The Role of Soil Insects as Allogenic Ecosystem Engineers in Nigeria

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Abstract

This paper examines the role of soil insects, (including their juveniles) as ecosystem engineers as complementary to the role of the rest of the soil fauna in the holistic ecosystem engineering process. Ecosystem engineers function either as allogenic engineers or as autogenic engineers. Apart from the role of humans which have been described as allogenic engineers parexcellence we explore the influence of the soil insects in relation to their activity and mechanical alteration of materials in the environment leading to modulation in the resource flow and eventual habitat modification. The important categories of soil insects are discussed as integral of the soil community and in relation to their overall impact in soil fertility, in addition to their constraints, peculiarities, and prospects in the realization of their maximum potentialities in ecosystem engineering in the Nigerian environment and elsewhere. Practical consideration and integration of the interests of ecosystem engineering into environmental engineering in Nigeria will lead to full harnessing and realization of the inherent potentialities in the functions and functioning of the allogenic engineers and indeed the entire ecosystems engineers in their peculiarly environment in order to arrest further impoverishment of the soils and agroecosystems.

Keywords:*Ecosystem engineers, allogenic engineers environmental engineering, habitat modification.*

Introduction

The soil ecosystem harbours wide varieties of organisms. The world above and below the soil provide for each other, and change the composition and structure of the soil (Anthoni, 2000). In fact the diversity and abundance of soil life exceeds that of any other ecosystem, with very numerous physical, chemical and biological entities allowing interactions to occur in them (Environmental Literacy Council, 2002). Understanding the role of the soil in the farm ecosystem and knowing how to manage the land are critical and difficult tasks facing the organic farmer (Canadian Organic Growers, 1992) with the proper management of the ecosystem engineers being central to soil productivity and fertility. Unarguably the concept of ecosystem engineering appears to be most controversial yet most widely adopted and applied in contemporary environmental sciences and ecology from varying perspectives since its introduction in the last decade by Jones *et al.* (1994). This concept however has rapidly worked its way into the ecological literature (Wright and Jones, 2006), and scientists have agreed that the effects of ecosystem engineering will be context dependent (Jones *et al.*, 1994; Wright and Jones, 2006). As suggested by Reichman and Seabloom (2002) the concept of ecosystem engineering should be restricted to instances where the physical modification of the environment is “large” in relation to “purely physical processes operating in the system (Wright and Jones, 2006), a definition similar but distinct from a “keystone species” which is a species that has a disproportionate effect on its environment relative to its biomass (Paine, 1995).

In Nigeria information is scanty regarding reports on ecosystem engineers and their activities. Some of the important studies in Nigeria include those of Badejo (1999, 2002), Badejo, Tian and Okoh (2004), Olusola *et al.* (2006) and Ewuim (2006,2007) Apart from Badejo, Tian and Okoh (2004) who discussed invertebrates as ecosystem engineers including mites and earthworms all the other mentioned studies focused on insect. This review will however focused on the role of soil insects as allogenic ecosystem engineers and the need for environmental engineering to recognize and protect ecosystem engineering at all times in practice (by the experts of environmental engineering) in other to achieve sustainable engineering and protect the organisms involved in Nigerian and elsewhere. Jones *et al.* (1994) recognized two categories of ecosystem engineers: allogenic engineers which alter the environment by mechanical alteration of materials from one form to the other and autogenic engineers which “modify the environment by modifying themselves”.

Berke (2010) also noted that recognition of the organisms that have been long known to modify create, or define habitats by altering the habitat’s physical properties as ecosystem engineers is a reflection of the growing consensus that environmental structuring by organisms represents a fundamental class of ecological interactions taking place in most or all ecosystems. Berke 2010 then suggested the subdivision of ecosystem engineering into four narrower functional categories, representing the four broad mechanism of occurrence of ecosystem engineering as: structural engineers, bioturbators, chemical engineers and light engineers. Ant bioturbation, for instance is evident from channels, chambers, soil aggregates and maculae in the soil (Folgarait, 1998) with the network of galleries and chambers increasing soil porosity, soil aeration and drainage (Majer *et al.*, 1987; Cherrett, 1989; Folgarait, 1998).

Ecosystem engineers range from plants to protists and their activities span over a wide range of habitats including those found in hot deserts, temperate, subtropical and tropical regions and Arctic and Antarctic regions. Ecosystem engineering has been formalized as a process by which “an organism directly or indirectly modulates the availability of other resources for other organisms (Jones *et al*, 1994; Lawton, 1994; Dangerfield *et al.*, 1998). Accordingly Badejo *et al.* (2004) have categorized ecosystem engineers in the soil as direct engineers made up of the macrofauna and the mesofauna and act as primary litter transformers while among the indirect engineers can be found the microfauna, mesofauna and the macrofauna. In this case they also categorized the microfauna as secondary litter transformers while the mesofauna and the macrofauna can also act as grazers. Badejo *et al.* (2004) also used size distribution to categorise soil fauna as: building/primary process engineers (earthworms, termites, millipedes and ants), primary process engineers (mites and springtails), indirect microprocessors (protozoa and nematode), secondary process engineers (direct microprocessors) (bacteria and fungi). Earthworms, termites and ants have been indentified as principal engineers in the soil ecosystem (Lavelle *et al.*, 1977; Badejo, 2002), with these groups selected based on their ability to pass through the soil and build organo-mineral structures.

Emmerling *et al.* (2002) have also noted that earthworms are the most important ecosystem engineers in arable soil due to their lasting effects in the soil physical and biochemical properties. We remark that other members of the soil fauna play major and significant role in the ecosystem engineering services. Badejo *et al.* (2004) in this regard have noted that in nutrient release from litter, for instance, no group is able of initiate this process exclusively without the involvement of at least another group.

Soil insects in allogenic ecosystem engineering services

Brussard (1997) has noted that the soil biota provides a number of ecosystem services which include decomposition of organic matter, nutrient cycling, bioturbation and suppression of soil borne diseases and pests (especially in natural ecosystems as apposed to agroecosystems), since low plant species diversity renders agroecosystems vulnerable to harmful soil organisms. The general role of soil insects (which usually spent all or part of their life history in the soil) will be discussed below with emphasis on four major allogenic ecosystem engineers – Collembola, ants, termites and beetles. Some studies have implicated Collembola as ecosystem engineers. The soil fauna is involved in the regulation of decomposition of dead organic matters through their influence on the functioning of microflora which are involved directly in organic matter breakdown to make available inorganic elements locked up in organic matter through mineralization (Badejo *et al.*, 2004). According to Badejo *et al.* (2004) litter-chewing mesofauna including oribatid mites and springtails "use exhabitational mutualism between them and microflora to digest what earthworms are capable of digesting internally" which predisposes all of them as ecosystem engineers. In related reports (e.g. Lavelle *et al.*, 2006) soil invertebrates including collembolans have been remarked as playing significant roles in ecosystem services and should be considered as resources that should be properly managed.

Although soil ants may belong to different trophic levels probably all can be classified as ecosystem engineers (Jones *et al.*, 1994; Folgarait, 1998). They attributed this classification to the basic similarity of their effects on soil structure and processes which directly and indirectly affect flow of energy and material in ecosystem and the habitat of other species.

According to Joquet *et al.* (2006) termites, ants and earthworms are considered as soil engineers because of their effects on soil properties and their influence on the availability of resources for organisms including plants and microorganisms, but considered ants and termites as extended phenotype engineers, since such engineers have "great effects on the maintenance of ecosystem heterogeneity" and concentrate their activities at a few points. Ants and their larvae have also been included as organisms that can alter the physical structure of the soil and fragment the litter, aerating the soil and forming channels for infiltration of water (Baskin, 1993)

There is also evidence that ground ants act as ecosystem engineers by creating biomantle i.e. that portion of the soil whose properties are as a result of the continual activity of soil fauna pedoturbators (Johnson, 1990; Folgarait, 1998) Ants also facilitate the development of other organisms including such peculiar plants that would otherwise not exist (Folgarait *et al.*, 1996) or increase the amounts of some microorganisms (Petal, 1980) in their habitats. In the long run ants are not only responsive to human impact but are important within the below ground process not only through their alteration of the physical environment but through their effects on plants and animals (Folgarait, 1998; Ewuim 2006, 2007). Although soil ants may belong to different trophic levels probably all can be categorized as ecosystem engineers (Jones *et al.*, 1994; Folgarait, 1998)

Termites and Beetles

Termites and beetles are also involved in nontrophic interactions capable of change their environment's physical properties or state and which can also affect other species. The number of termite species identified worldwide is about 2500 (Badejo, 2002), with nearly all them implicated in soil modification through their activities in making of subterranean galleries, changes in distribution of plant nutrients, changes in nature and distribution of organic matter, physical disturbance of soil profile and changes in soil texture (Wood, 1988; Badejo, 2002): Out of about 2500 species indentified about 300 of them are pestiferous (Logan *et al.*, 1990; Badejo, 2002).

Termites constitute 40-60% of the total soil macrofauna biomass in many tropical ecosystems (Wood and Sands 1978) while in African savannas the standing biomass of termites have been estimated in the range of 70 to 100kg ha (Ferrar, 1982; Wood *et al.*, 1982).

Dangerfield *et al.* (1998) agreed that termites are a prime example of allogenic ecosystem engineers and that consideration of an invertebrate as a modulator of resource flows is useful in helping to proffer answers to questions of how ecosystems are structured and maintained (Dangerfield *et al.*, 1998). Termites, especially species of the genus *Macrotermes* that build large epigeal nests and extensive underground gallery systems, have major affects on soil chemical and physical properties throughout the tropics and subtropics with *Macrotermes michaelseni* regarded as a consummate allogenic ecosystem engineer (Dangerfield *et al.*, 1998). Fungus-growing termites (eg. *Macrotermes*) are also capable of engineering their soil microclimate for the facilitation of the decomposition of plant matter by their symbiotic fungi (Freymann *et al.*, 2008).

Badejo (2002) also reported that if ecosystem engineering is extended to include the process of litter transformation, termites, would then be regarded as process engineers because of their ability to consume litter, digest cellulose (aided by symbiotic bacteria) and in turn liberate nutrients. Termites also remove substantial quantities of mammalian dung and associated soil mainly in the dry season over a relatively short period though apparently of opportunistic importance to them (Freymann *et al.*, 2008). They however opined that despite the lack of evidence that termites as a whole show preference for feeding on dung, there is support that the communition of mammalian dung affects ecosystem functioning through nutrient cycling. There is however insufficient quantitative data to conclude that termites in this regard fulfill comparable ecological role to dung beetles in the context of nutrient cycling(Freymann *et al.*, 2008).

According to Badejo (2000) this is precisely the role played by earthworms in temperate soils hence the reference to termites as the earthworms of the tropics. Other reports also implicating termites as ecosystem engineers include Ewuim (2007) because of the role in habitats. Beetles have also been implicated as allogenic ecosystem engineers. For instance members of Scarabaeidae which feed partly or wholly in faeces include the true dung beetle (roller) (noted for rolling dung into spherical balls as food source or building chambers), tunnelers (which bury dungs wherever they find them) and dwellers (which neither roll or bury dungs but dwell in manure) (Frolov, 2006) have been implicated as ecosystem engineers by their activities. Scarabaeinae from various studies (eg. Nichols *et al.*, 2008) which comprises over 5000 species (Milius, 2003) are found in deserts, farmlands, forest grasslands and forests in all continents except Antarctica (Frolov, 2006).

The ecological roles and indeed ecosystem engineering functions of the dung beetle include dispersal of cattle dung (Ridsdill-Smith and Kirk, 1981) and those of other herbivores like elephants, gaur and buffalos, maintenance of hydrological properties of the soil (Brown *etal.*, 2010), seed dispersal, cleaning up of the environment, among other roles. Some other beetle species like the ground beetles also play their ecological roles. For instance the possible role as ecosystem engineer of the great capricon (*Cerambyx cerdo)* an endangered beetle listed in the

European Habitats Directive and which has been witnessing a decline in population sizes in central Europe was noted by Buse *et al.* (2008). On the basis of the impact C.*cerdo* seem to have on saproxylic beetle assemblage they emphasized the need to reintroduce the species in regions where they are now extinct.

Challenges in Nigeria

Most of the studies reported in this review were investigated outside Nigeria. A lot more needs to be carried out in the Nigeria environment to further add to the existing knowledge of ecosystem engineering services by soil insects and indeed other members of the soil fauna and even the autogenic ecosystem engineers. The impact of human activities on the allogenic ecosystem engineers need to be addressed, in addition to identifying the keysone species among the soil fauna. Even though many studies have been carried out on the density and abundance of soil insects in Nigeria more studies need to be carried in relating abundance of the organism to their role as allogenic ecosystem engineers in Nigerian natural and agricultural ecosystems.

Ecosystem engineeringVs. Environmental engineering

In the application of principles of science and engineering to improve the qualities of environment the stride to provide healthy environment for humans and other organisms, and in the remediation of polluted sites in Nigeria, there are few challenges. There is the need to adhere strictly to laws as those existing in other countries like the National Environment Policy Act (NEPA) of the United States so that the gains obtained from the ecosystem engineering services e.g. in nutrients cycling will not be nullified.

There is need for close cooperation between the environmental engineers and the scientists for the actual sustainability of the environment. Environmental engineers in Nigeria need to be screened by boards, trained and retrained and licensed so that the objectives environmental engineering can be achieved and our ecosystem engineers protected in the various natural ecosystems. There is a strong need for generous funding and involvement of government at various tiers, promulgation of laws and compliance to save the ecosystems in Nigeria and elsewhere.

Conclusion

In the review, we have attempted to provide some information on the ecosystem engineering services, offered by four soil insects groups – Collembola, ants, termites and the beetles which are integral members of the soil fauna and emphasize that these allogenic ecosystem engineers need to be managed properly and protected in order to enhance soil fertility and productivity. There is evidence that a lot more studies need to be done to obtain more information on the biodiversity, ecology, behaviours and interactions among the various soil fauna to further enrich the state of knowledge of these groups. The need for mutual co-operation between the environmental engineers and the scientists was emphasized to protect the ecosystem and indeed agroecosystems in order to save the soil environment from further degradation.

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