EXOTIC EARTHWORM SPECIES DOMINANT IN SOILS ON SUGARCANE ESTATES IN THE ESHOWE AREA OF THE NORTH COAST OF KWAZULU-NATAL

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Abstract

The effects of land management including sugarcane, horticultural crops (citrus, avocado and banana), forestry (gum, wattle and pine), kikuyu pasture, native forest and native grassland on the size and composition of the earthworm community on sugarcane estates in northern KwaZulu-Natal was investigated. Earthworm numbers followed the order: burnt sugarcane < trashed sugarcane = grassveld = gum forest = pine forest = wattle forest = avocado orchard < citrus orchard < banana plantation < native forest < kikuyu pasture. The pattern of change in organic C, and particularly microbial biomass C, with land-use showed broadly similar trends to those of earthworm numbers. This demonstrates that the C input to the soil and the amount of labile, metabolizable C present are the major determining factors to the size of both the soil microbial and earthworm communities.

Over 80% of the earthworms identified were exotic species which are believed to have been accidentally introduced from India. The most numerous earthworm was *Pontoscolex corethrurus* which is a soil dwelling (endogeic) species. The predominant litter dwelling (epigeic) species was *Amynthas rodericencis* which made up a substantial proportion of the community under avocado, native and gum forest and banana. *P. corethrurus* was the dominant species in sugarcane fields. Earthworms were found to be much more prevalent in the cane rows than between them and they were generally associated with sugarcane roots. Compared with burning, earthworm numbers were more than twice as high under green cane harvesting with trash retention.

Introduction

Among the soil fauna, earthworms are recognized as having the most significant effects on soil fertility and structure (Edwards and Bohlen, 1996). Earthworms are involved in decomposition of litter, intermixing of inorganic and organic matter, enhancement of soil microbial activity, increased nutrient availability, formation of macroporosity and formation and stabilization of soil aggregates (Lee, 1985: Edwards and Bohlen, 1996). For these reasons, the size and composition of the earthworm community can be used as a biological indicator of soil quality (Lee and Pankhurst, 1992). The composition of the community is important because earthworms belong to one of three ecological groupings (Edwards and Bohlen, 1996). Epigeic earthworms do not have burrows, they are litter dwelling and pigmented and their main role is in litter decomposition. Endogeics are unpigmented and burrow throughout the upper 15-30cm of soil; they ingest mineral soil (with a preference for material high in organic matter) and deposit their casts below ground in burrows and other soil voids. Anecic species have permanent vertical, surface-connected burrows; they inhabit the subsoil but come to the soil surface to feed on litter and other decaying materials.

Much research in Australasia and the United States has centred on characterizing the size and composition of earthworm communities in agricultural soils and understanding the effects that agricultural management practices have on such communities (Fraser, 1994; Baker, 1998). In general, agricultural soils in these localities have been observed to contain mainly accidentally-introduced European earthworm species and few native species remain (Lee, 1985).

Very little is known regarding the size and composition of earthworm communities in the agricultural soils of South Africa. In this study, earthworm communities are characterized on sugar estates in the Eshowe-Empangeni area. Land uses on these estates included sugarcane, banana, citrus, avocado, indigenous and native forests and kikuyu pastures.

Materials and Methods

A total of 66 fields from 11 land uses (six replicates per use) were sampled in the Eshowe-Empangeni area from 12 commercial sugar estates. The land uses investigated were native forest, native grassland, permanent kikuyu pasture, banana, citrus and avocado plantations, pine, gum and wattle forests and sugarcane under pre-harvest burning or green cane harvesting with trash retention. Four replicate soil samples (25 x 25 x 25 cm) were taken randomly from each field and transported to the laboratory. Earthworms were separated by hand-sorting and identified by external characteristics and internal organisation following dissection using the keys of Gates (1972), Sims and Easton (1972) and Plisko (1992, 1997).

At each sampling site a soil sample (0-10 cm) was taken for subsequent analysis. Field moist soil was sieved (< 2 mm) and a subsample was stored at 5°C prior to analysis of microbial biomass C. Another subsample was air-dried and ground. Microbial biomass C was analysed by the fumigation-extraction method using a K_c factor of 0.38 (Vance *et al.*, 1987). Organic C was analysed on the ground soil by the Walkley and Black dichromate oxidation method (Blakemore *et al.*, 1972).

Results and Discussion

Changes in values for organic C, microbial biomass C and earthworm number with land use showed broadly similar trends. For example, all three parameters were higher for the native forest, kikuyu pasture and banana plantation than the other treatments (Figure 1). Differences were, however, very much more pronounced for microbial biomass C and earthworm numbers than for organic C. This reflects the fact that it is the supply of labile C (rather than the total C content) that is the principal food and energy source for the soil biota.

The original vegetation in the locality is native forest. Interestingly, the kikuyu pastures had similar organic C and microbial biomass C values and higher earthworm numbers than the native forest. An accumulation of soil organic matter and soil biota characteristically occurs under permanent pastures (Haynes and Williams, 1992). Continual organic matter inputs under permanent pasture include turnover of the large, ramified root system and associated rhizosphere microflora, above-ground plant debris and returns of dung via the grazing animals. The relatively high organic C content, and more particularly microbial biomass C and earthworm count, in the citrus orchards is also attributable to a 'pasture effect' since the orchards are permanently grassed-down with a sward dominated by kikuyu grass.

In banana plantations, vegetative debris from the banana trees are dumped in the interrow area. This provides a readily available C source for the soil biota and an organic input to the soil. For that reason, soils under banana had a notably high organic C and microbial biomass C content and large earthworm numbers. The very high microbial biomass C (>2000 mg C/kg) and earthworm numbers (>2500/m^2) under kikuyu pasture, native forest and banana reflect the tropical (high temperature and rainfall conditions) nature of the locality and the large C inputs that occur in these systems. Such conditions are highly conductive to large active soil microbial and earthworm communities.

Lowest values for organic C, microbial biomass C and earthworm numbers were recorded for the pre-harvest burnt sugarcane treatment (Figure 1). This reflects the characteristic loss of soil organic matter content that occurs under arable agriculture including sugarcane production (Haynes and Hamilton, 1999). Pre-harvest burning is particularly damaging since large amounts of trash C are lost as CO_2 rather than being returned to the soil. The fields sampled that had been under green cane harvested sugarcane for at least 10 years showed a noticeable increase in organic C content and a more marked increase in microbial biomass C and earthworm numbers. Such results confirm those from other studies (Wood, 1991; Graham *et al.*, 1999). Although earthworm numbers were relatively low under sugarcane, the fact that the crop remains in the ground for many years means it generally supports a larger earthworm community than annually-cultivated arable crops (Fragoso *et al.*, 1999).

When trends in values with land use are compared for microbial biomass C and earthworm numbers (Figure 1) it is clear that earthworm numbers in the gum, pine and wattle forests and veld are relatively low. Relatively low earthworm numbers in coniferous and eucalypt forest soils are common and can often be related to poor litter quality and low palatability (Curry, 1998: Paoletti, 1999). It seems possible this is also true for litter from wattle trees. As discussed later, the low numbers for veld are probably related to a significant difference in species composition in this treatment.

Nine earthworm species were identified at the sample sites along with four additional genera that could not be identified to species level because only juveniles were present. The distribution of the six most numerous species within the earthworm community under each land use is shown in Figure 2. The vast majority of species collected were exotic and native species made up a very small proportion (<10%) of the collection. Populations of exotic earthworms are generally spread from country to country through the transport of soil when planting gardens or trees. Soil was also transported as ballast for sailing ships up to four centuries ago (Lee, 1985). The exotic earthworm species identified in this study are believed to have been accidentally introduced from India by the large Indian community that emigrated to KwaZulu-Natal. They were then spread by man's activities and probably particularly by the sugar industry.

It is evident from Figure 2 that the most numerous species present was *Pontescolex corethrurus*; it accounted for 41% of the total number of earthworms collected and made up over 50% of the community under sugarcane, pine and wattle. It is an endogeic species that originates from South America but has been transported by man all over the humid tropics (Lavelle *et al.*, 1987). It came to South Africa via India. *P. corethrurus* has the ability to live in a great variety of soils differing in pH, organic matter content and texture and it is also tolerant of soil cultivation (Fragoso *et al.*, 1999). It is a rapid colonizer due to a rapid growth rate, asexual reproduction and an ability to produce a large number of cocoons per adult (Lavelle *et al.*, 1987). It also possesses an exceptionally effective digestion system for soil C (Barios and Lavelle, 1986). That *P. corethrurus* was present in significant numbers under all the land uses underlines its ubiquitous, peregrine nature. Indeed it has been identified in 56 tropical countries on four continents and is commonly found in natural ecosystems, crop land, pastures, tree plantations and even fallows (Fragoso *et al.*, 1999).

Under sugarcane, *P. corethrurus* made up about 70% of the earthworm community. Interestingly, Spain *et al.* (1990), working on sugarcane soils in northern Queensland, also found *P. corethrurus* was the major earthworm species present. As with this study (Figure 3) they observed that *P. corethrurus* numbers were considerably higher in the rows than between the rows and that the earthworms were intimately associated with the root system of sugarcane. Although others have suggested that *P. corethrurus* uses complex soil organic matter compounds as its major C source (Lavelle *et al.*, 1987), this suggests that the sugarcane rhizosphere provides the major source of C (e.g. as root exudates, root mucilages, living and dead soil microbes and living and dying root material) for these earthworms in sugarcane soils.

In this study, *P. corethrurus* numbers were markedly increased by trash retention, compared to burning (Figure 3) and, in fact,

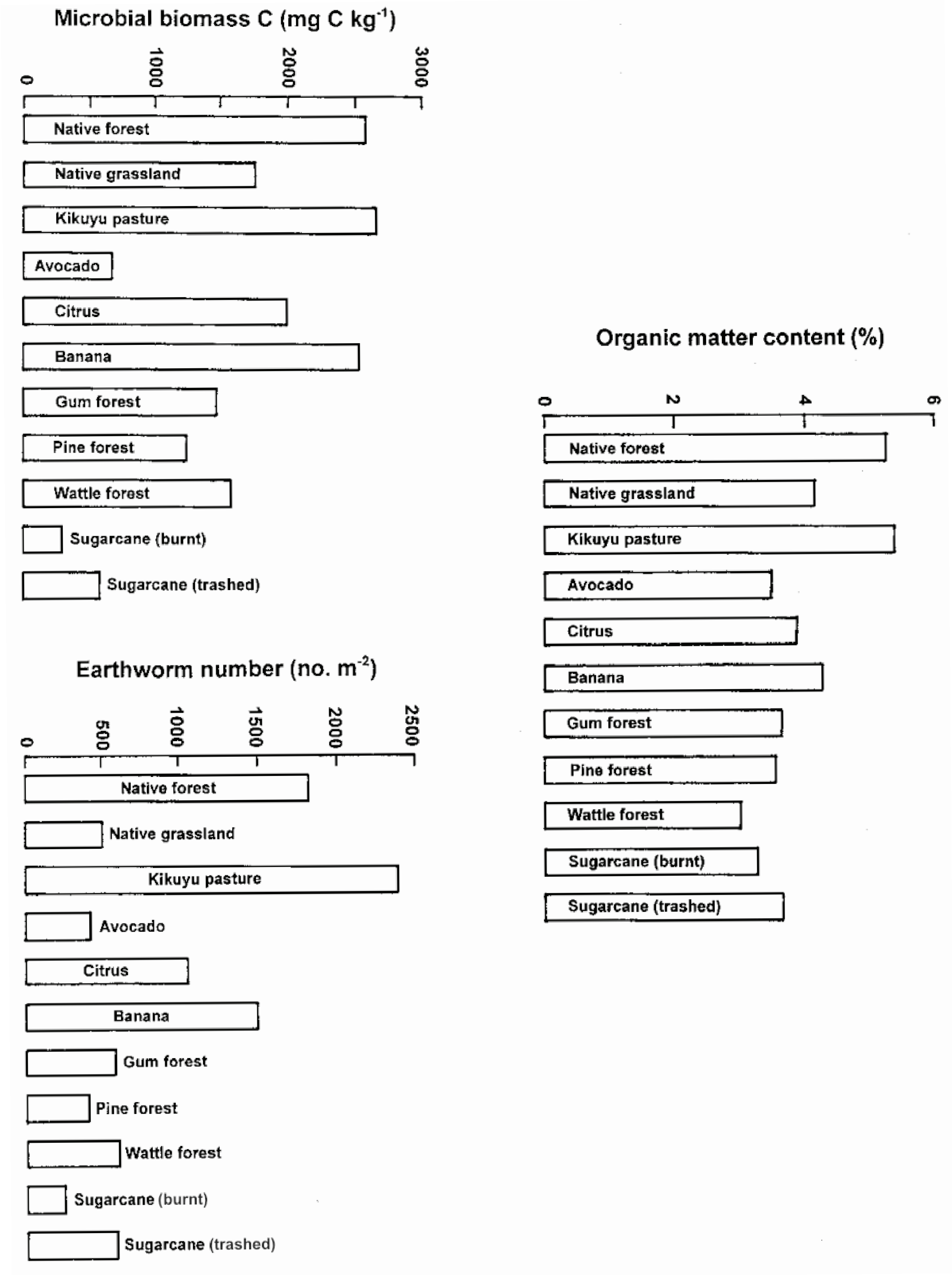

Figure 1. Effect of 11 land management practices on (a) soil organic matter content, (b) microbial biomass C content and (c) earthworm numbers.

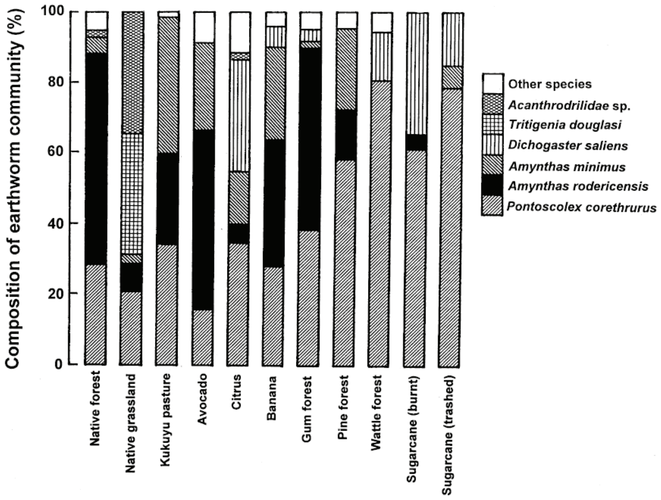

Figure 2. Effect of 11 land management practices on the species composition of the earthworm community.

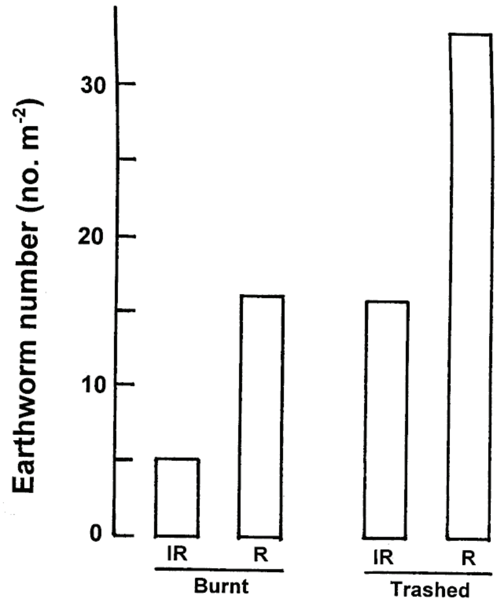

Figure 3. Effect of burning and green cane harvesting with trash retention on the numbers of earthworms below the row (R) and interrow space (IR) of sugarcane fields.

the proportion of the community present as this species increased from 58-79% due to trash retention. This is somewhat surprising since the return of organic residues to the soil surface would be expected to increase the proportion of epigeic, litter-dwelling species. Nevertheless, Spain *et al.* (1990) also observed that *P. corethrurus* numbers were markedly increased by conversion from burning to trash retention. They suggested that this endogeic species tends to inhabit the deeper layers of more humified trash during its latter stages of decomposition. The surface mulch on trashed plots also maintains a higher soil moisture content so that conditions are more favourable for earthworm activity in the interrow spaces than under a burning regime.

The dominance of *P. corethrurus* is likely to be of great importance to the fertility of soils in the region. Their continual burrowing, with the ingestion and excretion of large amounts of soil, can lead to increases in soil microbial activity, nutrient availability (particularly that of N and P), aggregation and macroporosity (Lavelle *et al.*, 1992; Pashanasi *et al.*, 1992; Barois *et al.*, 1993; Lopez-Hernandez *et al.*, 1993; Zund *et al.*, 1997).

The most numerous epigeic (litter-dwelling and feeding) earthworm was the Indian species *Amynthas rodericensis* (Figure 2) which made up 26% of the total collection. It was particularly numerous in the native and gum forest litter layers, in the leaf litter of the avocado orchard and in the decomposing trash in the banana plantation interrows. The large numbers of *A. rodericensis* found under native forest are not surprising since it has been identified in 26 tropical countries on three continents and it is characteristically numerous in natural ecosystems with an undisturbed litter layer (Fragoso *et al.*, 1999). It was evidently also an important species involved in degradation of litter in gum forests, avocado and banana plantations. Its relatively large numbers under grazed kikuyu pasture indicate it is involved in decomposition of pasture litter and possibly animal dung.

The third most numerous species was *Amynthas minimus,* which is an Indian polyhumic endogeic species (i.e., lives and feeds in the organic matter-rich surface soil). It was particularly numerous under pasture, banana, avocado and citrus plantations and pine forest. Another Indian, endogeic, polyhumic species, *Dichogaster saliens,* was also present in significant numbers under citrus and burnt cane. These species live in the humic layer in these systems. *A. minimus* was present in largest numbers under kikuyu pasture which, indeed, had the highest soil organic matter content of all the land uses studied. *D. saliens* was a significant contributor to the small earthworm community under sugarcane production. It was found predominantly in the row area and probably feeds on humified organic matter formed in the sugarcane rhizosphere.

The only land management that contained mainly native species was the grassveld, where *Tritigenia douglasi* and *Acanthrodilidae* sp. predominated. The areas of grassveld sampled were more or less separated from adjoining agricultural land by wasteland. By contrast, the native forest areas sampled adjoined agricultural land but were sampled at least 100 yards inside the forest. Sampling in native forest soils as far away as possible from agricultural land would be most likely to reveal native earthworm populations. It is, however, clear that both *P. corethrurus* and *A. rodericensis* have invaded areas of native vegetation and this underlines their strong colonizing nature (Lavelle *et al.*, 1987).

Conclusions

The size and composition of the earthworm communities in soils in the study locality are greatly affected by land management practice. The communities are dominated by exotic species accidently introduced from India. As is the case in many parts of northern Australia, South East Asia and northern tropical Africa, *P. corethrurus* is a ubiquitous species present in substantial numbers under all types of land use. It is the predominant species in sugarcane soils. The role of this species in influencing soil properties and soil fertility in the region deserves further study.

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