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# Ecosystem Engineering as a Concept: The Significance of Functional Classification of the True Engineers

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**Abstract**
*In this paper, ecosystem engineering as a concept is viewed critically from the point of view of its breath and different interpretations which have generated a lot of controversy. The definition of ecosystem engineers, though recent, is not seen as an excuse for its retarded development as a concept into a theory due to its historical antecedents right from the mid-19$^{th}$ century. The need to examine the various overlaps and differences between physical engineering 'processes' which could either be autogenic or allogenic on the one hand and ecosystem engineering 'consequences' on the other hand was stressed. Emphasis on the 'end-result' of the engineering process was identified as a factor which can facilitate the development of ecosystem engineering into a theoretical concept. If soil fertility is seen as the 'end-result' of ecosystem engineering in the soil, the application of the concept will be narrowed down to all activities that lead to maintaining soil fertility to the exclusion of activities that have hitherto been regarded as ecosystem engineering simply because they transform or affect the biotic and abiotic components of the ecosystem. The functional classification of ecosystem engineers in various ecosystem compartments in a wide variety of biota is stressed as another important exercise that can further strengthen the ecosystem engineering as a concept.*

**Keywords:***Ecosystem Engineering, autogenic, allogenic, soil fertility,*

## Introduction

Jones *et al.* (1994) originally defined ecosystem engineers as "organisms that directly or indirectly affect the availability of resources to other organisms through modifications of the physical environment." Various interpretations of this definition have been provided by various authors. For example, Buchman *et al.* (2007) described Jones *et al.*'s definition as "… an organism that creates, modifies, or maintains a habitat by altering the availability of resources to other organisms." Since then, various definitions of ecosystem engineers have emphasized their role in alteration of the physical environment to the extent that some definitions are so broad that every organism on earth could be considered an ecosystem engineer.

Historically, ecosystem engineering studies dates back to the mid-19$^{th}$ century when Morgan (1868) described how beavers affected stream ecosystems. Darwin (1890) wrote about the role of earthworms in ecosystem processes, while Shaler (1892) wrote extensively on how plants and animals affect soil processes. Many studies abound in Literature (see Fig. 1) for more than a century before Jones *et al.* established the phenomenon of ecosystem engineering as a concept through their first definition. According to Jones and Gutiérrez (2007), "no concept is ever born fully developed, they justify clarification." Concepts that cannot eventually be sufficiently unambiguously defined as to be made operational deserve to disappear. Furthermore, Pickett *et al.* (1994) had argued that while a concept is not a theory, it is a foundation upon which theory is built, and the foundation must be solid if one has any aspiration for theory development. The current situation now since Jones *et al.*'s definition of ecosystem engineering is that the questions generated by the various definitions beg for theory development.

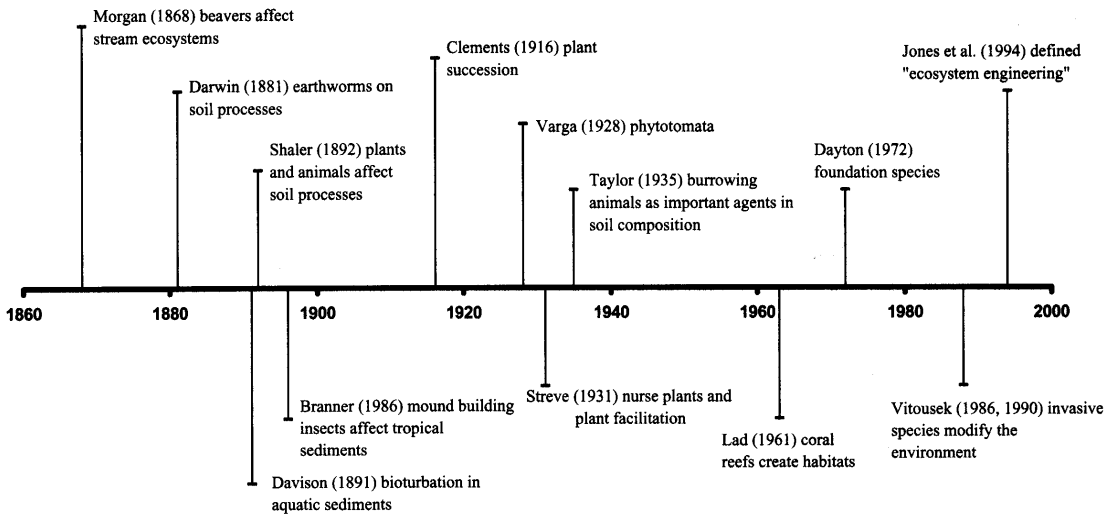


**Fig. 1. Time line of selected important studies related to the ecosystem engineering concept. Source: Buchman *et al.* (2007).**

In an extensive analysis of the controversies that this concept has generated and the uncertainty over its meaning, usage and purpose, Jones and Gutiérrez (2007) drew attention to the following questions which various definitions of ecosystem engineering have raised. *Don't all organisms change the environment? Aren't all organisms therefore ecosystem engineers? If so, isn't the concept too broad to be useful? Don't engineers always have large or large scale impacts? Shouldn't engineers be limited to species with large effects? Aren't engineers and keystone species the same? Isn't engineering equivalent to facilitation or positive influence? Isn't the approach overly reductionist? Why do we need the concept? How can we use it?*

The various responses to these questions have created uncertainty, misconstrual and misunderstanding, all of which according to Jones and Gutiérrez (2007) are capable of impeding scientific progress in building the concept of ecosystem engineering into a theory. It is in the light of this that the extensive breath and utility of the concept of ecosystem engineering is critically examined with a view to highlighting the hurdles to cross in making it a theoretical concept as opposed to a disappearing concept.

## Ecosystem Engineering as a Concept

The failure of the concept of ecosystem engineering to provide a solid foundation upon which theory can be built since 1994could be attributed to the inability to identify the areas of overlap as well as the differences between the processes of ecosystem engineering and their consequences. Physical ecosystem engineering processes are "organismally caused" and they imply structural changes which can occur either 'autogenically' (where the structure is a living organism) or 'allogenically' (where the organisms build the structure from living or non-living materials). Thus, uprooting of trees and creating tip-up mounds by strong winds or wild elephants are regarded as ecosystem engineering on the one hand while burial of litter in burrows by earthworms or sowing of leaves together by tailor ants have also been regarded as ecosystem engineering. In fact, shells of dead mollusks which provide shelter and protection from predation as well as physical and physiological stress for hermit crabs (Gutiérrez *et al.* 2003) have been seen as habitat creation within a broad concept of ecosystem engineering.

As for ecosystem engineering consequences, the starting point of 'consequence' is abiotic changes resulting from the ecosystem engineering process. Jones and Gutiérrez (2007) have defined 'consequence' as "Influence arising from engineer control on abiotic factors that occurs independent or irrespective of use of or impact of these abiotic factors on the engineer or the participation by the engineer in biotic interaction, despite the fact that all these can affect the engineer and its engineering activities." This complex definition is one of the impediments on the pathway of transformation of ecosystem engineering as a concept into a theory.

**Importance of '*end result*' in developing soil ecosystem engineering as a concept**

In order to reduce the controversy surrounding the interpretation of ecosystem engineering, the 'end result' must be considered in addition to the 'process' and 'consequence'. In the soil ecosystem for example, if the end result is soil fertility, the definition should be so directed towards the improvement of soil fertility. This is why Badejo *et al.* (2004) opined that "if the soil is the environment in focus, and surface litter is regarded as the first layer of the soil, litter transformation is indeed a process in ecosystem engineering." Litter transformation is indeed a complex stepwise process which starts with a raw material, the litter, and ends with liberated nutrients as products (Fig. 2).

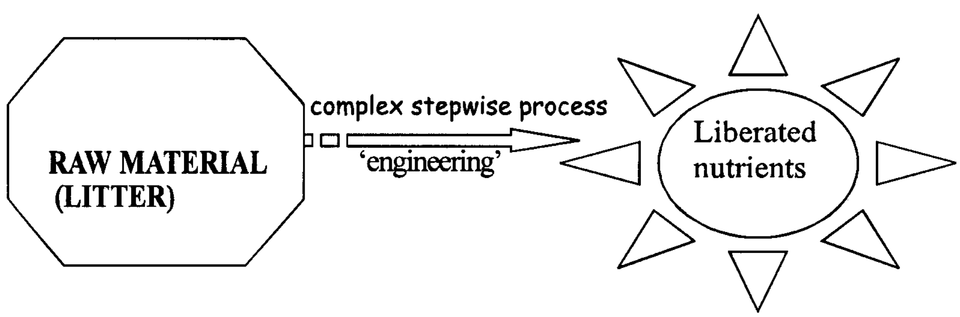


**Fig. 2. Litter transformation as an engineering process. Source: Badejo *et al.* (2004)**

Ecosystem engineers in the soil should include all fauna that take part in litter transformation and the liberation of inorganic nutrients locked up in the organic molecules, irrespective of their size or the quantity of material they act upon as individual units and not an animal like the elephant which uproots trees and creates mounds occasionally. To buttress this point is the fact that ecosystem engineering processes that improve soil fertility mean nothing to the civil engineer whose interest is in the tensile strength of the soil to support physical structures. Any attempt therefore by a soil ecologist to define ecosystem engineering to include the concerns of the civil engineer is an exercise in futility.

If decomposition and mineralization do not occur in nature, dead organic matter would continue to accumulate and lock away energy and plant nutrients. Litter disappearance and mineralization as well as agents that bring them about either directly or indirectly (Fig. 3) are therefore critical to the continued productivity of terrestrial ecosystems (Vitousek, 1982).

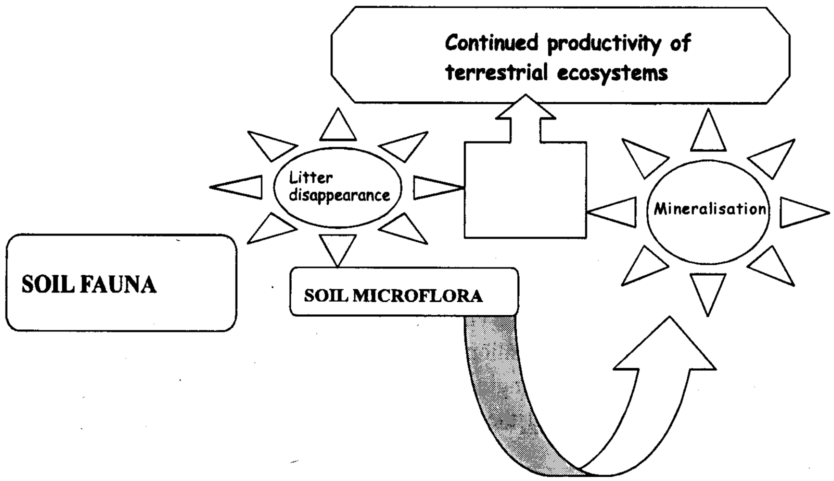


**Fig. 3. Role of soil fauna and microflora in maintenance of ecosystem productivity. (Source: Badejo *et al.*, 2004.)**

Litter transformers serve as the link between macrofauna and microfauna which carry out the most fundamental transformation of organic matter into particles. They are largely composed of invertebrates which influence microbial activity directly or indirectly through the physical and chemical modification of organic detritus. Soil dwelling macrofauna are also ecosystem engineers because they build organostructures in the soil. The most typical examples of soil dwelling macrofauna are the termites and earthworms which generate permanent or semi-permanent stability as they process organic detritus and determine specific functional domain in which other categories of soil fauna can be active. When biotic changes occur in the soil ecosystem, abiotic changes are bound to follow. It is therefore not necessary to separate abiotic from biotic consequences in any definition of ecosystem engineering.

**Functional Classification of Ecosystem Engineers**

Ecosystem engineering by soil microarthropods and other mesofauna for example can either be a direct process of communication of litter, or an indirect process of grazing on litter transformers (Badejo *et al.* 2004). The termites, ants and earthworms that build structures in the soil as they consume litter and other vegetable material are also process engineers but they are builders as well. The structures built by them are their faecal pellets which have been described by Lavelle (1996) as holorganic structures which are either temporary or permanent in nature. These structures merely serve as incubators for microbial activities. In the process of building these structures, they initiate the process of litter breakdown and also ensure that the litter is processed for nutrient release by microflora.

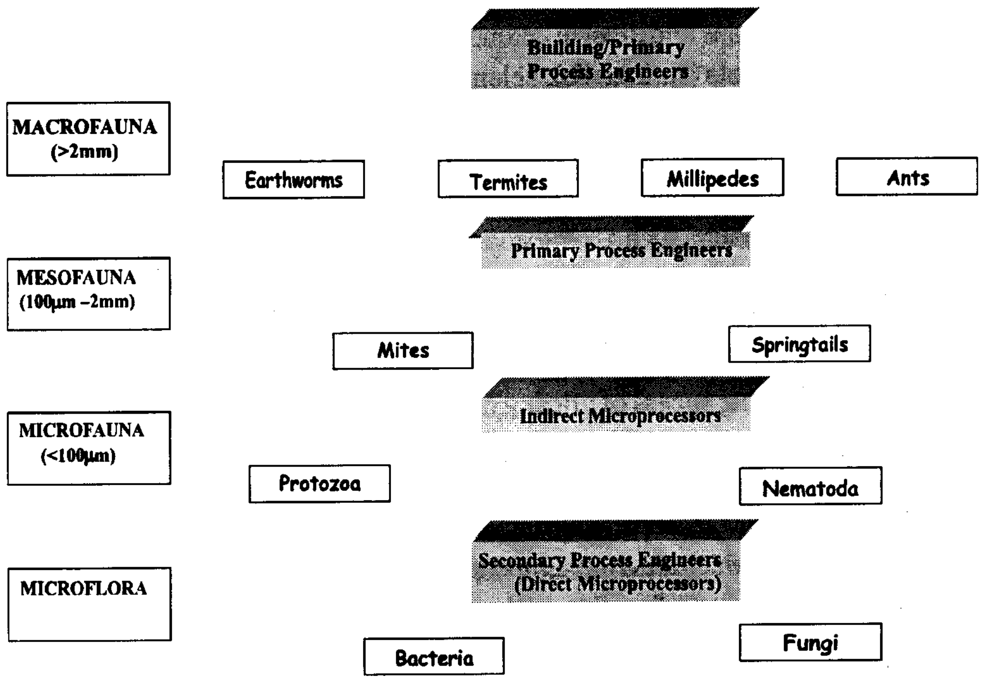


**Fig. 4. Size and Functional classification of the real ecosystem engineers involved in soil fertility maintenance. (Source: Badejo *et al.*, 2004)**

Like most mesofauna, they are also primary process engineers due to their involvement in decomposition the initial stage of litter transformation. The microflora takes over from the primary process engineers as they consume their droppings and dead bodies to liberate nutrients. They are therefore secondary processors and the microfauna such as nematodes and protozoa that graze on them are involved in this microprocessing albeit indirectly. The classification of these different categories of ecosystem engineers which was provided by Badejo *et al.* (2004) is one necessary step towards removing the stumbling blocks towards making ecosystem engineering an acceptable theoretical concept. (see Fig. 4).

In order to develop frameworks necessary for transforming ecosystem engineering into a theoretical concept, different ecosystem engineers within specific biota in diverse habitats (e.g. benthic fauna, tree canopies, wetlands, estuarine habitats, fish ponds, streams, rivers, etc.) should be classified functionally as Badejo *et al.* (2004) did for soil-dwelling fauna to provide information that will be complimentary to the extensive ones available already on physical transformation processes and ecosystem engineering consequences.

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