisii project (1973 - 1979) and the Kilifi project (1979 - 1982). All the activities of the T.P.I.P. are carried out in close consultation with the cooperating agency, the Kenya Soil Survey (KSS), part of the National Agricultural Laboratories (NAL) of the Ministry of Agriculture in Nairobi.
The objectives of this project are:

* to produce a reconnaissance soil map (1 : 100,000) of the Chuka and Ishiara map sheets of the Survey of Kenya, together with a detailed report and a land evaluation to assess the suitability of a number of land-uses.
* to train post-graduate students of the Wageningen Agricultural University in soil science, agronomy, biology and agricultural economics. The training consists of graduate-students work (6 months period) as well as research work for a MSc-thesis.

The selection of the project area took place in full cooperation with the KSS. The funds for the project are provided by the Agricultural University of Wageningen, the Netherlands.

1.2 Termite biology

In the T.P.I.P. sample area a project was planned in which soil biology and soil science were integrated. The accent was given to termites, because in this area they seem to be the dominant soil fauna.
Termites (order Isoptera) are principal inhabitants of tropical and sub-tropical semi-arid regions. They belong to the "social insects" (together with e.g. Hymenoptera (bees)), which live in colonies in nests of their own construction. These nests serve to house and protect the colony, store food and maintain an optimum environment. Subterranean galleries and covered runways or sheetings are used when the termites are searching for requisites as food, moisture and soil particles.
The individuals comprising a colony of termites consist of several castes which are morphologically and functionally distinct. Newly hatched individuals (larvae) are capable of developing into any caste depending upon the requirements of the colony. The reproductive castes consist of primary and secondary reproductives. Primary reproductives, winged imagines or alates, consist of males (kings) and females (queens). They leave the nest at certain times of the year, shed their wings and attempt to mate and establish a new colony. The secondary or supplementary reproductives are present in several forms, they act as substitutes for the king or queen. The sterile castes consist of workers and soldiers. The workers are responsible for all foraging activities and they care for the eggs, larvae and queen. Soldiers defend the colony within the precincts of the nest and also defend workers which may be foraging at some distance from the nest. Dimorphism, with the existence of major and minor forms is common for workers and soldiers.
The food collected by the workers is the basic energy resource of the colony. Depending on the species of termite it consists of plant material, either living, dead, partially or almost entirely decomposed (wood, grass,

herbs and plant litter, humus and fungi).
Termites have impact on both vegetation and soil:

- By feeding activities and subsequent decomposition termites affect the cycling of organic matter and nutrients,
- By building nests, mounds, subterranean galleries and sheetings termites cause a redistribution of soil particles, resulting in altered physical and chemical soil properties (Lee and Wood, 1971).

The sub-family Macrotermitinae are dominant in the research area. Termites of this sub-family construct special structures with faecal material, the "fungus combs" in their nests. On these combs various fungi are grown, continually eaten by the termites and replaced with fresh material. The fungus combs are of importance by providing nitrogenous materials and vitamins to the termites (Lee and Wood, 1971).
In general the fungus growers (Macrotermitinae) are very efficient in the decomposition of organic matter. Nearly all material transported to the nest is utilized, leaving a very small fraction undigested. Return to the ecosystem takes place only as:

- salivary secretions (for cementing soil particles)
- termite corpses (annual flights of alates)
- predation on termites (e.g. by birds, lizards, ants)
- faeces (in Macrotermitinae little or no return via faeces; only available when nest is abandoned)(Wood,1975).

1.3 Food and territory of Macrotermes spp.

The International Centre of Insect Physiology and Ecology (ICIPE) had a grassland termites research programme in which different aspects of termite biology were studied and especially the species Macrotermes michaelseni. Fieldwork was done near Kajiado (Kenya), on a semi-arid grassland ecosystem. The foraging behaviour is rather constant in the genus Macrotermes (at least in savanna ecosystems): the foraging populations flow in a network of underground galleries, emerging on the ground surface through foraging holes, to collect plant materials back to their nest. Soil shelters, tunnels or trails may be added outside the foraging holes. The underground network is more or less permanent and defines the territory of the colony (Lepage, 1983).
Darlington (1982 a) studied the nest system of M.michaelseni in Kajiado, Kenya and found that few large radial passages extend outwards at a depth of 50-80 cm for up to 10 metre from the mound. Then they rise steeply and level off at 9-15 cm below soil level, where they branch and interconnect to form a network of horizontal passages containing many storage pits. Beyond 30-40 metre from the mound, the network peters out into blind-ending peripheral passages.
Termites of the species M.michaelseni prefer to feed on grass litter, but they also will consume living plant material or roots if litter is in short supply (Lepage, 1979). M.subhyalinus usually feeds on grass litter and dung. Collins (1982) observed the termites feeding on standing grass only during two periods: January and April/May. During both times a high grass production combined with a low litter production and a low foraging intensity exists. A main peak in foraging level is measured during the long dry season (June till October) and a minor peak during the short dry season (February till March). Thus the seasonal pattern of termite foraging levels takes advantage of periods of high litter biomass (Collins, 1982). The main peak in consumption between June and September also coincides with the maturation of the sexual castes (Lepage, 1983).
Also a daily periodicity can be observed: foraging in the open, either on

the soil surface or on living plants, appears to be largely nocturnal, although it may occur during daylight hours if the sky is cloudy (Wood, 1978). Lepage (1983) concludes from several studies that high temperatures prevent surface-foraging in the early morning. For M.michaelseni two phases of foraging activity occur: one aboveground and one underground. The underground activity continued when aboveground activity had ceased and when the foraging holes were closed.

1.4 Termites and soils

The construction of termite mounds and therewith the movement of big quantities of soil was the research subject of several soil scientists. In some cases of subsoil material to the surface is expected to be beneficial to soil fertility (Arshad, 1982; Miedema and van Vuure, 1977). Wood and Sands (1978) on the other hand found that erosion of structures built by Macrotermitinae often added soil of a lower nitrogen content compared with the topsoil. Also the low organic matter content of the subsoil material is supposed unfavourable because this should imply an acceleration of erosion (Lee and Wood, 1971).
The dense network of galleries built by termites must affect porosity and aeration, but these effects have not yet been measured (Lee and Wood, 1971). Pomeroy (1983) tried to summarize the effects of Macrotermitinae in grazing lands of a semi-arid area in Kenya. He concluded that beneficial and harmfull effects - insofar it is possible to compare them- could well be of similar magnitude.
The construction of sheetings around "food" before this is transported to the nest can be seen as an adaptation to climatic conditions that are unfavourable for termites. Soil particles are cemented together with salivary secretions and this means a contribution of organic matter to these soil constructions (Wood, 1975; Robinson, 1958; Wood and Sands, 1978). An enormous quantity of soil is treated in this way: Bagine (1984) estimated for Odontotermes for an arid area in Kenya (200 mm rain annually)) a translocation of 1059 kg of soil to sheetings per hectare per year. Lepage (1974, in Bagine, 1984) estimated that the amount of Macrotermes subhyalinus soil sheeting ranged from 675-900 $kg.ha^{-1}.yr^{-1}$ in the sahel savanna in Senegal (annual rainfall 750 mm). Wood et al (1978, in Bagine,1984) estimated 300 $kg.ha^{-1}.yr^{-1}$ of Macrotermes soil sheeting in Southern Guinea woodland in Nigeria, with annual rainfall of 1000 mm.
Looking at the enormous amount of soil translocated, the addition of organic matter in the form of saliva is possibly of importance regarding soil fertility. However this item has never been described quantitatively untill now.
Since Drummond in 1886 (in Lee and Wood, 1971) regarded the termite as the tropical analogue of the earthworm, this comparison is often made. In some aspects this analogy is justifiable: both groups are often found in great numbers; both dominate the soil fauna; both make burrows that are prominent features of soil profiles and both physically re-sort horizons. Especially in the distribution of individuals in the soil and the decomposition process some striking differences exist between the role of earthworms and termites in ecosystems (Lee and Wood, 1971; Wood, 1975). Termites, and fungus growers in particular, are very efficient decomposers. Together with the concentration of organic material in their central nests this habit shows a violent contrast with the intensive mixing of organic matter and soil by earthworms.
The addition of organic matter in the form of saliva to soil sheetings is

probably small when compared with incorporation of organic matter by earthworms. Nevertheless this can be of importance in areas with termites as dominant soil fauna organisms.

1.5 Aim of the study

The activity of termites has consequences for the soil in two ways: it influences organic matter decomposition and therewith organic matter cycling and secondly it is of importance for the soil structure.
Bagine (1984) made a study of the amount of soil translocated in a more or less natural ecosystem in an arid area in Kenya. When soil is used for agricultural practices underground galleries are destroyed at certain intervals by soil tillage and the habitat becomes less attractive for some termites. A species like Microtermes (a small, no sheeting building termite) on the other hand is found to increase in numbers under agriculture (Wood et al in Ferrar, 1982 a).

In a preliminary study we tried to make an estimation of the amount of soil translocated under agriculture and made some chemical analyses on this soil material to get some idea of the influence of the termite saliva on soil fertility.
Also we were interested in the amount of litter consumption by termites in the field situation.
Our experimental area is situated on the footslope of Mount Kenya, due to the presence of the T.P.I.P. sample area there. The soils are all derived from volcanic material, but they differ due to development under different climatological conditions.
A comparative study is made of soil profiles, formed under different conditions of climate and land-use, concentrating on differences in structure and organic matter (Bongers, 1987). Very close to the experimental site for the termite study in the cottonzone (described in this report) a comparative study of a range of sites representing different stages of the rotation cycle is done, with emphasis on soil fertility as reflected in organic matter content, base saturation and structure (Kools, 1987).
In two zones (distincted by Jaetzold, 1982 for this area and representing different climatological conditions and related land-use types) the termite activity with regard to transporting soil and litter consumption are compared. The two zones used in the comparison are the tea zone, close to Mount Kenya Forest at $\pm$ 1800 m and the cotton zone at $\pm$ 1100 m.
In the cotton zone two land use types were chosen, because during the preliminary field trips visual differences in colour of the surface soil under banana and annual crops became visible. A higher termite activity is expected under banana because of the higher biomass production and the less extreme microclimate when compared with a maize field. Also no destroyment of the subterranean galleries by soil tillage takes place under banana.

2 METHODS

2.1 Methods for sampling termites

The social behaviour of termites makes the use of many of the soil sampling methods impossible. The populations are highly aggregated by living in subterranean nests and by manner of foraging. The polymorphicity with castes which have different distributions and densities and the periodicity of the sexual stages make population estimations not so easily done (Brian, 1971). The numbers of termites in the nest fluctuate both in relation to the season and diurnally (Lee and Wood, 1971).

For quantitative sampling, "direct soil sampling" (although only rarely suitable for social insects) is used when distinct colonies are not recognizable. Digging pits or the use of a soil core or soil auger and sorting out all termites are widely used methods (Sands, 1972). Size, number and density of the soil samples taken depend on practical experience. The digging or coring instrument should be quickly inserted because of the high mobility of the termites (Brian, 1971).

When distinct colonies are recognizable population density can be estimated by counting colonies in a sampling area and estimating their populations separately. Nest excavation can be done by digging a whole colony out (Brian, 1971). Darlington (1982b) sampled nest populations by fumigating with methylbromide, thus removing the whole contents of the nest and all castes and instars could be counted. With this method some sources of error, of importance when digging is practiced, diminish like damaging individuals and the rushing away of termites. In both cases those insects which are away foraging at the time are not included in the counting.

A widely used method for sampling subterranean termites qualitatively and examining differences in attack is the use of baits. Derived from the economic necessity of determining resistance of various timbers against attack by termites wooden poles (whether or not treated with preservatives or insecticides) are often used (Wood, 1987). La Fage et al. (1973) placed toilet rolls at close intervals in an area where all wood forage was removed for studying foraging behaviour. Ferrar (1982b) also used toilet roll baits in a comparative study for measuring speed, extent and seasonality of attack in different subhabitats. Termites locate and feed on toilet paper much more quickly than they do on wooden blocks (La Fage et al., 1973) and this shows that it is difficult to relate consumption of toilet rolls to natural forage.

In litter bag experiments decomposer organisms are offered their naturally occurring food in naturally occurring situations and in amounts which correspond to the natural access to leaves, branches etc. in the particular habitat (Wood, 1978).

Macrotermes sp. uses foraging holes, which are opened before and closed after foraging. Lepage (1979, 1981a and b) and Collins (1982) made use of this habit by marking the holes with white powder. When termites used these holes the powder is mixed with fresh soil particles. On certain strips (24 times 10 x 1.5 metre) the number of utilized foraging holes was counted during some days each month. Estimates were made of the grass consumption by termites by placing 5 grammes of dry grass and litter around a foraging hole and reweighing this when the hole had been opened overnight.

The methods used in our study concern several items:
* microclimatic conditions of soil and air
* litter production
* activity measurements
* litter consumption (above and underground)
These are described in the sections 2.3 - 2.6.

2.2 Selection of the plots

By the selection of the plots the following conditions were important:
- situation on a 0-2 % slope
- a field with annual crops, with preference for maize
- a plot with a dense bananaplant population (in the cotton zone)
- a plot close to the Mount Kenya Forest (in the tea zone).

In the cotton zone a maize field with a Macrotermes mound (to be sure of the presence of termites in the experiment) and a banana bush at very short distance were found.
On the maize field 10 plots, each 100 m^2 (10 x 10 metre) were marked by wooden poles at more or less distance from the Macrotermes mound. See figure 1.

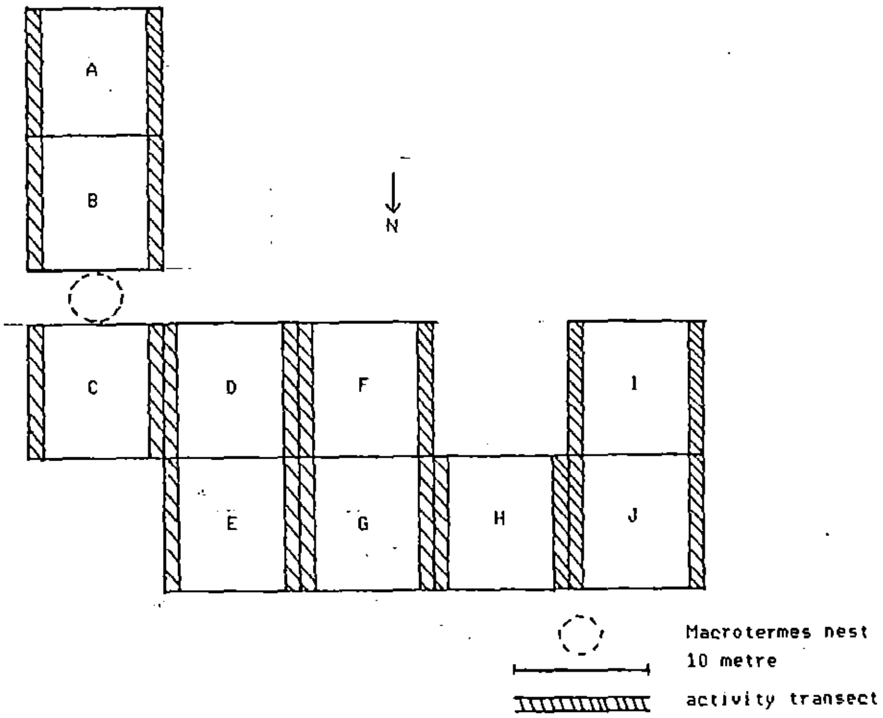

Figure 1 Location plots in maize field, cotton zone

The growth pattern of banana plants with a concentration of stems on a small acreage and the large heterogeneity in organic material inside the cluster of plants and between the several clusters, made construction of 10 x 10 metre plots less desirable. Also because of the dimension of the banana bush another approach was desirable. Three transect lines (6 x 5, 4 x 5 metre (litter bag transects) and 44 x 1 metre, later extended to 85 x 1 metre (activity transect) were laid between the banana clusters. On these lines the experiments were concentrated. See figure 2.

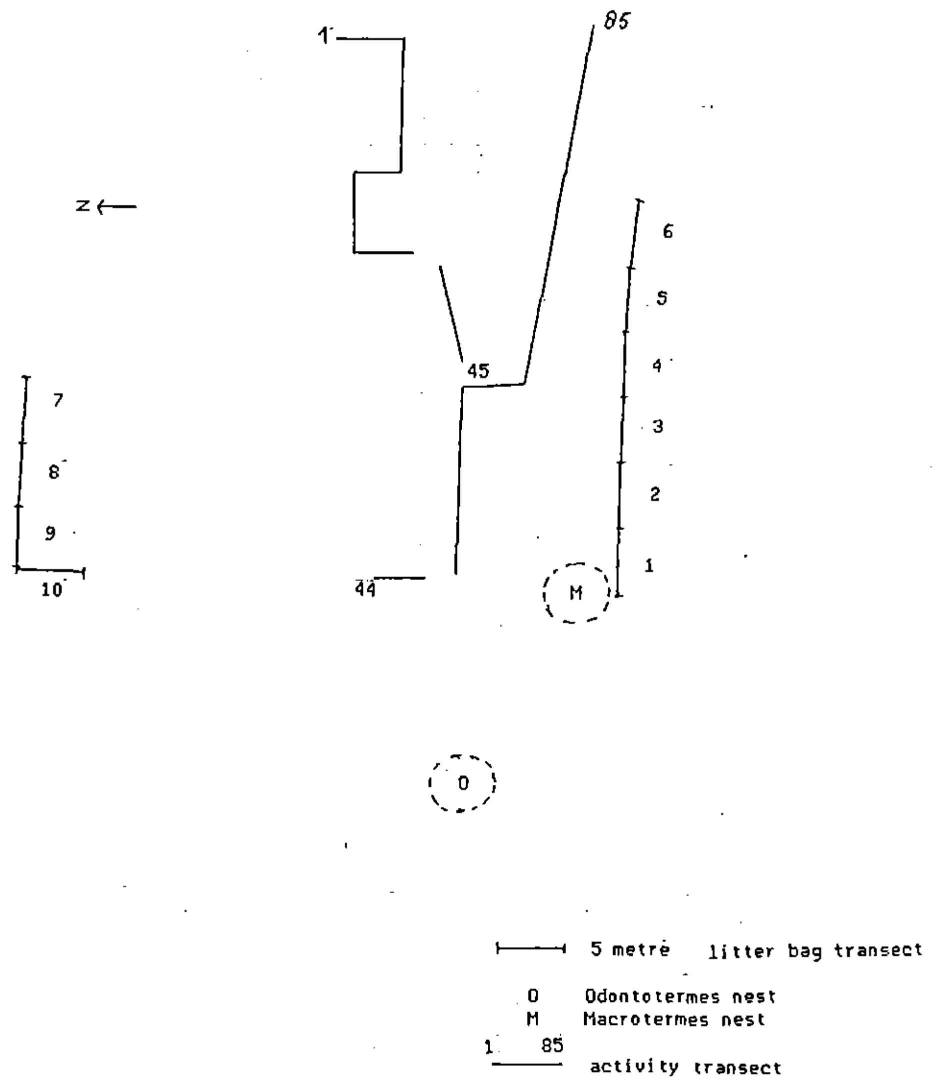

Figure 2 Location transect lines banana bush, cotton zone

In the tea zone a pure maize plot in a more or less flat position was not easy to find. Because of the low temperature the maize does not ripe very well. Maize is cultivated on small plots, mainly for use as cattle fodder. At least we found a 1 acre plot on which in October already maize grew, though very heterogenous: plants of 5 till 200 cm! Because of the size of the field only eight 10 x 10 metre plots were set out. See figure 3.

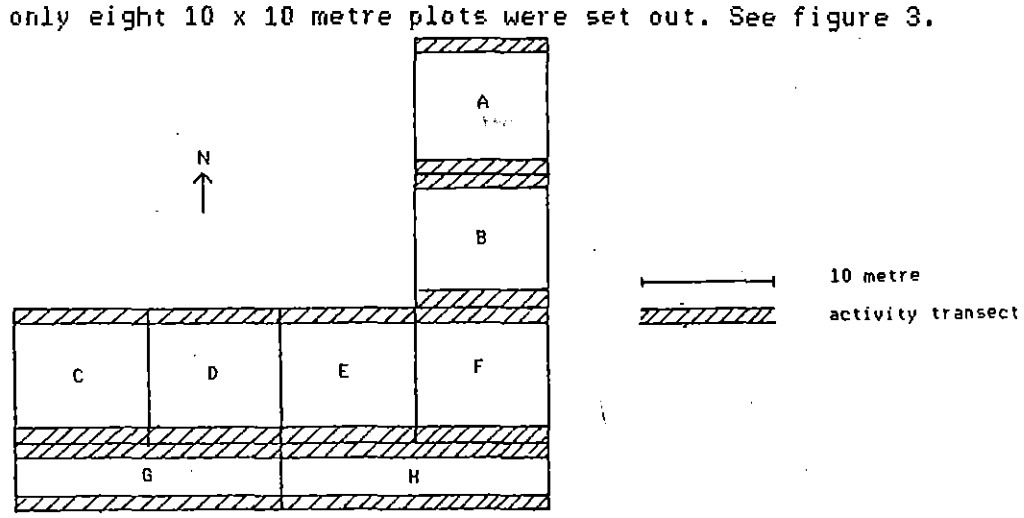

Figure 3 Location plots maize field, tea zone

2.3 Microclimate

The activity of termites, especially the foraging above the ground, is closely related to the climatic conditions.
For comparing the microclimatic differences between a maize field and a standing vegetation (in the cotton zone a banana bush and in the tea zone a tropical mountain forest, both close to the maize plot) during the seasons, air temperature and relative air humidity were measured every hour during the time we spent at the plots. Dry and wet bulb temperature were measured at about 150 cm above the earth surface.
Soil temperature at 5 and 15 cm below the surface were measured every three weeks (also every hour during the time we spent at the plots).
Because there were no automatic rain-gauges available at the start of the experiment, simple rain-gauges were constructed using a funnel and flask in a plastic pipe. Both in the tea zone and in the cotton zone rain-gauges were installed in the maize-plots. The amount of rain was measured as often as possible, but this method does not include intensity data.
Every three weeks soil humidity was determined, by taking a sample of the topsoil (0-20 and 20-30 cm) at the same time during the day and measuring the gravimetric water content after drying in the stove (24 hours at 105^{0}C).

2.4 Litter production

For the maize plots all litter was collected from three specific sites of 1 m^2 whenever material was found. Because of the size of the field more sites would influence the litter availability and therewith termite activity too much. This material was dried in the stove, the first months 24 hours at 105^{0}C (which is a too high temperature for a correct nitrogen analysis), later also 24 hours at 70^{0}C. These samples were analysed for carbon and nitrogen content.
Estimating the litter production in the banana bush was not so easily done, because of the big heterogeneity in the amount of litter at relatively short distance. In general biomass estimations in a forest are done by collecting all leaves which fall into a drained collector. In our situation the banana plants are cut when the fruits are harvested, producing at that moment a concentration of material. Compared with this amount, the litter falling before cutting the whole plant, is negligible. This means that very big collectors have to be used for getting a correct approach for the litter production. Because of the fact that this seemed not possible we invented an alternative method.
In the banana bush clusters were chosen at random and in each 15 plants (young and old) were marked at random. Both the inside as well as the outside part of a concentration of banana plants belong to a "cluster". The number of plants per cluster depended on the age of the cluster, in this plot on average more than 15 plants. For each cluster the density was estimated, resulting in an average acreage for 15 banana plants. After two months for each marked cluster the number of banana plants still standing was counted, thus making the assumption that these bananas have a constant fruit production (and therewith cutting of the plants) during the year. Also an estimation of the (dry) weight of a whole (already harvested) plant was made, by weighing the leaves and measuring the length and circumference of the stem (both at 1 metre from the base (c_1) and at 1 metre from the top (c_2)) and taking a sample for weighing.
With these data a very rough estimate of the litter production can be made.

2.5 Activity measurements

2.5.1 Transect observations

Termites bring their food into the nest through underground passages. These galleries radiate from the mound into the environment (pers.comm. J. Darlington), where they reach the surface as foraging holes. Foraging takes place mostly during the night: termite workers cover the food resource with soil particles cemented with salivary secretions, called "sheetings" and take the organic material to the nest (Lee and Wood, 1971).
The foraging activity of Macrotermes aff. subhyalinus can be measured by counting each month during 24 hours the number of foraging holes open (Lepage, 1979). For our purpose this seemed a suitable method, but our lamp was not strong enough to distinguish the foraging holes at night. We decided to look in the early morning, just at sunrise, and in the late afternoon, just before sunset. In the maize field only in the morning newly build sheetings, still wet, were present. By noting the presence and the dimensions (in cm^2) of those fresh sheetings we acquire a manner to describe the foraging activity. With a conversion factor the amount of soil transported can be calculated. Instead of observing once a month during 24 hours, we counted and measured every three weeks for three successive days. After some observations it became clear, that the termites forage in a certain direction from the mound for a few days and then change to another direction. So it seemed better to observe more often, so our observation pattern changed to observing in the early morning every few (2-5) days.
In the cotton zone a transect of 200 x 1 metre in the maize field was set out. For location see figure 1.
In the banana bush the heterogenity was a problem: because of the accumulation of organic material between the plants it was impossible to walk and make observations there. We decided to lay a transect near the inner border of the banana bush with a small plot of maize (with banana litter on the transect). Because of the expected higher activity and the dimension of the banana bush this transect was only 44 x 1 metre. As a result of only incidental termite activity observations a new transect of 41 x 1 metre was set out after four months, now also between banana clusters. See figure 2.
In the tea zone a transect of 200 x 1 metre was set out. See figure 3.

2.5.2 Sheeting buiding estimated with frame

For estimating the fastness of sheeting building, a frame of 45 x 45 cm with squares drawed on plastic of 1 x 1 cm was placed above a fresh sheeting. A drawing was made every few hours, so that the growth rate of the sheeting became visible.

2.5.3 Sampling with pitfall traps

Sampling of subterranean termites is one of the most awkward problems of termite fieldwork (Ferrar, 1982). Digging pits and collecting all termites is a method, which requires the taking of numerous soil cores. Beside errors in the number of caught termites because they run away during inserting the soil core, this method would be too destructive.
Therefore we tried to estimate the amount of termites active at a certain time interval and in a certain direction from the mound with the use of pitfall traps, in spite of disadvantages of this method (e.g. "digging-in effects" (Greenslade, 1973); preservatives may affect catches (Greenslade and Greenslade, 1971, in Greenslade, 1973)).
Van der Werff (1978) designed a pitfall trap in which he caught, among others, termites.

Based on this design we made some pitfall traps: see figure 4.

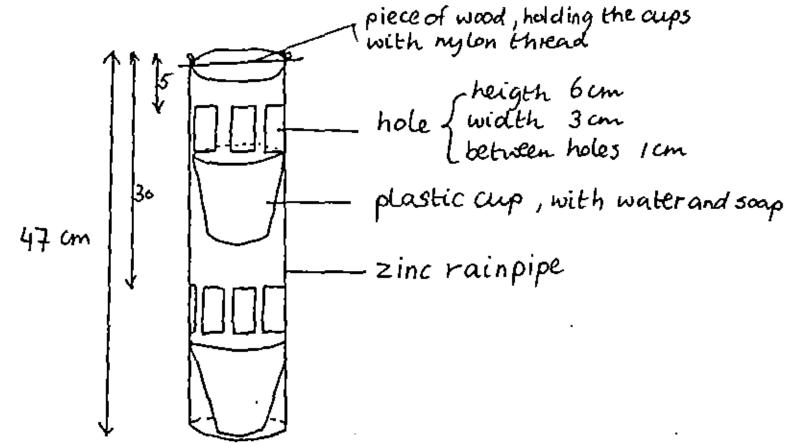

Figure 4 Pitfall trap

It was not possible to buy plastic cups in Kenya, which fit in the rainpipe, so coated paper cups were used. After one shower the cups appeared not firm enough. Plastic cups from the Netherlands arrived after some weeks, but because of the dry season it was not possible to install the traps. In March some traps were dug in: in the maize plot and in the banana bush, both situated in the cotton zone.

2.6 Litter consumption

To estimate the amount of litter consumed by termites and its seasonal variation and the amount of soil transported in relation to the amount of litter, litter bags were installed. Kooyman and Onck (1984) did experiences with litter bags and we copied their gauze measures and methods for underground litter bags. These litter bags were constructed by using coated iron gauze with mesh width of 0.5 x 0.5 cm, thus permitting termites to penetrate the bags. Both aboveground and underground litter bags were used because some termites are surface feeders (e.g. Odontotermes), while others forage more below the surface (e.g. Microtermes and Pseudocanthotermes) (Kooyman and Onck, 1984). For aboveground foraging gauzes of 30 x 30 cm were laid out, without top coverage to make the best simulation of the situation in the field. On top was laid the litter collected from 1 m^2 (maize fields in the cotton and tea zone), or from 0.25 m^2 (banana bush), the soil removed as much as possible with a brush. This litter was first weighed on a triple-beam balance in the field; the water content was determined by taking a sample at the same time. Thus the dry weight could be calculated. The aboveground litter bags were inspected every week: from the moment the termites started eating the litter and began to build sheetings to cover it, the litter bag was kept for two weeks. Subsequently the remaining litter and soil were recovered and new material was exposed on the same spot. From the remaining litter the dry weight was measured again and the sheeting was collected for weighing and analysis on CEC, base saturation, pH, C and N content.
The method used for measuring litter consumption by aboveground litter bags includes an estimation of the amount of litter present on the ground during the experimental period (litter availability).

For underground consumption gauze envelopes (30 x 30 cm) were dug in at a depth of 10-15 cm. They contained 25 g fresh litter from the field. A subsample was taken to measure water content. In advance a scheme was made, according to which the litter bags would be taken out. This consisted of cycli of 7 weeks, built up by 1, 2 and 4 weeks in varying order. Loss in dry weight was determined.

In the cotton zone in the maize field 20 aboveground and 10 underground litter bags were laid out, according to the scheme in appendix D.

In the banana bush 10 aboveground and 10 underground litter bags were distributed among the transects.

In the maize field in the tea zone 10 aboveground and 10 underground litter bags were placed.

At first we chose a higher number of litter bags (aboveground as well as underground) per field, but this number was not possible with our budget.

3 Description of the research area

3.1 Location of the research plots in two ecological zones

The project research area is located on the South-Eastern footslopes of Mount Kenya, just south of the equator (latitudes 0 15'S and 0 30'S; longitudes 37 30'E and 38 00'E), see figure 5.
It concerns the Chuka (122/3) and Ishiara (122/4) map sheets of the Survey of Kenya.

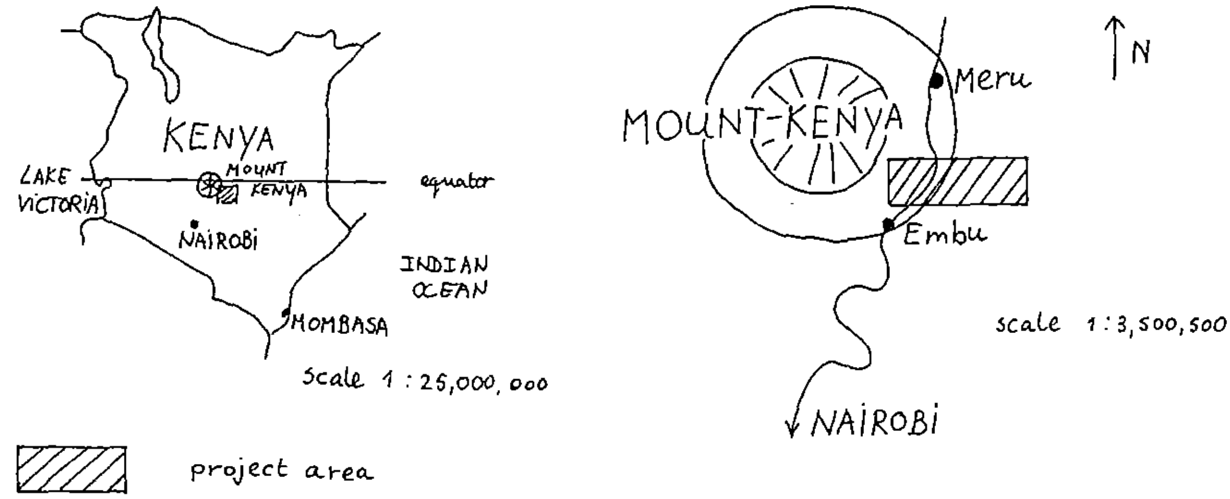

Figure 5 Situation of the project area in Kenya

Due to the situation on the footslope of Mount Kenya (the remains of a Tertiairy volcano), the elevation differs from 1100 metre in the Eastern part (edge of the volcanic influence near Kanyambora) and 1800 metre in the Western part (border of the Mount Kenya Forest). With difference in altitude and location on the windward side of the mountain, the rainfall increases in East-West direction: 1000-2200 mm average per annum. Also the temperature changes with the altitude: the mean annual temperature is 21-22 °C in the Eastern and 16-18 °C in the Western part of the mountain footslopes (Jaetzold, 1982).

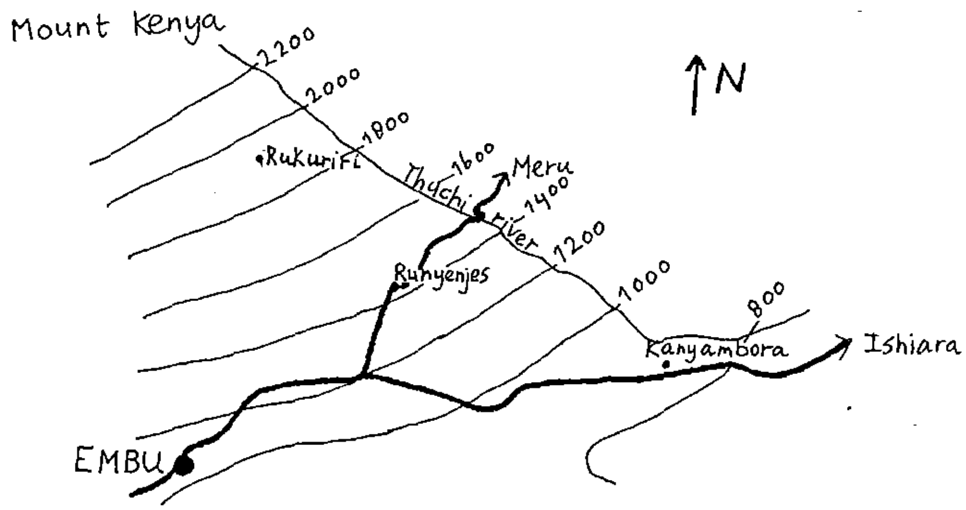

Figure 6 Average annual rainfall in mm (Jaetzold, 1982)

The mentioned ecological factors influence the farming systems in the area. Jaetzold et al. (1982) compiled a map using the ecological data, in which various zones are defined, named after the occurrence of crops.

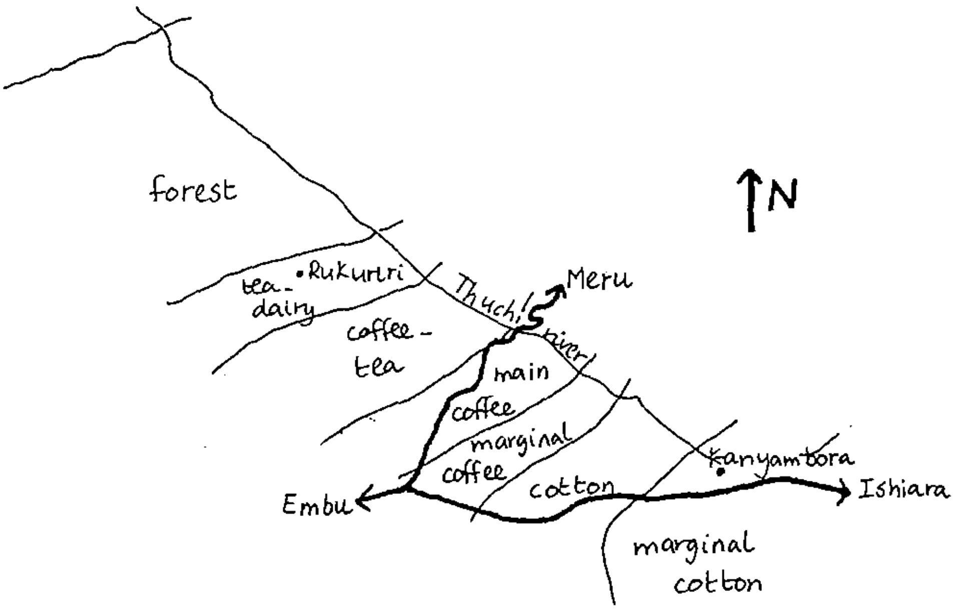

Figure 7 Agro-ecological zones (Jaetzold, 1982)

The termite research described in this report is concentrated in two zones : the Tea-Dairy zone (shortly "tea zone") and the Cottonzone ("cotton zone" or "mango zone", after the abundant presence of mango trees).

The **tea zone** (1800 m, 16-18^{o}C, 1800-2000 mm rain annually) received it's name because of tea being the most important cash crop in this area. Foodcrops in this zone are maize, beans, yam, potato. Coffee is also a cash crop, but is growing less well on this altitude. Cattle is kept at zero- or small grazing units and are fed on napier grass (Pennisetum purpureum) and maize. Except the nearby Mount Kenya Forest most land is cultivated continuous. For the tea fertilizer is used, to the foodcrops only manure is applied (if available). The main soil type is the humic Nitosol (according to FAO).

In the **cotton zone** (1100 m, 21-22^{o}C, 900-1100 mm rain annually) cotton, tobacco and mangoes are the most important cash crops. Maize, beans and banana are important food crops. Here also fertilizer is only applied to the cash crops (cotton and tobacco); manure if available to the food crops. Some parts of the area are fallow and used for cattle grazing (cows and goats). After a few years the bush is cleared and the land is cultivated again. This form of rotation declines, due to the growing shortage of land in this area. The main soil types are the chromic and humic Acrisols (according to FAO). (T.P.I.P., 1987).

3.2 Growth stage of the crops during the experiment

Maize field, cotton zone

After soil tillage with a fork jembe, maize, beans, cotton and some gourds were planted in the second week of October. In plots A and B (half) only maize and cotton, in the other plots also beans were planted. Litter at this moment consists mainly of maize stems, cotton stems and firm parts of the cotton boll (hardened carpels). In November/December weeding was done with a panga and the weeds left between the rows in small heaps. In December a big heterogeneity in height between the maize plants became visible: 35-200 cm, on average 150 cm. Especially A ,B and J were growing very poor,with a lot of open space. The first weeks of January the beans ripened, leaves fell down and thus produced a lot of light litter. The ripe beans were harvested in the fourth week of January, the remains were still in the ground, left unweeded. In February the litter is composed mostly of maize- and bean leaves till harvest of the maize cobs at the end of the month, which gave a big supply of leaves, cob leaves and stems. The first week of March the remaining maize plants were put down in the plots C-J, producing a lot of litter on the ground and more light for the cotton plants. In April also plots A and B were cleared from maize plants, leaving cotton as the only standing crop.

For the maize field in the cotton zone an estimation of the maize yield is made, according to Ooms (1986). Length and circumference of the plants were measured in the field, also amount of cobs per plant pit and plant pits per m^2. Ooms composed a formula for the Chuka area by which the weight of the average cob can be calculated: $Y = -6.59 + 0.39 X$,

in which Y is cob weight (gramme) and X is length x circumference (cm^2).

For the experimental area an average yield of 270 kg/acre is estimated. Ooms found yields of 865 $\pm$340 kg/acre for fields in the near distance of our plot. The formula is less reliable at such low yields, but together with the bad appearance of the crop this was without doubt a very low yield.

Shortage of phosphate and nitrate were clear and a lot of insects (among others bugs, beatles, ants and plantlice) were found on the cobs and leaves.

Maize field, tea zone

Maize is the only crop here. At the start of the experiment in November big differences in height of the maize were visible: A:50-150 cm, B:15-30 cm, C:50-200 cm, D:50-200 cm, E:100-200 cm, F:30-100 cm, G:30-125 cm, H:50-150 cm. These heights didn't change much during the months. Only the amount of weeds increased, but no weeding was done. The maize was growing not so well: a lot of deficiency symptoms were visible (especially nitrogen, phosphorous and potassium). From December on at times maize was harvested and fed to the cows (stems and cobs). Both the absence of weeding and the feeding of the maize stems to the cattle were responsible for the presence of very few litter. Only in plot A a concentration of maize litter was present. In the beginning of February the shamba was prepared for the next season by digging with a fork jembe, also digging the weeds under. In March new maize and potatoes were planted, while also a handful of manure was added to each plantpit. With the first rains the young plants appeared in March/April.

3.2 Map of termite nests near plots in the cotton zone

Estimating the population density of termites is not easy, because of the problems with sampling (see 2.3). For getting an impression of the presence of termites in the surroundings of the research plots a localization of the different nests was made as far as they were visible (and found) aboveground.

In the tea zone no aboveground nests were found.

For the cotton zone a map was drawn, see figure 8.

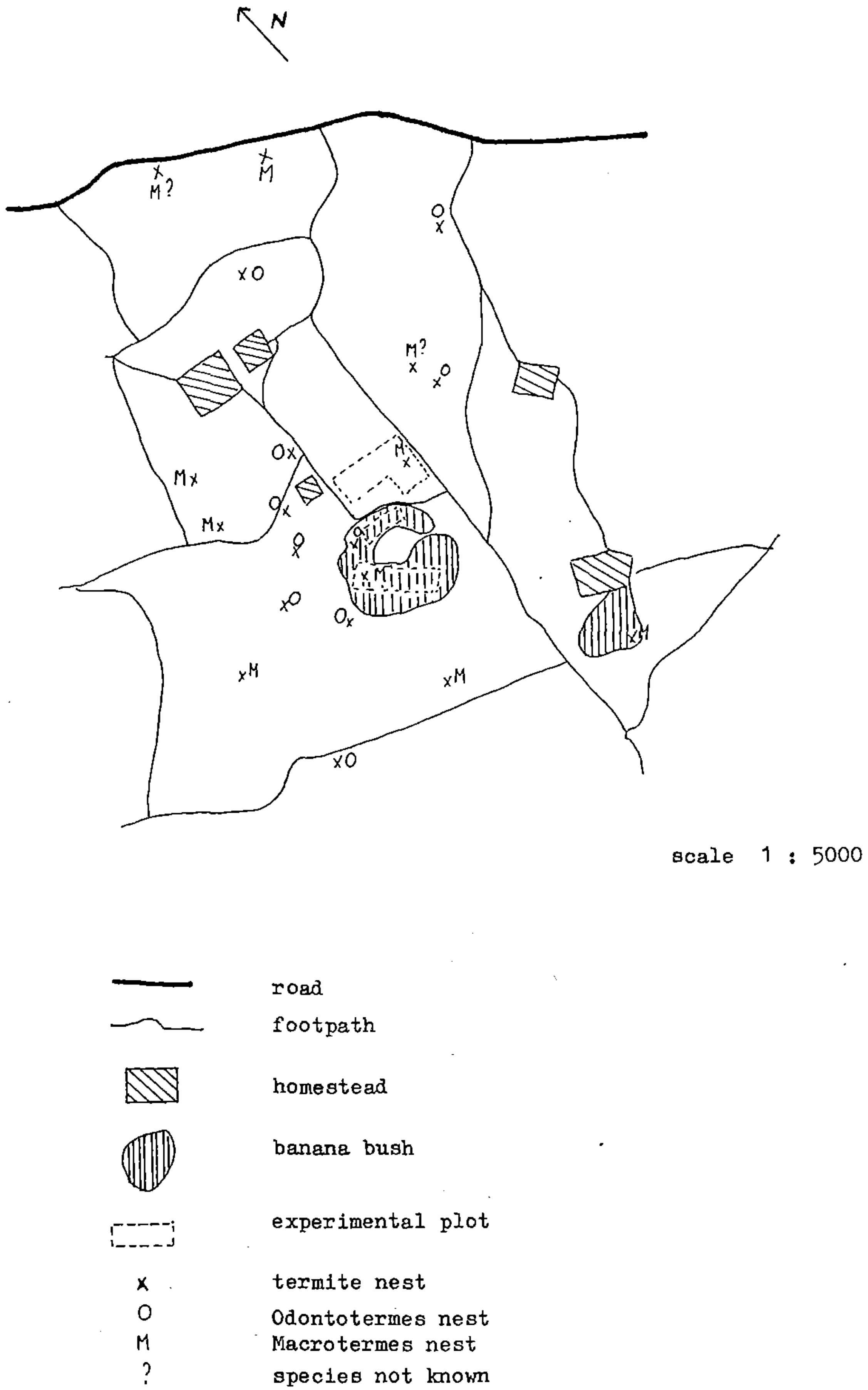

Figure 8 Map of termite nests in surroundings of experimental plots in the cotton zone.

By walking around in this area quite often, most nests were localized. Especially the Odontotermes nests were sometimes not easily found, because mostly the aboveground part consists only of a few holes, not extending above the surface. In the immediate surroundings of the banana and maize plot the nest localization therefore is most accurate.
The nests, indicated on the map are the "living" ones (termites or fresh formed nest parts seen). For nests marked with "?" on the map it was not sure if they were inhabited by termites during the experimental period.

4 Results and discussion of results

4.1 Microclimate

In Appendix A air temperature (dry and wet),relative air humidity, soil temperature at 5 and 15 cm and rainfall are given for the plots in the cotton zone and the tea zone.
Appendix B shows the soil water content for the plots and air temperature and relative air humidity comparatively for maize field and standing vegetation for both zones.
Comparing the air temperature of maize and banana (cotton zone) (appendix B) only a small difference can be seen, even during the course of the day. In general under banana a temperature which is a few degrees lower is measured than under maize. The relative air humidity under banana however is always higher than under maize at the same time. The soil temperature at 5 cm is in the banana bush 5 - 10 °C lower compared with the maize field. Even at 5 cm a difference of 2°C is common.
In the tea zone a comparable situation exists when is looked at a maize field and the Mount Kenya Forest: the air temperature is always lower and the relative air humidity is higher.
Our expectations about a more equal microclimate under a standing vegetation are in agreement with these observations.

4.2 Litter production

In table 1 and 2 the litter production of both maizefields in cotton zone and tea zone is represented.
For the maize field in the cotton zone average litter production for the three in 4.3.1 distincted periods is also calculated.

Table 1 Litter production maize, cotton zone; dryweight (gramme/m^2)
(- : no litter present)

date	site 1	site 2	site 3	average	kind of litter
8/11	60.7	230.1	194.9	221±23	maize- and cotton stems, cotton carpels
19/12	178.3	-	-		weeds
16/1	-	15.5	-	50±16	bean leaves
30/1	8.6	17.8	6.4		bean leaves
12/2	14.0	12.6	18.9		maize- and bean leaves
19/2	9.6	18.0	28.8		maize- and bean leaves
27/2	118.2	-	-	129±45	maize leaves,cobs and stems
13/3	-	170.3	81.2		idem
3/4	16.7	-	-		maize leaves
total	406.1	464.3	330.2	400±67	

An average litter production of 400 ± 67 gr/m^2 is calculated for the experimental period.

Table 2 Litter production maize, tea zone; dryweight (gramme/m^2)

date	site 1	site 2	site 3	kind of litter
13/11	125.2	54.2	39.7	maize stems
25/11	64.2	19.4	18.9	maize stems; tree leaves
19/12	-	-	-	sites 2 and 3: a lot of grass growing
15/1	14.1	-	_	
17/2	66.8	159.7	68.4	maize stems
19/3	-	-	-	
2/4	-	-	-	
total	270.3	233.3	127.0	

An average litter production of 210 $\pm$ 74 gramme/m^2 is calculated for the experimental period.

For estimating biomass in the banana bush a special method was used, described in section 2.3.
For the calculation of the volume of a banana stem the following formulas were used:

$$r_i = \frac{c_i}{2\pi}$$ in which c:circumference, i: 1,2

$$v = \pi r_1^2 \times 1/2\ l + \pi r_2^2 \times 1/2\ l$$ in which v :content; l :length; $r_{1,2}$:radius

Because of the calculated volume and the known dryweight of the sample, the dryweight of the whole stem can be calculated. In table 3 the measured data and the calculated weights are given.

Table 3 Biomass estimation of 5 (cut/harvested) banana plants

banana plant no.	sample l (cm)	sample c (cm)	sample w (gr.)	sample weight of 1cm	stem l (cm)	stem c_1 (cm)	stem c_2 (cm)	stem calc. wght(gr)	leaves dry-wght(gr)	total weight (gr)
1	30	49	339.4	0.059	460	66	51	7500	2570	10070
2	30	32	56.9	0.023	440	45	30	1160	785	1945
3	28	46	172.3	0.036	480	79	52	6179	2610	8789
4	35	44	202.1	0.038	390	57	42	2973	2000	4973
5	26	45	181.1	0.043	525	66	44	5653	1675	7328

l: length; c_1: circumference at 1 metre aboveground; c_2: circumference at 1 metre from top; w: weight
On average a total dryweight of 6600 $\pm$ 3230 gramme per cut (harvested) plant is calculated.

Table 4 Acreage of clusters of 15 banana plants and number of plants cut after 7 weeks

cluster no.	acreage (m^2)	no of cut plants	cluster no.	acreage (m^2)	no of cut plants
1	12	0	11	10.5	3
2	9	0	12	6	2
3	15	2	13	9	0
4	12	2	14	8	0
5	8	1	15	8	0
6	8	0	16	12	0
7	8	4	17	12	0
8	8	1	18	10	0
9	10	0	19	10;5	1
10	8	2	20	12	2

On average one cluster has an average of 10 $\pm$ 2 m^2 and per cluster 1 $\pm$ 1 plants were cut after 7 weeks.

A small rope has been tied around the stems to mark them. With this method a risk of people removing the ropes did exist, but luckily this did not occur.

An average density of 15 plants per 10 $\pm$ 2 m^2 was estimated. After 7 weeks 1 $\pm$ 1 plant per cluster was cut (see table). Together with the average weight per cut plant of 6600 $\pm$ 3230 gramme (from table) the very rough estimation of 5000 (500-11,000) gramme/m^2/year for the banana bush is calculated.
With these estimations we can conclude that the litter production in the banana bush is about 10-12 times higher than in the maize plot in the cotton zone. The litter production of the maize plot in the tea zone is only half the production of the maize plot in the cotton zone.

4.3 Activity measurements

4.3.1 Transect observations

Maizefield, cotton zone

As explained in the methods (2.5) the activity observations were first planned every three weeks for a few successive days, both in the morning and in the late afternoon. Soon it became clear that the termites forage in a certain direction from their nest and visit that area for some successive nights. Also especially the early morning observations were valuable: then a lot of freshly formed (still wet) sheetings were visible. During the day only rarely further building of the sheetings was observed with the frame method (see appendix C) and it concerned only small amounts of soil translocated. Therefore we changed our observation strategy: by visiting the fields more often and only doing observations in the (early) morning we tried to get more data about the amount of sheeting formation.
In the figures in appendix F the amount of sheetings (cm^2/m^2/day) observed in relation to the position in the field are represented. (These figures are composed using the data shown in appendix A).

Three periods are distinguished:

a. the (short) rainy season: the start of the experiment in November till the end of December, including the last rain of 24/12/1985.

b. the dry season: January, February and the first week of March

c. the (long) rainy season: starting with the first rain at 7/3/1986, till the end of the experiment in April.

The three periods are not entirely comparable: the observation method changed and the data obtained in November are not fully comparable with the other results; the number of observation days in the three periods is not the same (13, 20 and 10 days respectively) and the experiment started after the first rains of October, while in the third period the first rains are included. In spite of this the results are interpreted as if those differences are not of major importance.

A big difference in amount of sheetings in the rainy season of November/December compared with the rainy season of March/April becomes visible. An explanation for this difference is probably the kind of litter, which was present at the field. In November the litter was composed mostly of maize stems and cotton stems, on the ground since harvest in July-September (exact date not known, this period is valid for the cotton zone, according to Jaetzold, 1982). In March/April with the start of the rainy season, just after laying down the remaining maize plants, an enormous termite activity became visible. The still wet stems and especially the cob leaves showed to be very attractive for termite consumption. In plots A and B the maize plants were cut down a few weeks later than at the other plots. Before that time no termite activity was observed there. After the maize was felled already one week later fresh sheetings were present.

During the dry season (January/February) less sheetings were built, only sometimes on old maize stems. When freshly formed litter was available like the weed heaps in December and the bean leaves in January, this was preferred.

The figures show that the direction in which the termites are active differs in the different periods. In the November/December wet season activity is concentrated around the nest (plots A, B and C). The fact that the amount of sheetings in plot A is higher than in the other plots is possibly the result of the observation method: the first observations were done for some successive days from which it became visible that foraging is concentrated for a few days on the same spot (see 2.5, in Nov./Dec. plot A was visited for three successive observation days. In March/April Macrotermes especially forages in the plots C,D and F. This is likely the result of the litter availability on the field. In the plots A and B the maize plants were felled some weeks later than in the other plots. After cutting down the maize the termites were seen there as well (see appendix A and 2.5).

Another feature which follows from the figures is the relative short distance at which the termites are active. The plots near the termite mound (especially A,B,C and D) are more often visited by termites than the more distant plots (especially E,G,H and J). In the dry season the termites forage at the shortest distance from the nest. In March/April the largest distance is found: also sheetings in the plots E and G.

Macrotermes was responsible for the activity in the plots A,B,C and D, while in F,G,H,I and J also Odontotermes was found. From which nest the Odontotermes termites came is not clear: both Odontotermes nests are at about the same distance from the field (see map, 3.2). Also it was not clear if the Macrotermes' found in plot I came from the nest in the banana bush or from the maize field.

Because of the big heterogeneity both in distance and amount of sheetings formed on the transects (see Appendix F) an extrapolation to kg of soil replaced per hectare is not so simple to make.
In the figures in appendix F a simplified zonation is made to interprete the results about replaced soil by termites. Zones with sheetings are separated from zones without, only in the figure (Macrotermes, Mrch/Apr) different activity zones are distinguished. For all zones an average sheeting quantity in $cm^2/m^2/day$ is calculated. With help of a conversion factor (found by collecting soil of measured sheetings and weighing it) the soil quantity replaced in $gr/m^2/day$ can be calculated. As a very coarse estimation the overall quantity of soil replaced on the whole experimental plot is calculated.

Table 5 Calculated amount of soil replaced by termites from activity measurements (APP F) in $gr/m^2/day$

termite species	area	season					
		Nov./Dec.		Jan./Mrch.		Mrch./Apr.	
		m^2	$g/m^2/d$	m^2	$g/m^2/d$	m^2	$g/m^2/d$
Macrotermes	active zone	300	5	330	2	287	21
						112	13
						40	9
						200	5
	whole plot	1000	1.5	1000	0.7	1000	9
Odontotermes	active zone	150	0.02	100	0.06	274	2
	whole plot	1000	0.003	1000	0.006	1000	0.6

Conversion factor for Macrotermes sheeting: 1 cm^2 1.0 $\pm$ 0.8 gr
Odontotermes sheeting: 1 cm^2 0.09 $\pm$ 0.04 gr.

Note: Especially for Odontotermes the Nov./Dec. and Jan./Mrch values are based on very few observations and are therefore less reliable.

For the 24 weeks the experiment lasted (47 days Nov./Dec. period, 73 days Jan./Mrch period and 41 days Mrch./Apr. period) this means that 491 gr soil/m^2 is replaced by Macrotermes and 25 gr/m^2 by Odontotermes, holding for the experimental plot.
Because of the close relation of distance to the termite mound and litter availability (both amount and distribution) it is of importance to keep in mind some caution when extrapolating these results to bigger areas.

Banana bush, cotton zone
Although we observed termite activity in the banana bush not only in the early morning but also during the day, the same observation method as for the maize field was practised from point of view of efficiency.
As seen in appendix A very variable sheeting building observations on the transect become clear. Therefore no distinction between the different seasons is made, as is done for the maize field.
At the end of February a new transect (44-85) was added, because we had some doubt about the representativity of the old transect (0-44). The first weeks termite activity was seen on this new transect, but after a while it became quiet also there.

From incidental observations in other parts of the banana bush it became clear that termites were active during the whole period, although sometimes more sheetings were found and sometimes less. When sometimes sheeting building was observed it concerned always very big numbers of termites and mostly they were foraging on the same place for some successive days. An area of some square metres, covered with sheetings was often visible, although also eating without or with very few soil covering was observed. The assumption that use of a smaller transect than in the maize field was possible, because of an expected higher activity, is proved to be incorrect. Because of the scattered appearance of the activity, the chance of presence on the transect is not high and therefore a bigger sample area is needed. Maybe a higher density of transects at small distance of each other (comparable with the situation in the maize field) would have been more effective in estimating the termite activity. Because of the heterogeneity of organic material, the cluster appearance of the bananaplants and the shape of the banana bush (with the open space in the centre), it was not easy to define a representative transect. Looking at the results it is possible that the choice of the transect is responsible for the disappointing activity measurements in the banana bush.

Maize field, tea zone
In the maize field in the tea zone only a few times termites were observed on the transect: always Odontotermes and often without sheetings. Termites are occasionally found on the wooden poles of the fence of the adjacent cattle grazing plot. See Appendix A.
Because of the low activity it seemed better to us to spend not too much energy on activity observations and driving to and fro the plot. We reduced the amount of observations from January on. In the nearby Mount Kenya Forest (on the location of the maize plot the forest was cleared in 1947) also termites were found, but except humus feeders in the topsoil only Odontotermes on dead trees. This is in agreement with what Kooyman and Onck (1984) found in Kakamega Forest in West Kenya: in the forest only Odontotermes occurs, which consumes the dead trees from inside, without building sheetings.
With these facts the following assumption can be made: Odontotermes does occur in the tea zone and forages mainly on (dead) wood; only incidentally maize litter is consumed. Termites play not such a big role in the conversion of litter, especially when compared with the cotton zone.

4.3.2 Sheeting building estimated with frame

In Appendix C the results of drawing a certain sheeting every few hours are shown. Only a small fraction of the sheeting is built during daytime as can be seen from the pictures, especially when this is compared with the total number of sheetings built during the night.
Thus this method of observing during the day will not give a representative estimation of the overall sheeting building rate and we abandoned this method.

4.3.3 Sampling with pitfall traps

Because of the starting problems (see 2.5.3) the sampling with pitfall traps played only a small role in this experiment.
Traps were digged in in March, but appeared not to be successfull. In none of the four traps in the banana bush and the two in the maize field (both in the cotton zone) termites were collected. A lot of other insects (especially ants and locusts) and spiders were caught, but it seemed likely that they came from the surface. The plastic with soil on top was not able to prevent

the animals coming into the traps. Even with a better coverage and with more traps placed we don't expect better results with catching termites. Estimating numbers of active termites remains a problem!

4.4 Litter consumption

In November we started the experiments. As the rainy season had already begun, we were a bit in a hurry. Therefore the methods were not tested beforehand and some essential data lack from the first period. For example the first litter bags in the maize field, cotton zone have an unknown starting weight and some water contents are missing. Also the treatment of some samples in the laboratory went wrong, caused by incorrect instructions to our assistant or communication problems.
The litter samples were weighed in the field with a triple beam balance. Comparison of the accuracy with the Sartorius digital balance in the laboratory showed a difference of some 4 %. For samples with a weight of 25 gramme this means an inaccuracy of 1 gramme.

Especially at the start of the experiment a lot of termites were caught and named using a determination key (Bouillon, 1965) (see appendix G).
After some time most species were easily recognized in the field and their presence in the litter bags or on the activity transects just noted.
In the tea zone three species of **Odontotermes** were found:
* species 1 foraging under coffee and in a vegetable garden
* species 2 in the forest, foraging under wood
* species 3 in the maize plot and foraging under tea.

In the cotton zone of **Macrotermes**, **Pseudocanthotermes**, **Ancistrotermes** and **Microtermes** one species was found. Two **Odontotermes** species were found:
* species 4 in banana bush and maize plot
* species 5 other fields in the cotton zone.

Dominant species in the banana bush was Odontotermes sp.4, Macrotermes was often found, Pseudocanthotermes less often. In the maize plot Macrotermes was very numerous, also Microtermes was often found. Less often Odontotermes sp.4 were seen. Incidentally Pseudocanthotermes and Ancistrotermes were found.

4.4.1 Litter consumption from aboveground litter bags

Cottonzone
In appendix D schemes D1 and D2 for aboveground litter bags in maize field and banana bush in the cotton zone show in which week a certain litter bag was found eaten and when it was renewed. With these data table 4 is composed : eaten litter bags are related to the total amount of litter bags available (unattacked by termites the week before) per week.

Table 6 Aboveground litter bags in maize and banana, eaten in relation to total availability per week.

	week	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
maize	eaten	1	0	0	1	1	0	0	0	0	0	0	2	2	0	1	1	1	0	1	1	1	2	1	0
	total	20	16	19	20	19	18	19	20	20	16	16	16	18	15	17	19	10	10	10	9	9	9	8	8
	eaten/total	0.05	0	0	0.05	0.05	0	0	0	0	0	0	0.13	0.11	0	0.06	0.06	0.05	0	0.10	0.11	0.11	0.22	0.13	0
banana	eaten	0	0	1	1	0	3	2	0	1	0	0	0	2	0	0	1	1	0	2	0	2	1	0	0
	total	10	10	10	9	8	9	9	7	8	5	9	9	10	6	10	10	10	10	10	10	10	10	9	10
	eaten/total	0	0	0.10	0.11	0	0.33	0.22	0	0.13	0	0	0	0.20	0	0	0.10	0.10	0	0.20	0	0.20	0.10	0	0

On average: eaten litter bags / total litter bags for maize: 0.05 ± 0.06
banana: 0.07 ± 0.10

In spite of the big variance these averages give a slight indication about the area foraged by termites in the two habitats per unit of time. For example: a ratio of 0.05 means: on a part of 0.05 m^2 of a total area of 1 m^2 foraging by termites occurs in one week. Also: the whole area of 1 m^2 is foraged in 1/0.05 = 20 weeks.

Especially in December a lot of aboveground litter bags in the maize field were inhabited by ants. Although without doubt ants are of importance to soil formation, in this study we are especially interested in termites, because of their use of salivary excretions for cementing the soil particles for the building of sheetings. The presence of ants in aboveground litter bags is likely to inhibit the litter consumption by termites, because their "living in a state of war" (Lepage, 1981; Lepage and Darlington, 1984; Sheppe, 1970).

During the experiment a reasonable amount of aboveground litter bags was visited by termites in the cotton zone (termites seen during the weekly controls and/or obvious presence of sheetings). In spite of our request to the owner of the shamba not to remove the gauzes and to tell it also to the children, especially during the Christmas holiday a lot of aboveground litter bags were destroyed. Notes, tied to the gauze, in Kiembu and Kiswahili languages had no effect; some of them disappeared even faster. Especially after the disturbance of some eaten litter bags, we decided to remove litter bags with sheetings after one week or immediately after our observation of an eaten litter bag (in the case termites were already finished), instead of leaving the litter bags in the field for two more weeks.

In spite of some lacking water content data the remaining measured and calculated data are represented in the tables 7, 8, 9 and 10.

Table 7 Non-eaten aboveground litter bags maize field, cotton zone

season	litter bag number	in wet (g)	water content (%)	in dry (g)	out dry (g)	soil (g)	in-out (g)
Nov.-	A(9.4)	41	?		28	7	
Dec.	D(3.5)	63	?		49	53	
	E(3.3)	70	?		41	26	
	F(8.8)	33	?		15	-	
	H(3.4)	±162	?		54	18	
	I(6.8)	19	?		9	1	
	J(2,10)	±162	?		95	34	
	J(7.3)	76	?		65	8	
Mrch.-	A(9.4)	57	6	54	68	52	-14
Apr.	B(7.10)	28	6	26	29	39	-3
	G(2.2)	76	9	70	70	33	0
	I(3.3)	23	6	22	23	19	-1

In table 7, 8, 9 and 10 with "in dry" is meant the calculated in dry weight (from "in wet" and "water content"); "eaten" is calculated by subtracting "out dry" from " in dry". Under "remarks" the observed presence of termites is noticed.
For Nov.-Dec. all litter bags except H(3.4) and J(2.10) were set in at the same time. The litter bags in Mrch.-Apr. had a gauze cover.

Table 8 Non-eaten aboveground litter bags banana, cotton zone

season	litter bag number	in wet (g)	water content (%)	in dry (g)	out dry (g)	soil (g)	in-out (g)
Nov.- Dec.	2	432	58	181	76	32	105
	4	409	58	172	181	18	-9
	8	323	58	136	171	4	-35
	9	704	58	296	101	7	195
	10	446	58	187	111	17	76
Jan.- Febr.	3	83	19	67	54	3	13
	4	191	40	115	86	-	29
	5	196	40	118	97	3	21
Mrch.- Apr.	3	104	7	97	90	-	7
	4	78	7	73	79	-	-6
	5	79	7	74	102	-	-28
	6	82	9	75	67	-	8
	9	105	6	98	70	-	28
	10	89	8	82	54	-	28

At the start of the experiment some water content samples at the same time and place were taken, showing a small variance in the maize (11.4, 12.0 and 11.1%) and a bigger difference in the banana (23.2 and 30.6%). We concluded from these results that with emphasis on representativity this method should be workable. After all the error made by taking a water content sample was probably bigger than expected (although two (maize) samples taken at the same time in March had comparable water contents: 13.4 and 14.7%).
When is looked at table 5 and 6 (non-eaten aboveground litter bags) some big differences in "in" and "out" weight become clear. A possibility for this differences is the use of incorrect water contents: for litter bags 4 and 8 (Nov.-Dec.) and a water content of respectively 56% and 47% instead of 58% "nothing" is eaten. For the litter bags 2 and 9 on the other hand, with water contents of resp. 82 and 86% the consumption is zero. For litter bags 4 and 5 (Jan.-Febr.) when water contents of resp. 50 and 55% instead of 40% are considered, no difference in "in" and "out" weight is measured.
Another possibility is the loss of litter lying on the gauze, for example by people (harvesting bananas and cutting banana plants) or animals (chicken) or the wind (in the maize field). The use of envelope shaped litter bags would have given better results, although this is a less well simulation of the exposition of litter in the field situation. In the maize field such litter bags were installed in the beginning of March, due to the very light litter present at that moment (maize and bean leaves).

Table 9 Eaten aboveground litter bags, maize ,cotton zone.

season	litter bag number	in wet (g)	water content (%)	in dry (g)	out dry (g)	soil (g)	eaten (g)	remarks
Nov.- Dec.	D(9.6)	±245	34	±162	35	2506	?	Macrot.
	H(7.8)	63	?		24	178	?	Odontot.
Jan.- Febr.	C(2.2)	43	?		9	93	?	Macrot.
	G(2.2)	54	11	48	26	8	22	
	B(3.3)	138	?		7	83	?	Macrot.
	C(7.7)	98	11	87	56	21	31	
	D(9.6)	103	11	92	84	143	8	Macrot.
	D(3.5)	31	?		17	56	?	Macrot.
	D(9.6)	82	9	75	40	28	35	
Mrch.- Apr.	D(9.6)	55	9	50	37	191	13	Macrot.
	D(9.6)	95	12	84	44	49	40	Macrot.
	C(7.7)	36	6	34	7	147	27	Macrot.
	C(7.7)	96	21	76	47	349	29	Macrot.
	F(9.4)	106	11	95	34	667	61	Macrot.
	E(9.7)	45	6	42	24	29	18	?
average				68+23		163± 206	28±15	

In spite of the above posed consideration about incorrect water contents, possible loss of litter and inaccuracy of weighing on the balance we used in the field, found losses in weight from "eaten" litter bags are contributed to foraging by termites, although with some reserves.
See table 9 and 10.
The amount of litter eaten by termites is not constant: sometimes quite a lot is eaten and sometimes only a few grammes, it seems independent of the amount offered on the litter bag.
A certain amount of litter consumed (in gramme) compared to the amount of soil covering (in gramme) cannot be concluded with these results and this seemed reasonable because sheetings are built round a volume instead of round a certain weight. For example a piece of maize stem weighs more than some cobleaves, but has a much smaller volume.
In the banana bush often signs of termites eating on leaves were seen (numerous small bites) and also termites foraging inside banana stems without soil coverings. In the maize field these signs on leaves were also found, although less often.

Table 10 Eaten aboveground litter bags, banana, cotton zone

season	litter bag number	in wet (g)	water content (%)	in dry (g)	out dry (g)	soil (g)	eaten (g)	remarks
Nov.-	3	294	58	124	121	9	3	
Dec.	5	431	58	181	130	48	51	
	1	330	58	139	111	12	28	Odontot.
	6	385	58	162	109	83	53	Macrot.
	7	338	58	142	134	112	8	
Jan.-	8	139	40	83	56	25	27	
Febr.	8	90	19	73	45	15	28	Pseudoc.
	10	154	6	145	85	11	60	
	10	104	9	95	64	75	31	
Mrch.-	1	100	8	92	57	19	35	
Apr.	2	210	40	126	99	-	27	
	7	96	6	90	82	37	9	
	8	126	7	117	93	19	24	
	2	59	7	55	51	6	4	Odontot.
average				116± 36		34± 34	28±18	

Although some big differences in amount eaten occur averages are calculated: for the maize field offered 68 ± 23 gr, eaten 28 ±15 gr and for the banana bush offered 116 ±36 gr and eaten 28 ±18 gr.
With the assumption that the amount eaten is a constant factor, independent of the amount of litter available (using the above mentioned averages for maize 59% and for banana 76% left) and the average area foraged by termites per week (from table 4) a very coarse approach about the amount of litter left in the field can be made. It should be noted that the obtained data about litter consumption for maize are mainly based on the litter bags B, C and D, at short distance of the Macrotermes mound. Without paying attention to differences in litter availability during the growing season in the maize field a pool of 400 ± 67 gr litter/m^2 was present during the 24 weeks of our experiment. Using very simple calculations an estimation of total litter disappearance can be made. For the maize field this could be done as follows:
Ratio eaten litter bags / total litter bags: 0.05 ± 0.06 (table 4). That means that after 1/0.05 = 20 weeks 1 m^2 is foraged.
On 1 m^2 400 gr litter is present. After the first 20 weeks, taking the figures from the litter bag experiments, 400 x 0.59 = 236 gr is left. In the next 4 weeks 0.05 x 4 = 0.2 m^2 is foraged. On 0.2 m^2 is 236 x 0.2 = 47 gr litter present, after foraging 47 x 0.59 = 28 gr. Unforaged is 0.8 m^2 with 0.8 x 236 = 189 gr litter. Together 189 + 28 = 217 gr/m^2 left after 24 weeks. The maximum foraging rate would be 1/0.05+0.06 = 9 weeks for 1 m^2. Calculation of the litter disappearance in the same way results in 101 gr/m^2 left.

With above mentioned assumptions after 24 weeks 101-217 gr/m^2 is still present at the maize field. For the banana bush with an average litter production input of 2308 gr/m^2/24 weeks after 24 weeks 770-1496 gr/m^2 is left.
According to this estimation some seven times as much litter remains in the banana bush compared with the maize field. However especially under banana, where a more humid microclimate exists other soil organisms probably play an important role (often other soil organisms seen in the litter layer, in litter bags often fungi present in contrast with those from the maize field).
With the use of these coarse average values concluding should be done very cautiously. For banana the biomass estimation is a handicap, while for maize by using the overall litter production eventual periods of shortage of litter are excluded. This experiment is done including the short dry season only, thus the results are maybe not representative for a whole year. The long dry season is expected to be of more importance, especially in relation to litter shortage. In this respect it has to be mentioned that in October, at the end of the preceeding long dry period still a reasonable amount of litter was present in the field. (see also table (litter production))

Litter availability
By exposing litter, collected from 1 m^2, at aboveground litter bags an estimation of the litter availability is obtained.
Because not all litter bags are replaced at the same time and the lack of some water contents the data have to be combined to the values given in table 11.

Table 11 Litter availability in gr/m^2 as calculated from the in-weight from the aboveground litter bags, maize, cotton zone

	Nov.	Dec.	Jan.-Febr.	Mrch.-Apr.
maize	162±89	79±30	29±9	73±22

With litter production we tried to estimate how much litter is produced (2.4), while with litter availability an estimation of the amount of litter present on the ground is given. Probably with litter production an overestimation is made, e.g. by wind moving litter towards the collecting sites; while with litter availablity an underestimation is made, e.g. by not taking every small piece of litter, especially when a lot of organic matter is available. Despite these inaccuracies a coarse estimation about aboveground consumption can be done:
During the experimental period 400 gr/m^2 is produced (see table 1).. In March/April only a quantity of 73 gr/m^2 is present in the field (table 9). An amount of 400 - 73 = 327 gr/m^2 disappeared, in other words is consumed by termites.
For banana the amount of litter placed on the gauzes did not give a reasonable approximation of the litter availablity. The heterogeneity is very high and in particular the fresh banana litter is very voluminous: concentrating litter from 0.25 m^2 on a 0.09 m^2 gauze thus impossible. In the banana bush litter from less dense accumulated sites was used for exposition to termite consumption.

Tea zone
Ten aboveground litter bags were laid out in the eight plots in November. Six weeks later none showed signs of eating by termites and on all the litter was replaced by fresh material. These new litter bags also remained untouched and were removed at the end of January on request of the farmer for tillage of the shamba. Because of the lack of eating, our decreased attention for this plot and the risk of gauzes removed by people on a shamba without crops, we didn't replace aboveground litter bags again. Instead part of the gauzes was used for extra underground litter bags and part to replace the lost ones in the cotton zone.
A low termite consumption and sheeting formation appears from this experiment with aboveground litter bags in the tea zone.

4.4.2 Litter consumption from underground litter bags

The schemes E1 and E2 in appendix E show in which week which litter bag was renewed and the dryweights "in", "out" and "eaten". When termites or obvious eating signs were seen during renewing the litter, this was also written in the scheme.
The weights are given in grammes, according to the very probable inaccuracies in the methods. Water content samples for calculating the dryweight "in" were chosen representatively in the field. Sometimes however the measured decrease in weight seemed unreasonable, for example when no eating signs were visible or when dryweight "out" is some grammes more than the dryweight "in". A possible explanation for this difference is the use of incorrect water contents percentages, see also 4.4.1. Also with the weighing in the field an error of about one gramme is easily made. For a decrease in weight without visible eating signs can be thought of consumption by micro- or mesofauna, although this is not expected to be more than a few grammes. For some series, when this seemed likely, the "in"-weight is adapted, thus resulting in more "natural" results (also written in the scheme).
All other weight decreases are considered as caused by termite foraging.
Just after laying out the transect line and installating the litter bags in the banana bush it became clear that transect 1 was very close, nearly part of a Macrotermes mound. The first eight weeks a high consumption was measured. After this period of high activity we didn't see termites at this site again.

Cotton zone
In the underground less extreme microclimatic differences occurred and in this respect no distinction between the wet and dry periods should be expected. As the overall termite activity possibly differs in the different periods and also the soil moisture content is may be importance for termite foraging, thus the results are also interpreted with attention to the three periods as described in 4.3.1. Expected differences in foraging quantity between bigger and smaller termites (in this experiment resp. Macrotermes and Odontotermes versus Microtermes) can not be concluded from these results, owing to the used method. Collecting the litter bags occurred independent of visible eating signs by termites (in contrast with the aboveground litter bags). The time during which termites were active in the litter bag is therefore unknown. (E.g. Bigger termites which were only present for a short time meant only small losses in weight of the litter found).
With the data from Appendix E average eating is calculated for the touched litter bags for the whole period and the three in 4.3.1 distincted periods

(table 12). The in-weight varies between 18 and 24 gramme, but this seems of no importance to the amount eaten and therefore only average eating is represented here.

Table 12 Average eating per foraged litter bag in gramme for maize plot and banana plot in different periods

	maize	banana
whole period	5.9 ±5.0	4.7 ±5.0
Nov.-Dec.	4.0 ±2.7	5.3 ±4.7
Jan.-Mrch.	6.6 ±4.8	6.5 ±6.5
Mrch.-Apr.	6.8 ±6.0	2.7 ±3.0

Interpreting the results from table 10 immediately the big variance becomes clear, mainly due to foraging by different termite species (in general: bigger and smaller eaters) and by the unknown foraging time. In spite of these imperfections we will try to interprete the results.
For the maize plot the November/December period seems to act as a kind of accustomating period, while from January on the consumption remains constant. Looking at scheme (appendix E) the presence of Microtermes in the maize field is remarkable: once present these termites stay at a specific site, only driven out temporary by the bigger Macrotermes or Odontotermes. In this way the Nov./Dec. period can be seen as a colonization period for Microtermes to sites high in organic matter.
Another feature which becomes clear from scheme E1 is the presence of Macrotermes in litter bags B, C, D and F; Odontotermes in litter bags F, H and J and Microtermes foraging at all sites. For Macrotermes and Odontotermes this is in agreement with the activity observations (4.3).
Kooyman and Onck (1984) also found Microtermes to increase under agriculture. The small, diffuse underground nests are relatively unaffected by agricultural practises. In litter consumption Microtermes would not be unimportant, especially due to the area they inhabit.
In our experiment with litter bags at fixed positions consumption estimations for a situation with Microtermes present can be done: on average 1-5 gr/week(Appendix E , only those counted when the sample also was visited by Microtermes before). This estimation will be too optimistic, because searching and colonization will take time (dependent among others on population density in the field). Microtermes needed only 5 weeks to find 9 out of 10 underground litter bags, so they seem to be very effective in locating food sources all over the field. Calculations about the amount of litter consumption per m^2 by Microtermes are not so easily made: The ratio eaten/ total litter bags can only be determined for the first 5 weeks, because after localizing a litter bag Microtermes stays at the same spot, using the fresh material of the new litter bag. Although thus no precise estimation of litter consumption per square metre by Microtermes can be made, it seemed likely that they are important in-removal of underground litter, being very effective in locating food sources and staying there. On the other hand they consumed only a small amount of litter per week compared to foraging activity of bigger termites, which are only very incidentally visiting the underground litter bags.
Banana litter seems to be popular in the Jan./Mrch. (dry) period, especially when compared with the Mrch./Apr, (wet) period. The banana bush could act as a kind of foraging place during times of litter scarcity ,but the relatively low numbers of termites compared with the maize field do suppose that maybe

something else is important, for example the role of other soil organisms can't be excluded (see 4.4.1).
Comparing both schemes (maize and banana in Appendix E) the difference in number of times termites were present in litter bags when digging them up becomes clear. In the maize field much more often termites were seen than in the banana bush.

The ratio eaten to total litter bags differentiated per 1, 2 and 4 weeks the litter bags stayed underground for the different periods is shown in table 13 and 14.

Table 13 Ratio eaten/total litter bags per 1, 2 and 4 weeks underground in different periods, maize

weeks	1	2	4
whole period	0.65	0.78	0.86
Nov./Dec.	0.38	0.78	1.0
Jan./Mrch.	0.67	0.75	0.69
Mrch./Apr.	0.81	0.85	1.0

Table 14 Ratio eaten/total litter bags per 1, 2 and 4 weeks underground in different periods, banana

weeks	1	2	4
whole period	0.53	0.63	0.61
Nov./Dec.	0.50	0.53	0.50
Jan./Mrch.	0.57	0.67	0.54
Mrch./Apr.	0.53	0.69	0.83

The high ratios for maize, compared with banana are mainly the result of the Microtermes termites remaining at the site were the litter bag is dug under. Especially in the banana bush a 4-week period did not result in more consumption than measured in a 2-week period. Although the differences between a 1-week and a 2-week period are small, we think a 2-week period recommendable for further experiments from underground litter bags.

Tea zone
Also in Appendix E the obtained data from underground litter bags in the tea zone are shown. Only two times eating signs were observed and together with the absence of other visual observations about presence of termites, it seemed not legitimate to ascribe losses in weight to foraging by termites. Also from these results we can conclude that only a very low termite activity in the tea zone is present.

5 Conclusions and discussion

In this chapter first the used methods are discussed, followed by a discussion of the results and general conclusions.
Because of the preliminary character of this research the methods we used were just try outs based on descriptions by other researchers. Most of the other researchers have worked in a more natural situation. Working on agricultural land imposes some unexpected difficulties on the research as disturbance by man and domestic animals.
In general, following our results, more accurate methods should be used.
This research was done during the short dry season (January-March) including periods of the "short" and the "long" wet season. Especially for conclusions concerning litter availability and consumption by termites the long dry period (May-October) is of special interest. Consumption during periods of litter shortage can be of great importance, in particular when the termites start eating the crops.
The error resulted by weighing both under and above ground litterbags in the field and taking not enough representative water content samples makes it hard to relate measured litter disappearance to consumption by termites. More water content samples and more specified samples should be taken to obtain more reliable in-weight estimations. As a consequence of working in a densely populated area the litterbags laid out aboveground proved to be vulnerable for removal by people. Working in a fenced area can be considered, but was not possible in this research project. For aboveground consumption measurements envelope-shaped litterbags are a necessity, especially when light, easily blown litter is used.
Representativity of the data should be higher, therefore more observations should be done, in particular concerning the litter production estimates (more experimental sites) and the activity observations in the banana bush (use of a longer and more representative transect). Sampling under a crop as heterogenous as banana remains problematically, especially when overall estimations are required.
According to Bagine (1984) once a week collecting all sheetings from the whole transect was also possible (at least in the dry season): removing of the soil sheetings does not inhibit or enhance further soil transformation. In our experimental plot however, chicken destroyed a lot of sheetings, especially when there was a low crop density on the field, so the method of observing a lot of times was not bad, although very time consuming. By collecting the soil sheetings the use of a conversion factor (converting cm^2 into grammes) is avoided, resulting in a more reliable estimation of soil translocation.

A low termite activity in the tea zone, compared to the cotton zone becomes clear from the different observations (both on litter consumption and termite activity). It seems that termites are relatively unimportant in soil translocation and litter consumption in the tea zone.
For the cotton zone the hypothesis was posed that under banana termites have a greater influence on enrichment of the soil (visible by a darker topsoil) compared with maize as a result of both a less extreme microclimate and a higher litter production.
From our incidental observations indeed a more equable microclimate under banana follows (section 4.1):

* the variation of air temperatures of maize and banana don't differ much, even during the course of the day (although under maize the temperature

is often a few degrees higher).

* the relative air humidity in the banana bush is mostly higher compared to the maize field at the same time.
* the soil temperature at 5 cm depth is 5-10°C less for banana compared to maize, especially during the warmest part of the day. Even at 15 cm depth a difference of 2°C between banana and maize was observed.

The production of litter under banana was obviously higher and more constant than under maize.
It was not possible to quantify termite activity under banana by direct observations on a transect (4.3.1). This activity is still expected to be high, according to the incidental presence of great numbers of termites foraging on an area of a few square metres. In the maize field the termite activity was related to the presence of the termite nest: beyond a radius of about 20 metres from the Macrotermes mound a high activity was observed from both transect observations (4.3) and litter consumption (both above and under ground) experiments (4.4). On the experimental field also a zone of activity by Odontotermes (from which nest is unknown) exists, resulting in the overall estimation for quantity of soil translocated of 491 gr/m^2 for Macrotermes and 25 gr/m^2 for Odontotermes, holding for this location and the 24 weeks the experiment lasted.
Because of the dependence of termite activity to distance from the mound and the big heterogeneity in distribution of the sheetings (connected with litter distribution and availability) some caution must be practiced with extrapolation of these results to bigger areas.
Underground litter consumption experiments showed that besides bigger termites (as Macrotermes and Odontotermes) the smaller termite Microtermes is very numerous in the whole maize field. Only 1-5 gramme per week is foraged by Microtermes, but together with the high probability of presence (in 5 weeks 9 of the 10 underground litterbags were inhabited by Microtermes) these termites seemed to be important in underground litter consumption.
According to the above and under ground litter bag measurements the amount eaten from the litter bag by termites is comparable for maize and banana. The possibility of underestimating the real consumption for banana seems not unreasonable, especially when keeping the probably low representativity of the activity observations in mind. The use of more litterbags in the banana bush very likely should result in a higher attack rate and thus a higher litter consumption would be measured. The aboveground litterbags under banana are foraged a bit more often than the litterbags under maize, resulting in a slight higher ratio for banana: 0.07 ± 0.10 m^2/m^2.week against 0.05 ± 0.06 m^2/m^2.week for maize.
The litter consumption rates at aboveground litter bags together with some rather crude hypotheses concerning the foraging rate, the amount eaten by termites and the amount of litter present, resulted in a very coarse estimation of the amount of litter left after the 24 experimental weeks: for maize 100-220 gr/m^2 and for banana 770-1500 gr/m^2. This means that 180-300 gr/m^2 or 45-75% of the maize litter and 810-1540 gr/m^2 or 35-66% of the banana litter is eaten during the experimental period. From the litter availability calculations follows a consumption of 327 gr/m^2 for the maize field in the same period. Although both calculations must be seen as very coarse estimations, it is remarkable that the order of magnitude corresponds. Very generally 3/4 part of the available litter of the maize field has been consumed by termites during the 24 week experimental period.
A litter availability calculation for banana was not possible, but it seems likely that more litter disappears because of the higher activity of other soil organisms (both soil fauna and fungi were observed at the experimental

site.
Retrospectively, do termites enrich the soil by their activities and is this effect higher under banana than under maize?

* Termites are very likely the only important litter consumers in the maize field and of important consumers under banana. The nutrients however aren't brought back to the topsoil: sheeting analyses show that these have a higher C/N ratio and a lower Cation Exchange Capacity (CEC) than the topsoil (Bongers, 1987). Termite sheetings thus did not contribute to an increased soil fertility.
* Data about physical influence of termite activity on the soil of this site are not yet available, but from other research it seems very probably that termite presence has a favourable effect on soil physical properties (Wielemaker, 1984).
* The darker topsoil under banana is very probably the result of the activity of other soil organisms. Stimulation of these organisms by termite activity (e.g. by the continuous transport of soil material to the surface with the formation of sheetings) can't be excluded.

7 Literature

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The following pages contain the appendices.

Appendix A Transect observations tea zone: maize
cotton zone: maize and banana

B Microclimate: air temperature and relative air humidity
Soil water content

C Sheeting building estimated with frame

D Scheme position litter bags (both aboveground and underground) maize plot cotton zone
Schematic presentation aboveground litter bags, maize and banana cotton zone

E Underground litter bags, tea zone: maize
cotton zone: maize and banana

F Activity measurements- Sheeting formation in relation to position in the field, maize cotton zone; Nov/Dec, Jan/Mrch, Mrch/Apr.

G List of termites

Explanation

A In this appendix measured data concerning microclimate are given in relation to time of the day (air temperature (wet and dry), relative air humidity and soil temperature at 5 and 15 cm below soil surface, rainfall)
Under activity on transect a code is given: 7Ae15 means on transect A east, 7 metres 15 cm^2 freshly formed sheeting was found. 5Aw646: on transect A west, 5 metres 646 cm^2 sheeting was found.

B Air temperature and relative air humidity in relation to time of the day for the maize plot and a standing vegetation (Mount Kenya Forest in the tea zone and a banana bush in the cotton zone).

C Part of the sheeting which is freshly formed in relation to time of the day the observations were done.

E In Appendix E a schematic presentation of the renewal of the underground litter bags is given. In the same scheme the "in", "out" and "eaten" weights are given as well as the observed presence of termites in the litter bag:

An Ancistrotermes
Mi Microtermes
Od Odontotermes
Ma Macrotermes
Ps Pseudocanthotermes

F In Appendix F the sheeting formation as measured by the acreage is shown in relation to the position on the activity transect. For the two termite species Macrotermes and Odontotermes and the three periods (Nov/Dec wet season 1985; Jan/Mrch dry season 1986 and Mrch/Apr wet season 1986) separate figures are given. The number of times a certain above or underground litter bag was found eaten is also represented in these figures.

APPENDIX A
Transect observations
Maize cottonzone

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
7/11							33		
8/11	7	18.5	18	95			11	-	
	9	23.5	20	72				7Ae15	
	14.15	26	20.5	60				-	
	17.15	22.5	19	71				-	
9/11	7	20	18.5	86			2	6Ce116, 2Ce25, 1Ce16	Macrotermes
27/11	10.30	23	20	75			?	6Ae230, 3Fw62	at 15 and 18 hour still present, no fresh
	15	26	20	57				-	sheetings.
	18	22.5	18.5	67				-	A and B lot of weeds, F and I weeded.
28/11	8.30	23.5	20	72	21	22	0	6Ae205, 3Fw51	Macrotermes, at 12, 15 and 18 hour sheetings
	12.15	25.5	19.5	56	26.5	24			not bigger.
	15.15	27	19	46	31	26.5		6Ie45	Odontotermes
	18	23	18.5	65	31	26.5			
29/11	7.30	19	17.5	86			41	6Ae172	at 11.30 and 15.30 no new sheetings.
	9.45	23	18.5	65					
	11.30	26.5	20	54					
	14.15	27	19	46					
	16	26	18	44					
2/12							73		
4/12	11.30	24	20	69			22	0Bw69(Ma), 3Je30(Od)	soil wet (rain night before); A weeded.
9/12	10.15	25	20.5	66			1	6Ae1313(Ma)	
11/12	8	20.5	19	96			19	5Aw646, 6Aw18, 7Aw60, 9Aw24	
	11.45	25	20	63	23	22.5			
	15	25	20	63	27.5	24.5			
14/12	8.45	19	18.5	95			25	10Ae10	at night and day before rain.
17/12	10	25	20	63			0	6Ae22, 7Ae76, 9Ae25, 10Ae30, 10Cw10	all Macrotermes
19/12	9.30	24	20	69			0	4Ae8, 1Bw122, 2Bw698, 10Cw164	A: many sheetings, big activity(esp. weedheaps).
24/12	9	23	19	69			4	2Ae15, 6Ae44, 9Ae50, 10Ae18	C: many (old) sheetings; D-J: none.
30/12	9.30	23	18.5	65			0	10Be184, 10De75	A: many sheetings; also around nest.
8/1	9.45	25.5	18.5	50			0	-	no wet sheetings: too late in the morning?
16/1	8	22	16	54			0	-	
	13	30.5	17	24	27.5	25.5		4Bw71	
23/1	8	20	18	83	21.5	20	?	3Be59, 9Bw15, 8Cw10, 10Cw35, 1Ce14, 5Ce38, 8Ee46,	rain night before
	11	26.5	20	55	25	25		10Ee92, 2Ge15,1Iw3	
	12.45	28.5	20	45	26.5	25.5			
27/1	8	22.5	18.5	68			0	6Bw63	many sheetings on beanleaf litter.
30/1	8	22	18.5	72			0	5Ie15	
31/1	8.45	24	18.5	59			0	-	outside transect some activity.
	11	27	20	52	22.5	23			
3/2	9	25	20	63			0	2Be101, 4Be48, 5Ie162, 9Ie60	B:Macrotermes, I:Odontotermes
	11.30	30	21.5	47					
6/2	8.15	22	17	61			?	1Bw22, 9Be93, 7Dw8	cloudy day; some rainfall night before.
	11	24	18.5	59					

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
	14	29.5	19	38					
8/2	8.30	26	19	51			0	5Bw151, 1Ce20	sheetings on beanleaves.
10/2	8	22	15	47			0	-	
12/2	8.30	25	17	44			0	1Bw62, 2Be113	
	10	27	18.5	44	20.5	21			
	11	29	19	38	21.5	21.5			
	12.30	33	19	25	24.5	22			
	15	34	20	26	28	23			
	16	30.5	18.5	30	28.5	23.5			
	17	29.5	18	31	28.5	23.5			
	18	28	18	37	28	23			
13/2	7.30	20	15.5	63			0	4Be54, 5Be420	
15/2	7.30	20	15	59			0	4Be256, 0Ce3, 5Dw24, 8 Je44	B: sheeting + Macrotermes on maizecob.
17/2	7	16	14	81			0	-	
	8	21	17	67					
19/2	7.15	17	15	81			0	9Ce8, 4Fe83	cloudy till 10 a.m., afterwards sun.
	10	23	18.5	65	25	26			
	11	27	21	58	27.5	28			
	12	31	20.5	38	31	30			soil thermometers in the sun and metal case very
	14	32	20	32	37?	32?			hot.
	15.30	31	19	31	39?	33?			
	17	31	19	31	38?	33?			
22/2	7.30	22	17	61			0	-	
26/2	7	18	14.5	69			0	2Ce36	many signs of termite eating on maize leaves,
28/2	7.15	18	15	73			0	-	without sheetings (esp. plot D).
6/3	8.30	21.5	19	79			0	2Cw360	
	10	24	19.5	66	28	27.5			
	11	27	20.5	56	31	29.5			
	12	28	21	53	33	31			
8/3	8.15	22.5	19.5	76			?	8Ae223, 10Ae302, 1Ce77, 2Ce144, 3Ce377, 3Cw76,	after the first rain (some mm).
								4Cw90, 9Cw44, 10Cw51, 3De765, 4De177, 5De232,	plots C-G: maizeplants down.
								7De98, 8De103, 9De89, 8Dw496	
10/3	9	24	19.5	66			?	1Ae64, 10Be249, 5Bw232, 6Bw256, 1Ce65, 3Ce28, 5Cw48	rain at night before.
	11	26	24	85	26	24		7Cw126, 9Cw78, 10Cw147, 3Cw400, 4Cw292, 5De155,	plots H-J: maizeplants down.
	12	28	25	78	28	25		1Dw75, 3Dw170, 5Dw329, 7Dw1075, 8Dw105, 9Jw69	
	13	30	26	73	30	26			
12/3	8.30	25	20	63			0	4Ae204, 9Be23, 1Ce11, 2Ce67, 6Ce14, 7Ce99, 7Cw136	
								5De205, 8De23, 9De20, 1Dw170, 4Dw108, 6Dw66,	
								9Dw193, 10Ew250, 3Fe84, 5Ie331, 8Ie79, 10Ie60	
15/3	8.30	25	19.5	60			0	9Be40, 9Ce40	
18/3	9	23.5	20	72			5	4Ce183, 6Ce114, 4De44, 5De153, 7De504, 8De150,	D and E: Macrotermes
								9Ee233, 10Ee136, 8Fe12, 9Fe150, 10Hw133, 1Ie38,	8 F east: Ancistrotermes, 9 F east: Odontotermes
								2Ie40, 5Ie222, 6Ie84, 6Iw429	I west: Odontotermes
19/3	10.30				23	24			
	11.15				24.5	24			
20/3	9.15						6	0Ce276, 1Ce174, 8Ce72, 0Cw60, 2Cw36, 3Cw68, 4Cw499	C west: Macrotermes

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
								5Cw76, 6Cw156, 1De84, 3De108, 4De53, 5De154,	C west: Macrotermes, 1 F west: Odontotermes
								6De97, 10De318, 7Cw54, 10Cw81, 1Dw200, 3Dw147, 5Dw80	10 G west: Odontotermes
								7Dw165, 8Dw25, 8Ew176, 9Ew199, 10Ew159, 3Fe144	6 I west: Odontotermes
								5Fe150, 8Fe75, 9Fe63, 1Fw154, 10Gw636, 6Ie203,7Ie96	8 I east: Macrotermes
								8Ie376, 5Iw5400, 6Iw93 , 7Iw121,9Hw45, 10Hw205,	J west: Odontotermes
								4Jw72, 5Jw140	I west: Odontotermes
22/3							10		
24/3	8.45	22.5	18.5	68			0	1Ce[462], 3Cw100+[330] , 5Cw15+[306], 7Cw157, 9Ee32	
								8Ew66, 9Ew88, 2Fe45, 7 Gw900, 9Hw230, 10Hw125,	G west: Odontotermes; H and I west: Macrotermes
								7Iw154, 9Ie324	
26/3	8.45	23.5	19.5	69				6Cw265, 7Cw280, 8Ew42, 0Dw78, 1Fe88, 6Dw229	
	10	26	20	58					
	11	28	20	48					
	12	30	21.5	47					
	13	29	19.5	41					
	14	32	20	32					
	15	31	20.5	38					
1/4	9	26.5	21.5	64				7Cw39+[128], 6Hw156, 7 Iw42	rain more than one night before, a lot of
									sheetings washed away. few fresh sheetings on
									transect; some on termite mound.
8/4	8.30	24	18	56				8Bw291, 7Bw572, 6Bw145 , 5Bw36, 6Ew75, 9Ew60, 10Ew69	H west: Odontotermes; I west: Macrotermes
								6Ge260, 7Ge132, 8Ge45, 9Fw96, 6Fw1941(O), 5Fw758(M)	many sheetings destroyed by chicken; many signs
								2Fw3150(O), 7He1456(O) , 8He416, 5Jw915, 3Jw84(O)	of eating without sheeting formation, esp. on
								3Hw112, 9Iw1050	maize leaves.
10/4	9	23	19	69			36	no observations done	A: Macrotermes; E west: Macrotermes
	10.30	24	19.5	66					after a big shower at night: most sheetings
	12	24	19	62					washed away. termites active during whole
16/4							89	no observations done	morning (cloudy day).

APPENDIX A
Transect observations
Banana cottonzone

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
7/11	15.30	27	22	64			33		
8/11	7.15	18.5	18.5	100	20	21.5	11		
	10	23.5	20.5	75	20	21		9-450, 31-225, 3-16	9 and 31: Odontotermes; 3: Microtermes
	13.45	28.5	21	50	21	21		9-300, 31-150	
	16.45	22.5	20	78	22	21.5		31-54	
9/11	7.45	20	19.5	95			2	-	
16/11	14.30	29	19.5	40			?	-	raingauge stolen
27/11	11	23	21.5	88				-	30-31: Macrotermes building on nest (not on
	15.30	25	20	62				-	transect).
	18	23	19	68				37-0	Odontotermes under bananaleaves, no sheetings.
28/11	9.15	21.5	19.5	84				-	Odontotermes working on nest.
	12.30	25	20	63				-	
	15.45	24.5	19	59				-	
	17.30	23	18.5	65				-	
29/11	7.45	18.5	18	95	18.5	20	41	-	no activity on transect, many sheetings in
	12	25.5	20.5	63	19	20		-	bananabush.
	15.30	26	18	44	20.5	20		-	
	17.45	23	18.5	65	20.5	20.5		-	
2/12							73		
4/12	14	25	21	70	20	20	22	41-800	sheeting on bananaleaves.
9/12	10.45	23	20.5	79	19	20	1	10-(241)	
11/12	8.30	20.5	19	87	18.5	20	19	-	no activity on transect, on litterbag transect
	11.30	24	20.5	73					6-10 many sheetings. 7: 968; 9:393(Ps); 10: 869.
	15	25	21	70					
14/12	9.15	18.5	18.5	100			25	-	no activity on transect.
17/12	10.30	23	18.5	65			0	10-(120)	
19/12	9.45	22	19	76			0	-	litterbag transect: 1:2700(O),9:110,10:85(M).
24/12	9.30	22.5	19.5	76			4	21-(231)	
30/12	9.45	20.5	18.5	83			0	3-0, 9-249+(264), 11-0 , 13-(61), 14-70	3 and 11: Macrotermes eating without sheetings;
									14: sheetings formed on maize litter.
8/1	9.45	24.5	18.5	56			0	12-(198), 15-221+(58), 16-(71), 22-(185), 23-(162),	topsoil very dry!
								21-(205), 37-(50)	
16/1	9	22.5	16	54			0	-	
	13	27	16	31					
23/1	9	20	18.5	87			?	14-36, 17-(50)	14: on wooden pole.
	11.15	23.5	19.5	69					
	12.45	26	18.5	49					
27/1	8.30	22	18	68			0	-	
30/1	8	20.5	18	87			0	15-(45), 24-(546)	many signs of eating on dead and green leaves.
31/1	8.45	22.5	17	57			0	-	
3/2	9.45	25	18.5	54			0	-	
	11.30	29.5	20.5	43				1-(725), 34-405	34: Odontotermes, also eating without sheetings.
6/2	8.30	18.5	17	86			?	-	

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
	11	23.5	18.5	62	19	20			
	14	29.5	20	41	21	20			
8/2	9	23	18.5	65	18.5	19.5	0	-	
10/2	8	20	15.5	63	18	19	0	-	
12/2	9	23.5	17	52			0	-	Odontotermes' active, still at 15 hour in the
	10	26.5	18	43					shadow under mangotree at Southern border of
	11	28.5	19	40					bananabush: enormous sheeting on bananastem and
	12.30	32	19.5	30					leaves.
	15	32	20	32					
	16	30.5	18.5	31					
	17	29.5	18.5	33					
	18	28	18.5	40					
13/2	7.30	18.5	15	69			0	-	Odonto's near mangotree still active (see 12/2).
15/2	7.45	19	16	74	19.5	20	0	-	litterbag transect 4: Odontotermes, many
									termites, few sheetings.
17/2	7.45	17	15.5	86			0	-	
19/2	7.30	17	15	81			0	-	litterbag transect 10: 813 cm^2.
	10	22	18	68					
	11	26	19.5	54					
	12	28.5	20	45					
	14	32	19.5	30					
	15.30	30	19	35					
	17	28	18.5	40					
22/2	8	20	17.5	78			0	-	
26/2	7.45	18	15.5	77			0	47-143, 59-81	new transect: 81: Odontotermes
28/2	7.45	18	15.5	77			0	53-23, 69-100, 82-174	69 and 82: Odontotermes
8/3	8.30	21.5	20	87			?	-	activity in other parts of bananabush.
10/3	9.30	24	21	77			?	-	
12/3	9.15	24	19.5	66			0	-	
15/3	9	24	19	62			0	-	
18/3	10	23	19.5	72			5	14-1330, 41-54, 55-219	14 and 41: Odontotermes; 55: Macrotermes
20/3							6		
24/3	9.15	21.5	18	71			0	-	
26/3	10	25	20	63	20.5	21	0	-	
	11	28	20	48	21	21			
	12	31	21	40	22	21			
	13	29	20	43	22.5	21			
	14	32	21	37	23	21			
	15	30	19	35	23	21			
1/4	9.30	24.5	20	66			5		
3/4							4		
8/4	9.15	25	19	57			37	82-18	
10/4	9	23	19	69			36	no observations done	because of heavy rain sheetings washed away.
	10.30	24	19	62					
	12	24	19.5	66					
16/4							89	no observations done	idem

APPENDIX A

Transect observations

Maize teazone

date	time	air temp. °C	wet temp. °C	rel. hum. %	temp. soil 5 cm	temp. soil 15 cm	rain (mm)	activity on transect	remarks
15/11	14.15	25	18	49			0	-	termites seen in adjacent coffeeshamba.
24/11							99		no observations done.
25/11	10.15	19	17	81			6	-	no termite activity, quite a lot of ants.
	12.45	20.5	17.5	74	24	20		1Gs0	Odontotermes under piece of wood. no sheeting
	15.30	23.5	18	58	24	20			
26/11	13.45	23	18	62	26	21	0	-	no activity on transect.
	15.30	23	17.5	57	25	21		7An0	Odontotermes found in adjacent coffeeshamba and
									in vegetable garden. humusfeeders found in
									coffeeshamba. 15.30: Od. under maizestems.
27/11	12				23	20	0		
4/12	16.30	21	17.5	71			65	-	
10/12	9.45	19.5	18	84			2	2Cn208+(81)	Odontotermes
	11.45	20	17.5	77				1Fs5+(8), 5Cn29	also Odontotermes on fence poles: 405 cm²
	15	20	17.5	77				5Cn60, 28n10	freshly formed.
12/12	8.30	18	16.5	86			2	2Cn57+(107), 8Cn(18)	Odontotermes.
16/12	14	21	18	75			3	-	
19/12	16	22	18.5	72			0	-	A south: beyond transect 195 cm²
28/12	10	21	17	67			4	-	
7/1	13.30	22	17	60			0	8Cn(54)	
8/1	16	21.5	17.5	67			0	-	Odontotermes on fence poles + sheetings.
15/1	8.30	19	14	58			0	-	idem
	10.45	24	16.5	46	25	22			
	11.45	24	16	43	30	24.5			
20/1	8.30	21.5	15.5	53			0	-	beyond B old sheetings: 14 cm².
29/1	8.30	20	16	66			0	-	
4/2	9.15	20.5	16	63			0	-	
10/2	11.45	25	15.5	36	24	20	0	-	profile pit in maize field with 3 old termite
	12.30	26	15.5	32	27	20.5			(Odontotermes?) nests.
	14.15	27	16	31	30	22			
	17				33	25			
7/3	14	22	18	68			?	no observations done	because of planting no observations.
14/3							2	-	
19/3							6	-	
2/4	10	20	16.5	70			75	0An91	in A: Odontotermes without sheeting.
	11	19.5	16.5	74					
	12	22.5	17	57					
14/4	14.30	21	18	75		-	244	-	

APPENDIX B Soil watercontent

Table B.1 Soil watercontent (5), cottonzone

date	maize		banana	
	0-20cm	20-30cm	0-20cm	20-30cm
9/11	25.3	25.4	28.5	28.1
28/11	21.3	23.4	27.3	26.6
17/12	23.2	23.5	26.0	25.5
16/1	17.3	19.5	-	-
30/1	14.9	17.4	18.1	19.2
19/2	13.9	14.6	16.1	17.7
13/3	17.7	17.1	25.3	23.3
26/3	18.1	18.6	25.0	23.2
10/4	27.6	27.1	27.4	31.1

Table B.2 Soil watercontent (%), teazone

date	maize	
	0-20cm	20-30cm
25/11	27.6	23.6
19/12	23.4	27.7
15/1	22.6	26.1
5/2	18.6	21.7
17/2	17.8	13.4
14/3	24.5	23.3
2/4	33.8	34.4

For the soil watercontent at about 9.30 a.m. samples were taken.

APPENDIX B
Microclimate: airtemperature and relative humidity
Cottonzone

Maize (1150 metre) | Banana (1150 metre)

date	time	air temp. °C	wet temp. °C	rel. hum. %	date	time	air temp. °C	wet temp. °C	rel. hum. %
7/11					7/11	15.30	27	22	64
8/11	7	18.5	18	95	8/11	7.15	18.5	18.5	100
	9	23.5	20	72		10	23.5	20.5	75
	14.15	26	20.5	60		13.45	28.5	21	50
	17.15	22.5	19	71		16.45	22.5	20	78
9/11	7	20	18.5	86	9/11	7.45	20	19.5	95
16/11	12	28	20.5	50	16/11	14.30	29	19.5	40
27/11	10.30	23	20	75	27/11	11	23	21.5	88
	15	26	20	57		15.30	25	20	62
	18	22.5	18.5	67		18	23	19	68
28/11	8.30	23.5	20	72	28/11	9.15	21.5	19.5	64
	12.15	25.5	19.5	56		12.30	25	20	63
	15.15	27	19	46		15.45	24.5	19	59
	18	23	18.5	65		17.30	23	18.5	65
29/11	7.30	19	17.5	86	29/11	7.45	18.5	18	95
	9.45	23	18.5	65					
	11.30	26.5	20	54		12	25.5	20.5	63
	14.15	27	19	46		15.30	26	18	44
	16	26	18	44		17.45	23	18.5	65
4/12	11.30	24	20	69	4/12	14	25	21	70
9/12	10.15	25	20.5	66	9/12	10.45	23	20.5	79
11/12	8	20.5	19	96	11/12	8.30	20.5	19	87
	11.45	25	20	63		11.30	24	20.5	73
	15	25	20	63		15	25	21	70
14/12	8.45	19	18.5	95	14/12	9.15	18.5	18.5	100
17/12	10	25	20	63	17/12	10.30	23	18.5	65
19/12	9.30	24	20	69	19/12	9.45	22	19	76
24/12	9	23	19	69	24/12	9.30	22.5	19.5	76
30/12	9.30	23	18.5	65	30/12	9.45	20.5	18.5	83
8/1	9.45	25.5	18.5	50	8/1	9.45	24.5	18.5	
16/1	8	22	16	54	16/1	9	22.5	16	56
	13	30.5	17	24		13	27	16	54
23/1	8	20	18	83	23/1	9	20	18.5	31
	11	26.5	20	55		11.15	23.5	19.5	87
	12.45	28.5	20	45		12.45	26	18.5	69
27/1	8	22.5	18.5	68	27/1	8.30	22	18	49
30/1	8	22	18.5	72	30/1	8	20.5	18	68
31/1	8.45	24	18.5	59	31/1	8.45	22.5	17	87
	11	27	20	52					57
3/2	9	25	20	63	3/2	9.45	25	18.5	54
	11.30	30	21.5	47		11.30	29.5	20.5	43

date	time	air temp. °C	wet temp. °C	rel. hum. %	date	time	air temp. °C	wet temp. °C	rel. hum. %
	11	28	20	48		11	28	20	48
	12	30	21.5	47		12	31	21	40
	13	29	19.5	41		13	29	20	43
	14	32	20	32		14	32	21	37
	15	31	20.5	38		15	30	19	35
1/4	9	26.5	21.5	64	1/4	9.30	24.5	20	66
8/4	8.30	24	18	56	8/4	9.15	25	19	57
10/4	9	23	19	69	10/4	9	23	19	69
	10.30	24	19.5	66		10.30	24	19	62
	12	24	19	62		12	24	19.5	66

APPENDIX 8
Microclimate: air temperature and relative humidity
Teazone

Maize teazone (1790 meter) | Mount Kenya Forest (1840 meter)

date	time	air temp. °C	wet temp. °C	rel. hum. %	date	time	air temp. °C	wet temp. °C	rel. hum. %
15/11	14.15	25	18	49					
25/11	10.15	19	17	81	25/11	11.15	18.5	17	86
	12.45	20.5	17.5	74		14.45	19	17	80.5
	15.30	23.5	18	58					
26/11	13.45	23	18	62	26/11	14	21	18	74
	15.30	23	17.5	57					
4/12	16.30	21	17.5	71					
10/12	9.45	19.5	18	84	10/12	10.30	17	16.5	95
	11.45	20	17.5	77					
	15	20	17.5	77		15.45	19	17.5	87
12/12	8.30	18	16.5	86					
16/12	14	21	18	75					
19/12	16	22	18.5	72	19/12	16.30	21	18.5	79
23/12	10	21	17	67					
7/1	13.30	22	17	60					
8/1	16	21.5	17.5	67	8/1	16	21	18.5	79
15/1	8.30	19	14	58					
	10.45	24	16.5	46					
	11.45	24	16	43					
20/1	8.30	21.5	15.5	53					
29/1	8.30	20	16	66					
4/2	9.15	20.5	16	63					
					7/2	9.45	18	15.5	77
						11	20.5	15.5	59
						12.45	22.5	16.5	54
						14	23	17	55
						15	23.5	16.5	48
						16	22	16.5	57
						17	21	17	67
10/2	11.45	25	15.5	36	10/2				
	12.30	26	15.5	32		13	23.5	15.5	42
	14.15	27	16	31		14.30	24	15.5	40
						15.30	23	15.5	45
						16.30	22.5	15	44
						17	22	15.5	50
7/3	14	22	18	68					
2/4	10	20	16.5	70		10.15	17	16	90
	11	19.5	16.5	74					
	12	22.5	17	57					
14/4	14.30	21	18	75		14	20	18	83

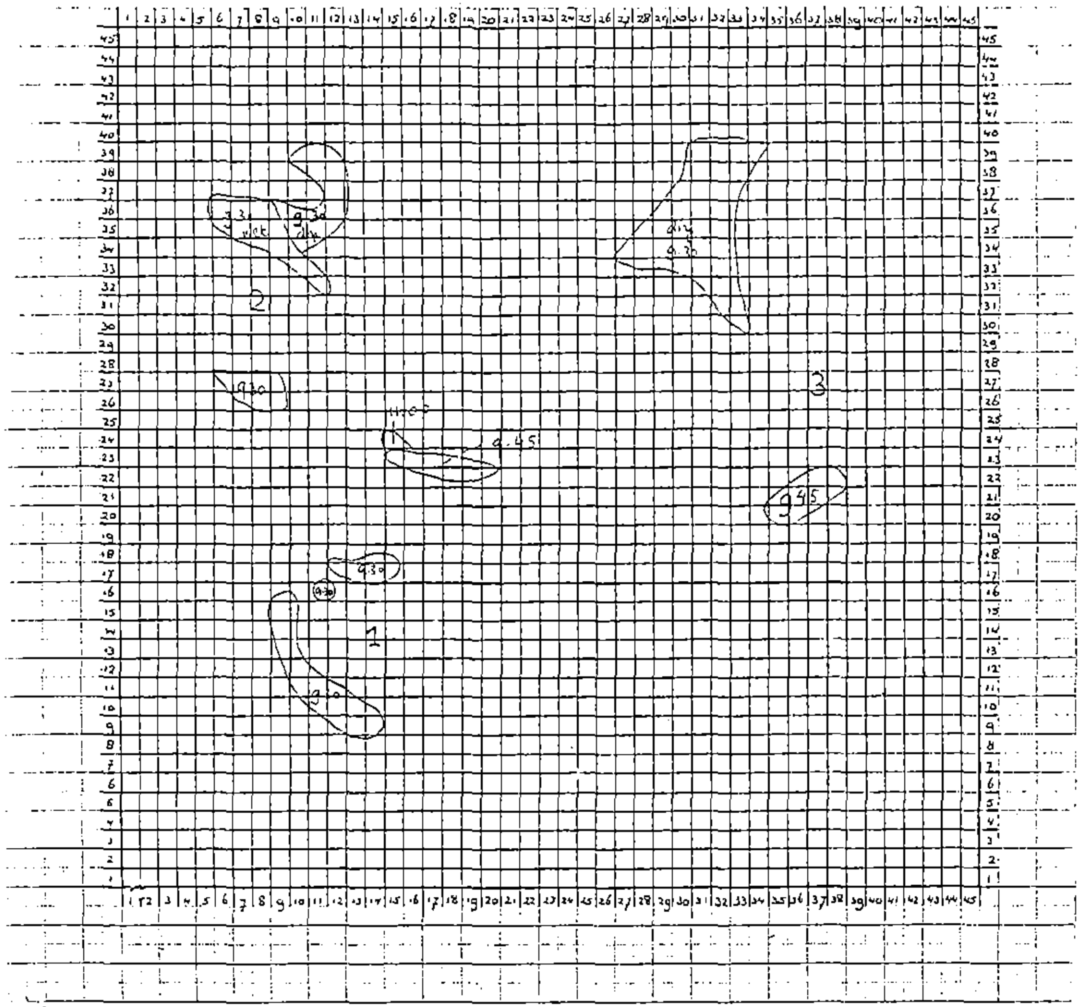
date	time	air temp. °C	wet temp. °C	rel. hum. %	date	time	air temp. °C	wet temp. °C	rel. hum. %
6/2	8.15	22	17	61	6/2	8.30	18.5	17	86
	11	24	18.5	59		11	23.5	18.5	62
	14	29.5	19	33		14	29.5	20	41
8/2	8.30	26	19	51	8/2	9	23	18.5	65
10/2	8	22	15	47	10/2	8	20	15.5	63
12/2	8.30	25	17	44	12/2	9	23.5	17	52
	10	27	18.5	44		10	26.5	18	43
	11	29	19	38		11	28.5	19	40
	12.30	33	19	25		12.30	32	19.5	30
	15	34	20	26		15	32	20	32
	16	30.5	18.5	30		16	30.5	18.5	31
	17	29.5	18	31		17	29.5	18.5	33
	18	28	18	37		18	28	18.5	40
13/2	7.30	20	15.5	63	13/2	7.30	18.5	15	69
15/2	7.30	20	15	59	15/2	7.45	19	16	74
17/2	7	16	14	81					
	8	21	17	67	17/2	7.45	17	15.5	86
19/2	7.15	17	15	81	19/2	7.30	17	15	81
	10	23	18.5	65		10	22	18	68
	11	27	21	58		11	26	19.5	54
	12	31	20.5	38		12	28.5	20	45
	14	32	20	32		14	32	19.5	30
	15.30	31	19	31		15.30	30	19	35
	17	31	19	31		17	28	18.5	40
22/2	7.30	22	17	61	22/2	8	20	17.5	78
26/2	7	18	14.5	69	26/2	7.45	18	15.5	77
28/2	7.15	18	15	73	28/2	7.45	18	15.5	77
6/3	8.30	21.5	19	79					
	10	24	19.5	66					
	11	27	20.5	56					
	12	28	21	53					
8/3	8.15	22.5	19.5	76	8/3	8.30	21.5	20	87
10/3	9	24	19.5	66	10/3	9.30	24	21	77
	11	26	24	85					
	12	28	25	78					
	13	30	26	73					
12/3	8.30	25	20	63	12/3	9.15	24	19.5	66
15/3	8.30	25	19.5	60	15/3	9	24	19	62
18/3	9	23.5	20	72	18/3	10	23	19.5	72
24/3	8.45	22.5	18.5	68	24/3	9.15	21.5	18	71
26/3	8.45	23.5	19.5	69	26/3				
	10	26	20	58		10	25	20	63

APPENDIX C

Sheeting building estimated with frame

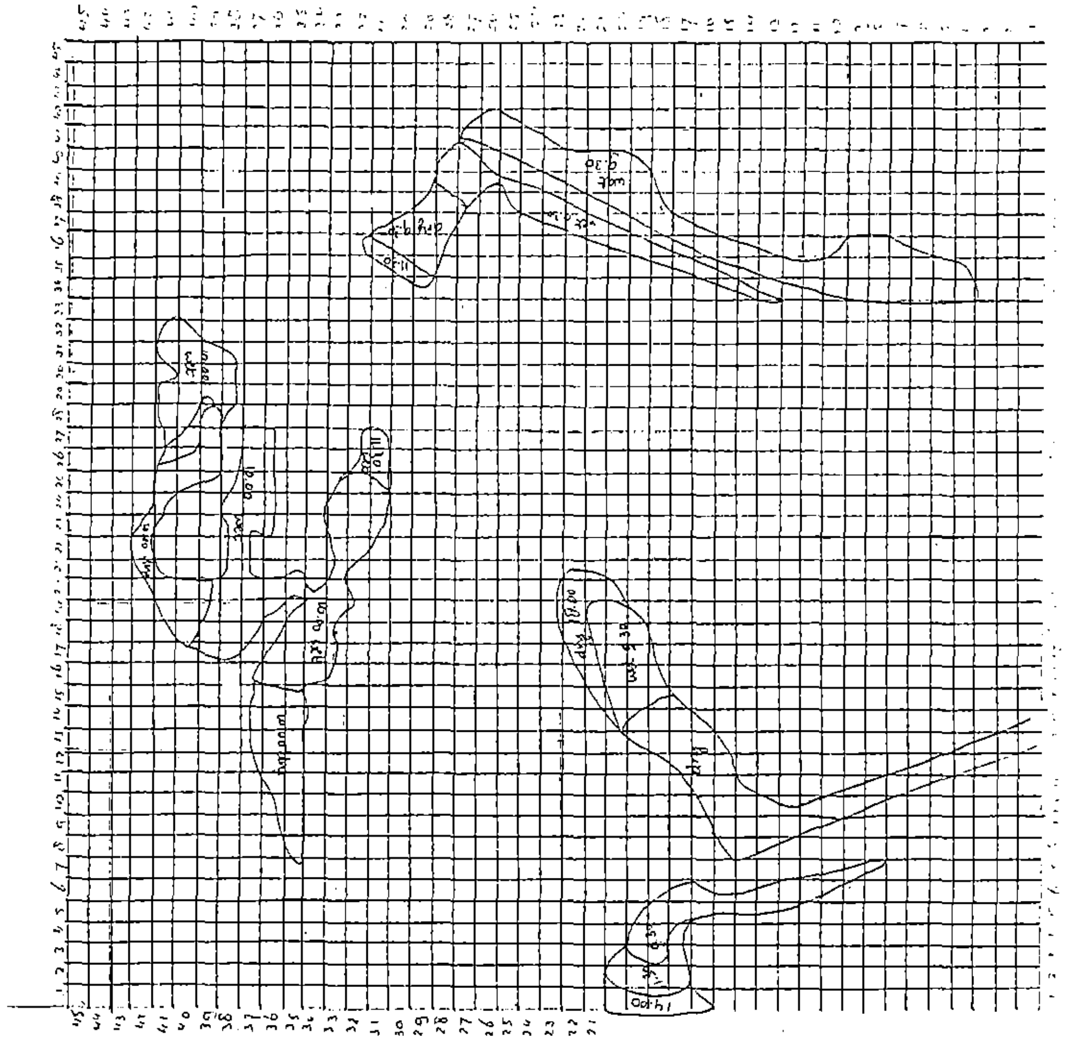
maize cotton zone 11/12/1985

time	air temp. ^{o}C	rel.hum. %
9.30	22.5	76
11.00	25	63



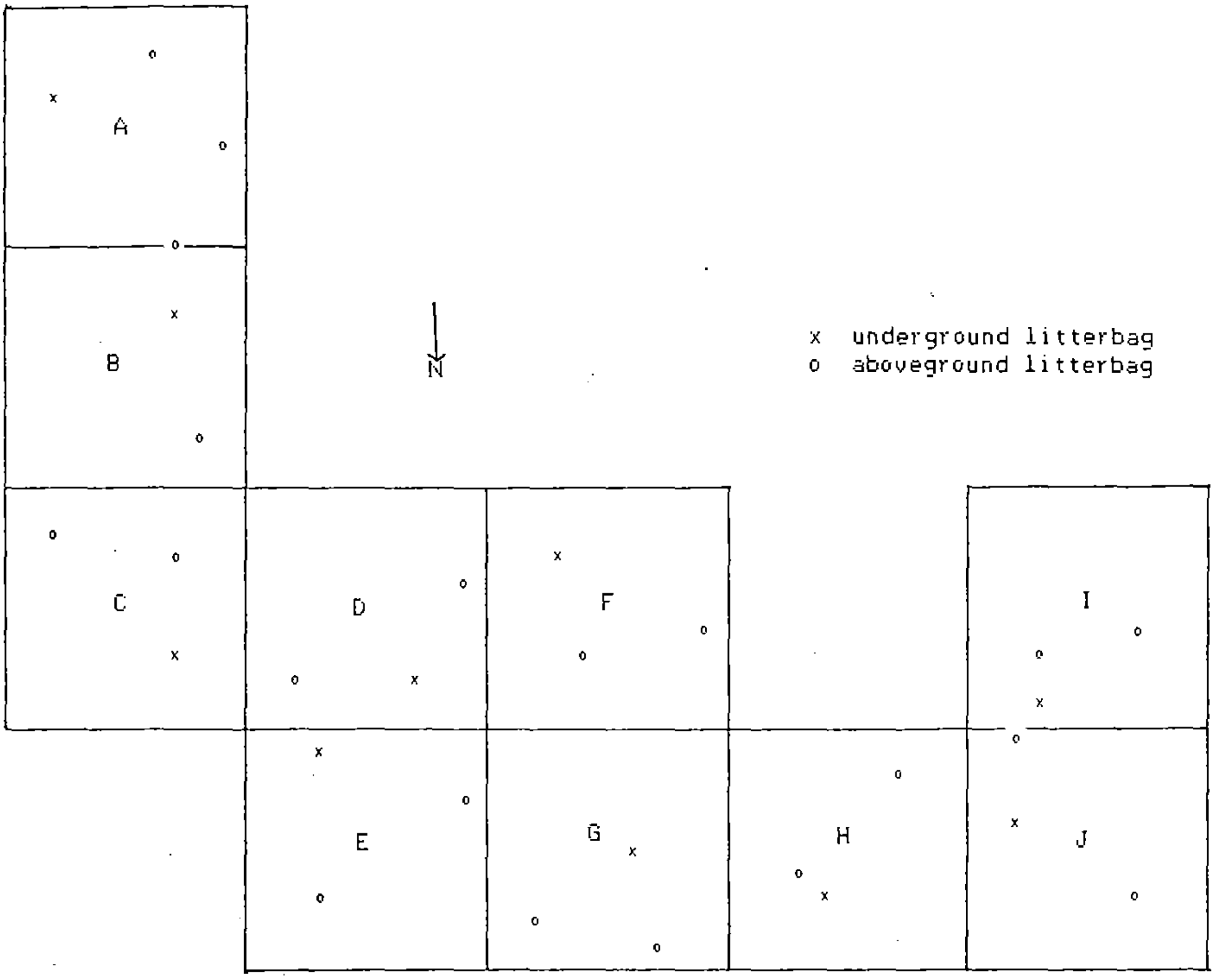
maize cotton zone 29/11/1985

time	air temp. ^{o}C	rel.hum. %
9.30	23	65
11.30	26.5	54
14.00	27	46
18.00	22.5	67



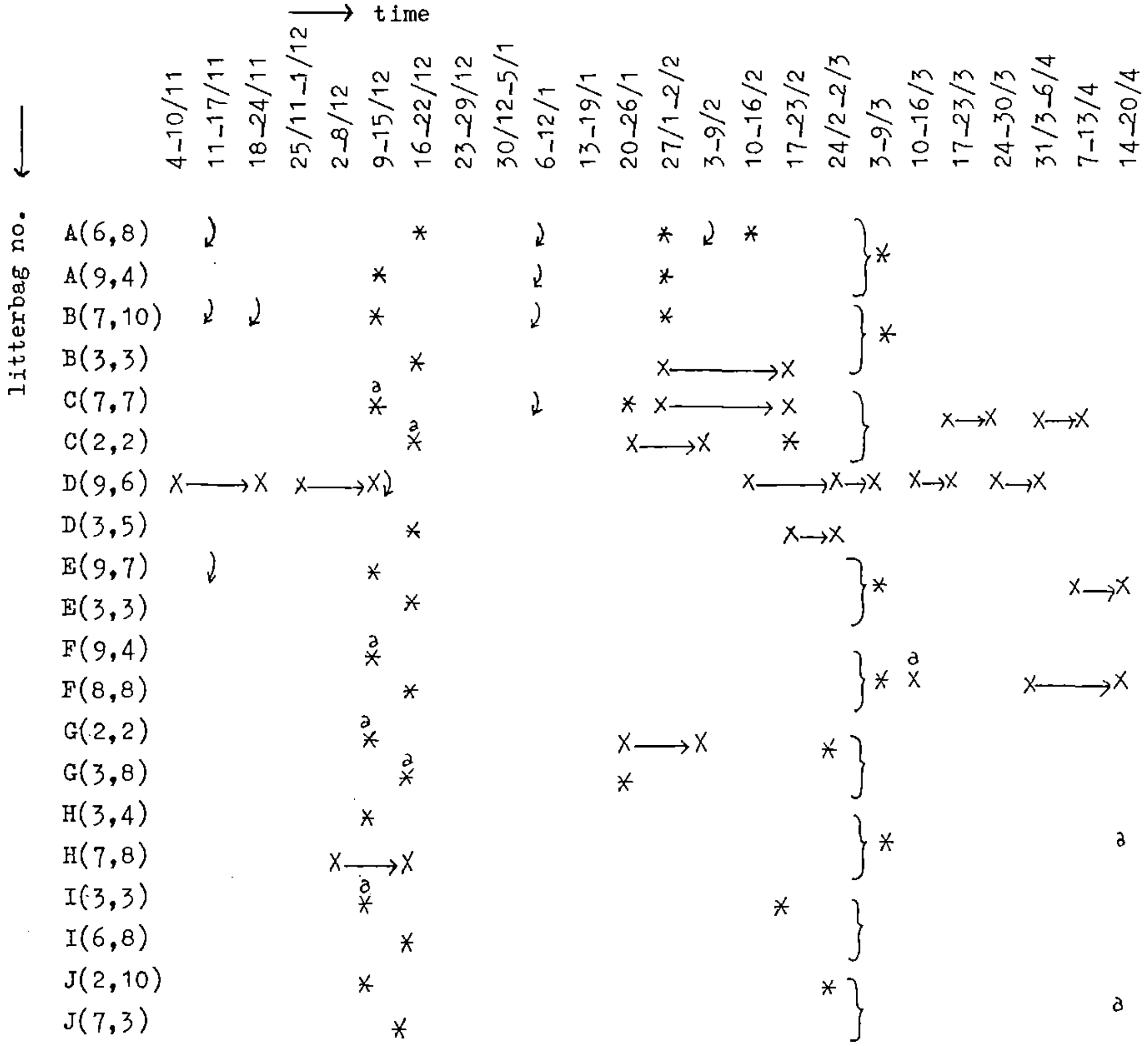
APPENDIX D

Scheme position litterbags (both aboveground and underground), maize plot cottonzone



APPENDIX D 1
Schematic presentation

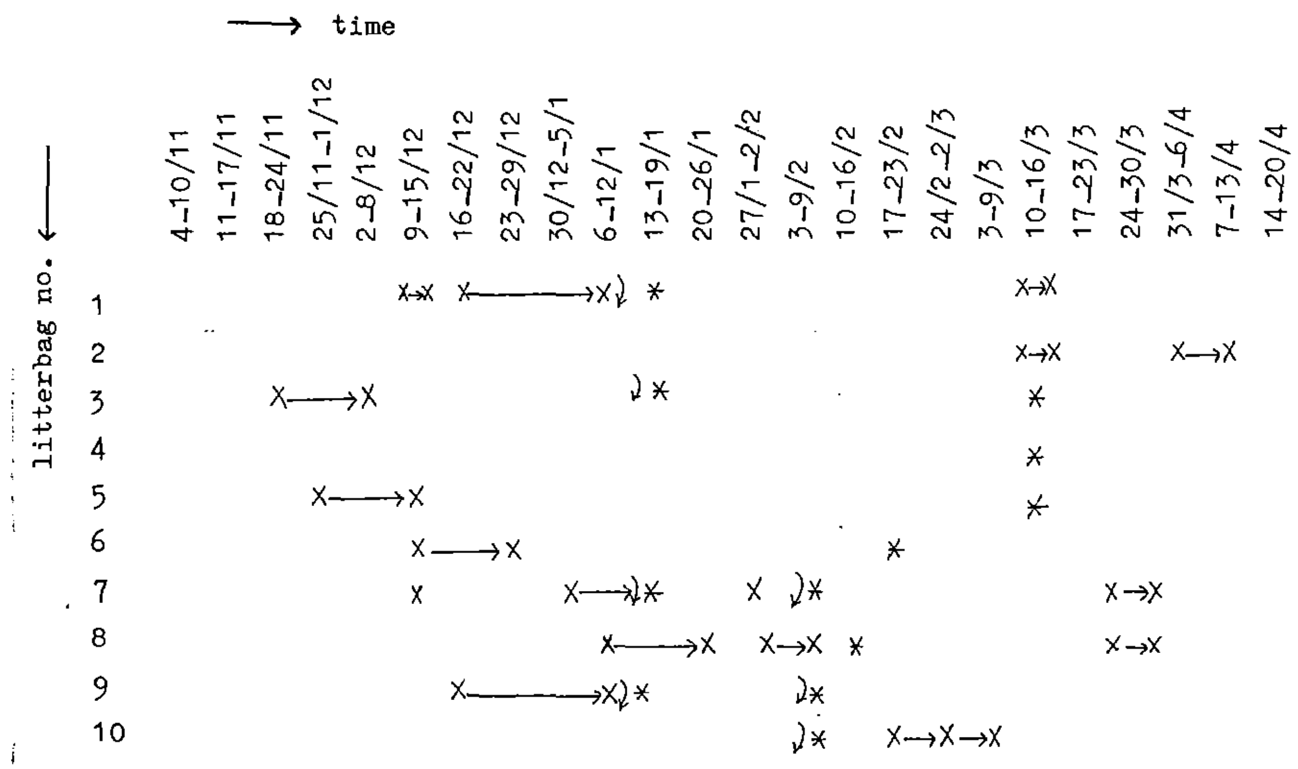
Aboveground litterbags, maize, cottonzone.



x——→x found eaten, 1 or 2 weeks left in the field and replaced
↲ litterbag disappeared
ə ants in litterbag
* litterbag renewed

APPENDIX D 2
Schematic presentation

Aboveground litterbags, banana, cottonzone.



x→x found eaten, left in the field for a few weeks and replaced
↲ litterbag disappeared
* litterbag renewed

APPENDIX E I

Underground litterbags, maize, cottonzone.

litterbag	8/11	16/11	24/11	28/11 29/11	4/12	11/12	17/12	24/12	30/12	8/1	16/1	23/1
water%	11.6	-	18.9	11.2 19.0	31.6	52.5	-	9.1	6.9	5.6	4.6	13.7
A			22 19 Mi 3	-			17 12 5		(21) ? 14 Mi 7			
B		22 17 5		-		22 16 6	12 12 0	(21) ? 21 Mi 0		23 15 8		
C					22 14 Mi 8		17 14 Mi 3				(21) ? 21	24 4 ants 20
D			22 16 6	-			17 16 1		(21) ? 17 Mi 4			
E		22 22 0		-		22 20 Mi 2	12 7 Mi 5	(21) ? 24 Mi 0		23 14 Mi 9		
F					22 15 7		17 13 4				(21) ? 18 3	24 22 2
G					22 16 6		17 16 1				(21) ? 15 6	24 21 Mi 3
H		22 18 4		-		22 13 Fe 9	-	(21) ? 21 0		23 22 An 1		
I					22 16 Mi 6		17 10 0				(21) ? 14 Mi 7	24 19 Mi 5
J			22 7 15	-			17 13 Mi 4		(21) ? 18 3			

litterbag	30/1	6/2	12/2	19/2	27/2	6/3	13/3	19/3	26/3	3/4	10/4	16/4
water%	20.9	25.9	5.9	6.3	8.5	14.1	10.6	37.6	21.0	18.5	30.1	
A	23 34 Mi ?	20 (22) 18 Mi (4) ?		19 14 Mi 5				23 15 Mi 8	16 11 Mi 5		20 19 1	17 16 1
B			(16) 19 2 Ma 17 (14)		19 3 Ma 16				23 21 Mi 2	20 19 Mi 1		20 3 Ma 17
C						19 11 Mi 8	22 22 ants 0		21 20 Ma 1		20 8 Mi 12	17 0 17
D	23 20 Mi 3	(22) 20 22 0		19 18 Mi 1				23 13 Ma 10	16 5 Ma 11	20 4 Ma 16		20 1 Ma 19
E			(16) 19 16 3 (0)		19 16 no eating 3				23 18 5		20 22 0	17 15 2
F						19 20 0	22 15 Ma 9		21 20 Ma 1	20 9 Od 11		20 18 Mi 2
G						19 11 Mi 8	22 21 Mi 1		21 21 Mi 0		20 14 Mi 6	17 17 0
H			(16) 19 16 (0) 3		19 20 no eating 0				23 21 Mi 2	20 16 no eating 4		20 17 Od 3
I						19 12 Mi 7	22 21 Mi 1		21 19 3		20 2 18	17 8 9
J	23 5 Od 8	(22) 20 22 0		19 21 0				23 12 Od 11	(7) 16 22 Od 0	20 22 0		20 19 1

APPENDIX E 2

Underground litterbags, banana, cottonzone.

litterbag \ date	8/11	16/11	24/11	28/11 29/11	4/12	11/12	17/12	24/12
water%	58	-	56.1	16.2 18.9	39.0	28.4	-	12.9
1			18 11 Ma 7	-	20 4 Ma 16		15 5 10	
2		18 16 2		-		21 19 3	18 (20) 19 0	? (21) 22 0
3					18 16 2		15 20 0	
4			18 14 4	-	20 12 Ma 8		15 14 Mi 1	
5		18 16 2		-		21 23 0	18 (20) 21 0	? (21) 22 0
6					18 19 0		15 15 0	
7					18 19 0		15 15 0	
8		18 17 1		-		21 15 Od 8	18 (20) 14 Od 4	? (21) 21 0
9					18 14 4		15 13 Ma 2	
10			18 18 0	-	20 21 0		15 14 1	

litterbag \ date	30/12	8/1	16/1	23/1	30/1	6/2	12/2	19/2
water%	11.8	11.8	8.1	19.1	8.2	5.9	6.9	9.3
1	? (21) 6 15				22 (27) 28 0	23 24 0		24 24 0
2		22 (21) 21 1					24 (22) 22 0	
3			? (21) 10 11	23 25 Pe 0		20 20 0		
4	? (21) 21 0				22 (27) 17 10	23 14 7		24 22 2
5		22 (21) 20 2					24 (22) 22 0	
6			? (21) 19 2	23 22 1		20 21 0		
7			? (21) 18 3	23 22 ante 1		20 8 12		
8		22 (21) 21 1					24 (22) 22 0	
9			-	23 17 Ma 6		20 5 15		
10	? (21) 17 4				22 (27) 27 0	23 21 2		24 22 2

litterbag \ date	27/2	6/3	13/3	19/3	26/3	3/4	10/4	16/4
water%	9.0	13.2	8.1	13.2	7.5	11.9	20.8	
1				23 23 0	22 21 1		23 21 2	20 20 0
2	24 8 16				23 21 2	23 (22) 21 2		22 20 2
3		24 0 24	22 7 14		23 (24) 25 0		23 23 0	20 16 4
4	24 24 0			23 14 Mi 9	22 22 0	23 (22) 22 1		22 21 1
5					23 22 1		23 22 Mi 1	20 20 0
6		24 21 3	22 22 0		23 (24) 24 0	23 (22) 22 1		22 20 2
7		24 34 0	22 20 2		23 (24) 24 0		23 22 1	20 17 3
8	-				23 21 2	23 (22) 23 0		22 21 1
9		24 22 2	22 20 2		23 (24) 25 0		23 21 2	20 20 0
10				23 18 Mi 5	22 20 2	23 (22) 22 1		22 20 2

APPENDIX E 3

Underground litterbags, maize, teazone.

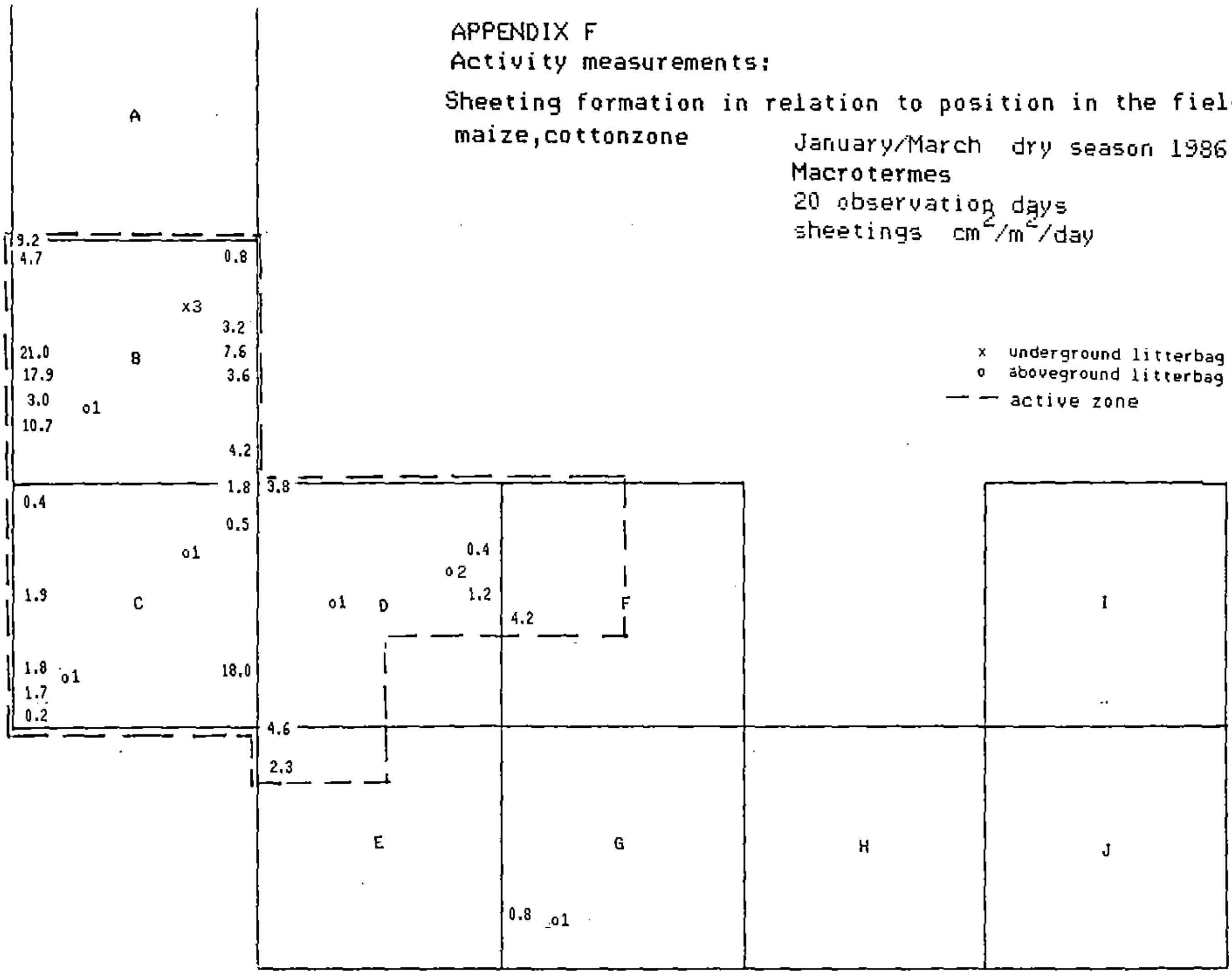
litterbag	13/11	24/11	'	4/12	10/12	19/12	28/12	'	7/1	15/1	'	29/1	'	'	17/2	'	'	'	19/3	'	2/4	'	14/4
water%	20.6	36.8		52.9	51.4	4.4	11.8		8.6	6.8		'			7.9 30.8				8.1		55.8		
A (4.2)					not - found				20 (15) 12 8 (3)						x				17 13 4		23 11 eating signs 12		11 11 0
A (2.6)						new			24 23 1		23 (15) 16 0 7				x				not found				
B (7.7)		(15) 20 17 (2) 3	-			7 12 19 0	24 24 0		22 20 2		(15) 23 14 (1) 9				x				17 12 5				23 10 13
C (6.3)					20 (15) 14 (1) 6	7 12 20 0				24 22 2					x				17 18 ants 0		23 11 no eating signs 12		11 13 0
D (7.2)					15 17 0	7 12 20 0			24 23 1		23 (15) 12 (3) 11				x				17 16 1				23 18 5
E (3.9)		(15) 20 15 0 5	-			7 12 20 0	24 24 0		22 21 1		(15) 23 14 (1) 9				x				17 15 2		23 15 8		11 9 2
F (3.7)					20 (15) 16 (0) 4	12 7 19 0				24 23 1					x				not found				17 11 6
G (6.5)					20 (15) 16 (0) 4	12 7 13 0				24 24 0					x				not found				
H (4.3)		20 (15) 21 0	-			12 12 0	24 23 1		22 23 0		(15) 23 18 (0) 6				x				17 12 5		23 19 4		23 11 12
H (14.2)					15 16 0	7 12 15 0			24 22 2		(15) 23 13 10 (2)				x				17 8 eating signs 9				11 14 0

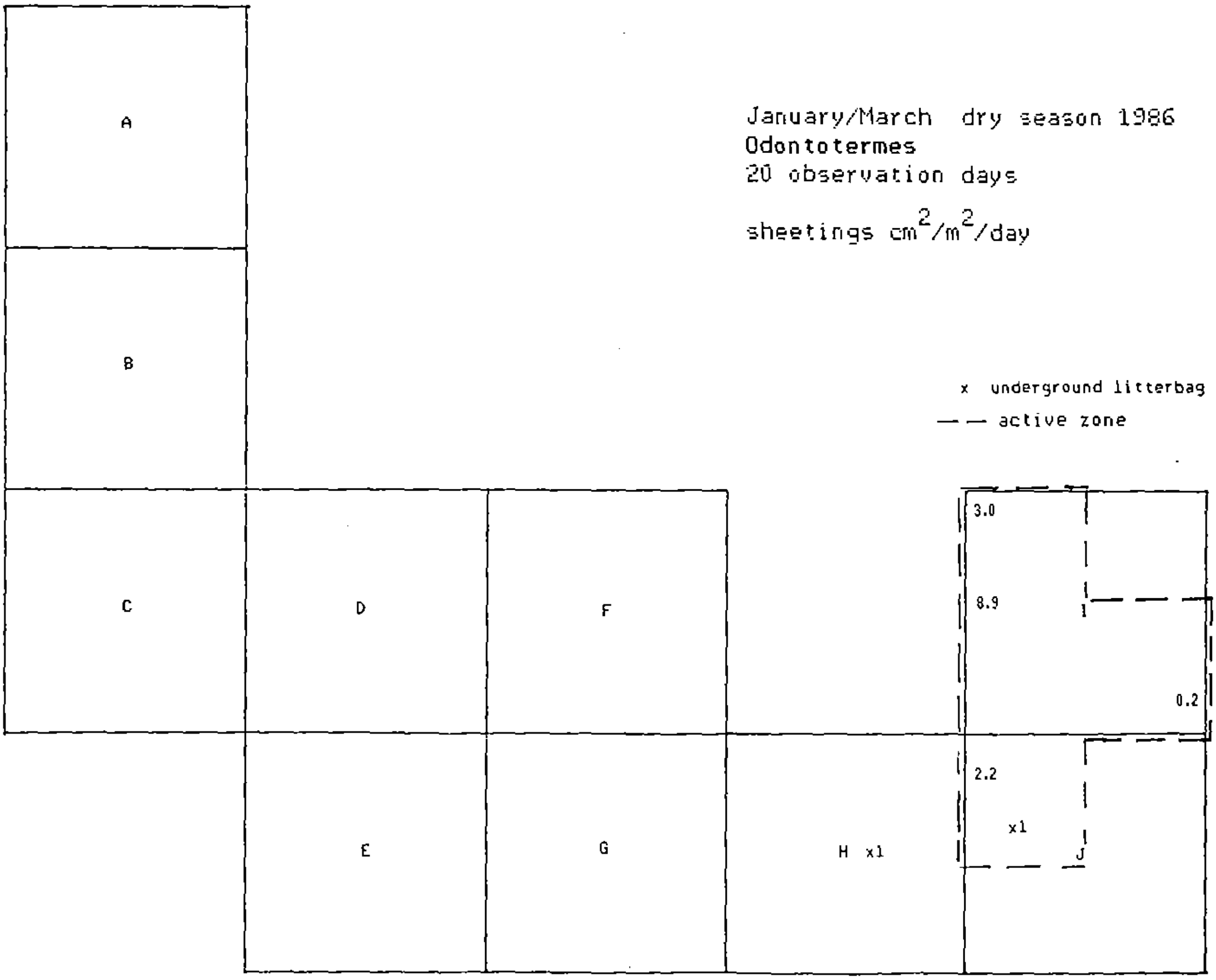
APPENDIX F

Activity measurements:

Sheeting formation in relation to position in the field

maize, cottonzone

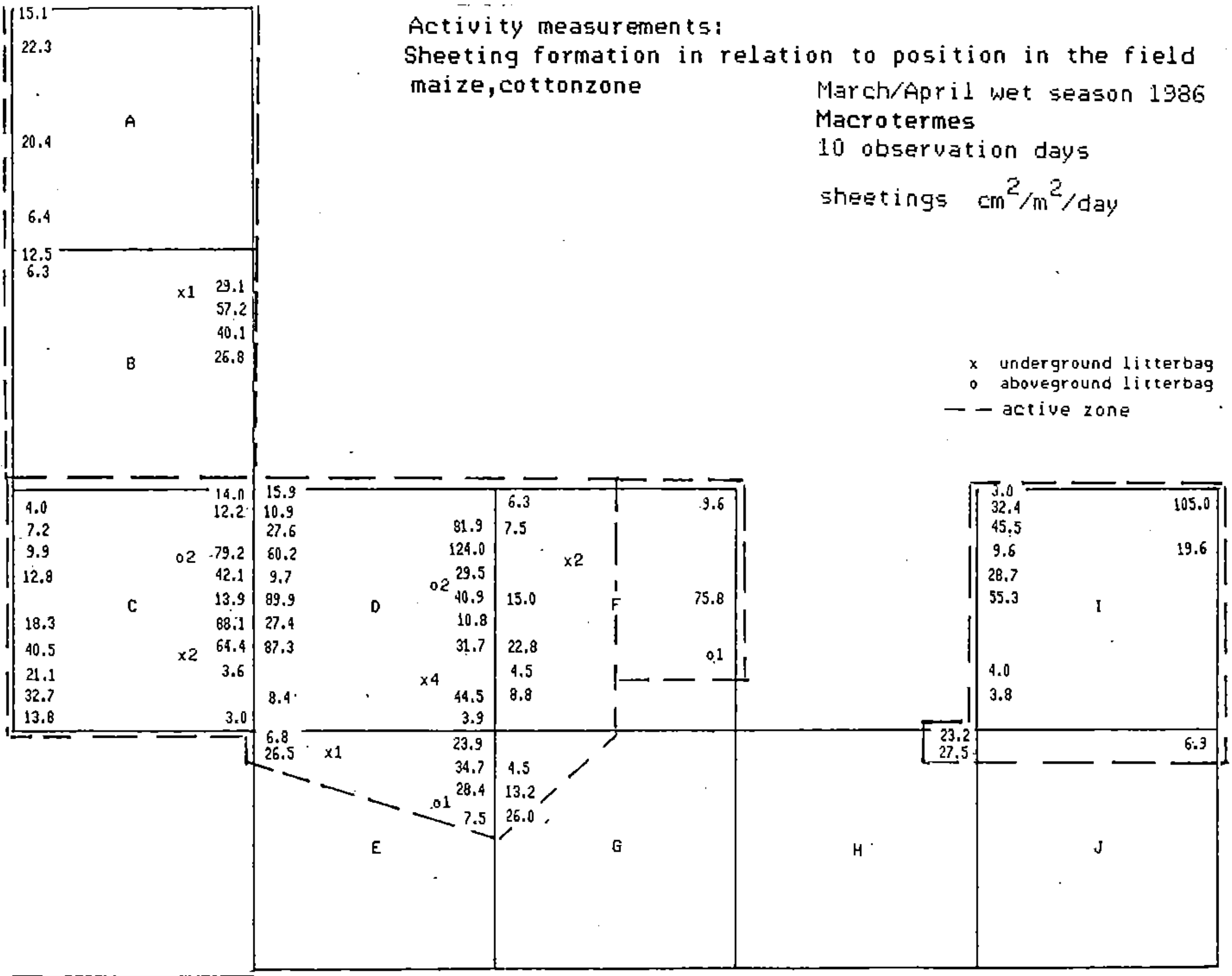




Activity measurements:
Sheeting formation in relation to position in the field
maize, cottonzone

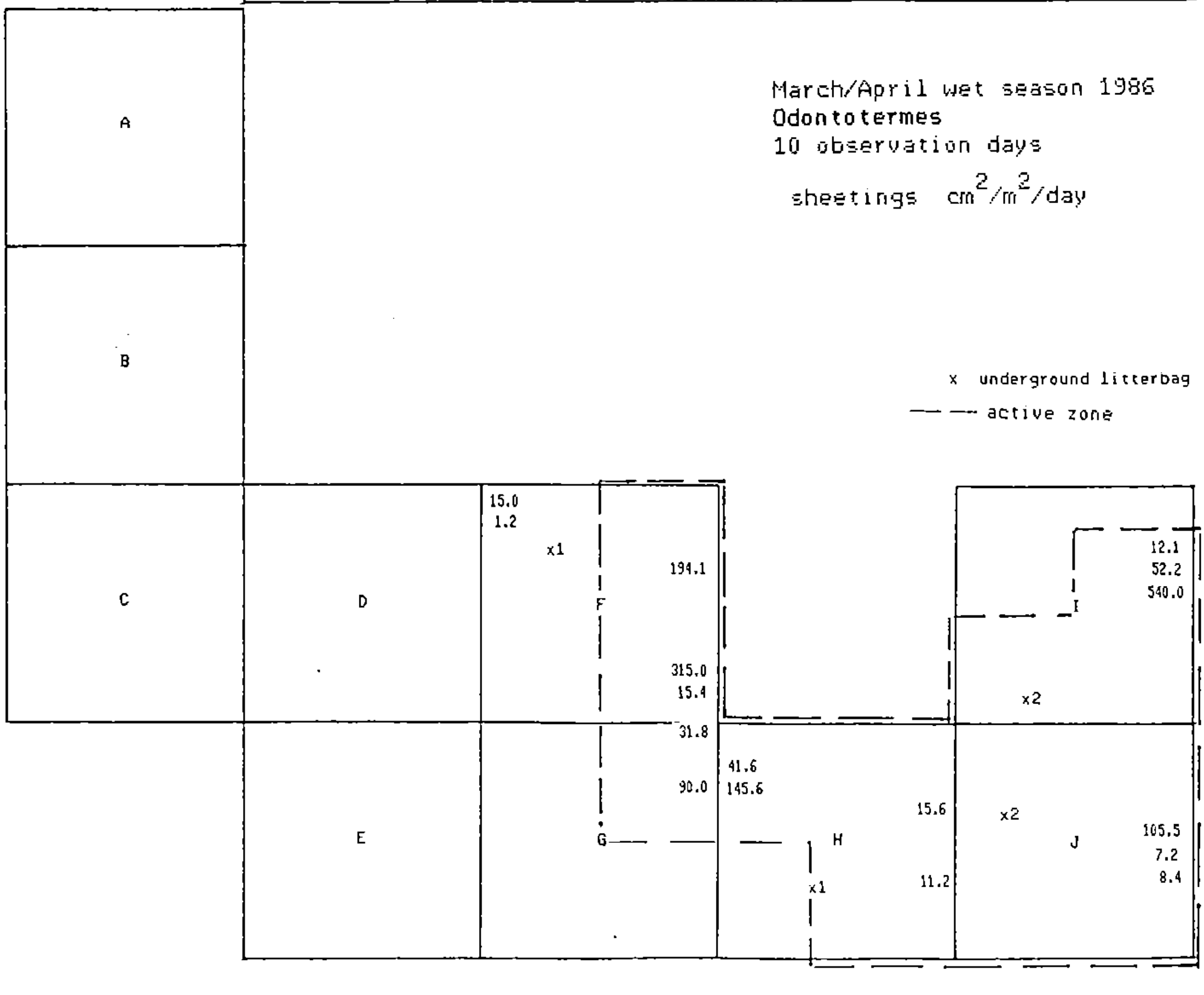
March/April wet season 1986
Macrotermes
10 observation days

sheetings $cm^2/m^2/day$



March/April wet season 1986
Odontotermes
10 observation days

sheetings $cm^2/m^2/day$



APPENDIX G
List of termites
Maizefield cottonzone

date	species	remarks
9/10/''85	Macrotermes	foraging in maizefield
6/11/''85	Ancistrotermes	under maizestem
16/11/''85	Microtermes	aboveground litterbag B
28/11/''85	Pseudocanthotermes	activity transect G west, 7 meter
11/12/''85	Macrotermes	activity transect A east, 1 meter
11/12/''85	Pseudocanthotermes	underground litterbag H
17/12/''85	Microtermes	pole A south
8/1/''86	Ancistrotermes	underground litterbag H
30/1/''86	Odontotermes sp. 4	activity transect I east, 5 meter
26/3/''86	Ancistrotermes	underground litterbag J

Bananabush cottonzone

date	species	remarks
9/10/''85	Pseudocanthotermes	near bananapit, foraging on banana
8/11/''85	Odontotermes sp. 4	activity transect 9
8/11/''85	Odontotermes sp. 4	activity transect 30-31
16/11/''85	Odontotermes sp. 4	underground litterbag 2
27/11/''85	Macrotermes	foraging near nest
27/11/''85	Odontotermes sp. 4	activity transect 37
27/11/''85	Microtermes	activity transect 2-3
27/11/''85	Odontotermes sp. 4	near maizefield
28/11/''85	Microtermes	activity transect 31
28/11/''85	Odontotermes sp. 4	foraging under sheeting
28/11/''85	Odontotermes sp. 4	Odontotermes nest in bananabush
11/12/''85	Odontotermes sp. 4	aboveground litterbag 1
11/12/''85	Pseudocanthotermes	litterbag transect 9
11/12/''85	Ancistrotermes	litterbag transect 7
17/12/''85	Macrotermes	aboveground litterbag 9
17/12/''85	Macrotermes	litterbag transect 10
17/12/''85	Odontotermes sp. 4	litterbag transect 5
17/12/''85	Odontotermes sp. 4	litterbag transect 9
23/1/''86	Pseudocanthotermes	underground litterbag 3
30/1/''86	Pseudocanthotermes	activity transect 3, foraging on banana
30/1/''86	Microtermes	wooden pole, litterbag transect 10
3/2/''86	Odontotermes sp. 4	activity transect 34
12/2/''86	Odontotermes sp. 4	under mangotree, South edge bananabush
14/2/''86	Odontotermes sp. 4	near litterbag transect 5
19/2/''86	Odontotermes sp. 4	South-East corner bananabush

Immediate surroundings maizefield and bananabush, cottonzone

date	species	remarks
9/10/''85	Odontotermes sp. 4	ploughed maizefield
17/10/''85	Pseudocanthotermes	cottonfield
17/10/''85	Microtermes	idem
8/11/''85	Macrotermes	edge bananabush - milletfield
27/11/''85	Odontotermes sp. 5	under mangotree in bush, South of bananabush
27/11/''85	Pseudocanthotermes	idem
28/11/''85	Macrotermes	nest near road
29/11/''85	Macrotermes	nest West of homestead
9/12/''85	Microtermes	idem
11/12/''85	Microtermes	Odontonest near homestead
14/12/''85	Macrotermes	young nest, West of homestead
8/2/''86	Odontotermes sp. 4	foraging near road
10/3/''86	Odontotermes sp. 4	milletfield

Cottonzone

date	species	remarks
9/10/''85	Odontotermes sp. 5	foraging on dead tree in bush
5/12/''85	Odontotermes sp. 5	big nest under mangotree, 1 km South of plot
5/12/''85	Odontotermes sp. 4	farm South of bananabush
27/1/''86	Odontotermes sp. 4	behind teashop of Kavengero, on tree
27/1/''86	Odontotermes sp. 5	behind teashop of Kavengero, on maizestems
18/2/''86	Microtermes	profilepit in 3 year old bush

Teazone

date	species	remarks
8/10/''85	Odontotermes sp. 2	forest, foraging under log
8/10/''85	Odontotermes sp. 3	foraging under tea
8/10/''85	Odontotermes sp. 1	coffeeshamba
16/10/''85	Odontotermes sp. 1	roadside
15/11/''85	Odontotermes sp. 1	near maizeplot, in adjacent coffeeshamba
25/11/''85	Odontotermes sp. 3	maizeplot G, activity transect, under wood
26/11/''85	Odontotermes sp. 1	near maizeplot, in adjacent vegetable garden
26/11/''85	Odontotermes sp. 1	near maizeplot, in adjacent coffeeshamba
26/11/''85	humusfeeders	idem
12/12/''85	Odontotermes sp. 3	maizeplot C, under maizestem
10/2/''86	Odontotermes sp. 2	foraging under wood in forest
2/4/''86	Odontotermes sp. 3	maizeplot A, under maizestem