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TERMITES AS ECOSYSTEM ENGINEERS IN TROPICAL AND SUBTROPICAL ECOSYSTEMS

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Abstract
Important ecosystem engineers are termites. Termites build enormous underground tubes and mounds that change properties of the soil, both physical and chemical. This activity also enhances water infiltration and soil aeration, which are known as fertility hotspots. These are abundant in carbon, nitrogen, and phosphorus, making them vital nutrients for the growth of plants. Further it helps organic matter break down, converting cellulose-based materials into nutrients that plants can need. Termites have an impact on soil structure and nutrient distribution at many different sizes, ranging from aggregate to the landscape level. Termites preserve ecosystems during droughts by preserving humidity in the soil in tropical rainforests. The surrounding landscape's greater microbiological plant and animal variety is supported by dear mountains and activities. By breaking things down and releasing nutrients, termites operate as essential carbon cyclers and promote decomposition.

1. INTRODUCTION

The field of ecological engineering, which involves designing ecologically friendly ecosystems that serve both human culture and the surrounding environment, has made considerable strides in the previous 30 years, particularly in the last 10 years. Its objectives include the creation of new environmentally friendly ecosystems with ecological and human values as well as the regeneration of ecosystems that were severely damaged by human activity. There are five ecological engineering tenets: Its foundations include, the ability of ecosystems to self-design; the potential for ecological theories to be put to the test; system approaches; the conservation of energy that is not renewable sources; and it encourages the preservation of biology (Mitsch et al., 2003).

As soil engineers, termites are vital to the way many tropical and subtropical environments operate. As illustrated in Figure 01 One of the primary macroinvertebrate decomposers in arid and semi-arid regions is termites. Additionally, they alter the earth's chemical and physical attributes by forming bio structures like caves, gaps, sheeting, etc. They have an impact on the distribution of natural resources throughout the landscape, including water and nutrients which affects the variety of plants, animals, and soil microbes (Jouquet et al., 2011). Termite communities are a good indicator of the health of the soil and the ecosystem services they offer (Duran-Bautista et al., 2020). In sub-Saharan western Africa, the current study shows the efficiency of particular termite species in preserving long-term soil production and replenishing barren soil, thus boosting agricultural sustainability (Kaiser et al., 2017).

The five main environments that termites can be found in are semi-desert, temperate rain forest ecosystems, tropical savanna forests, tropical rain forests, and mild woodland. This study compares and contrasts 23 example habitats around the world. The African Congolese humid forest (62 genera) has the highest generic richness, followed by the Neotropical Guinean rain rainforest (55 genera) and the Asian rain forest (44 genera) of the northern region. Compared to the other major tropical rain forest locations, the Australian continent and New Guinea, specifically the Bornean rain forest contains nearly one-third as many taxa. The African representative is the most prevalent among the six savanna woodlands environments, with 37 genera. Following with 25 and 24 genera, respectively, are the Neotropical and Australian ecosystems (Jones & Eggleton, 2010).

Termites have a significant role in scenarios of climate change because they release greenhouse gases like $CO_2$and CH_4 and have an enormous biomass in various tropical environments (Sugimoto et al., 2000). Mounds of termites and field dykes had greater diversity and density than rice plots, particularly during the rainy period. Because they serve as havens for other types of macrofauna in both the rainy and dry seasons, termite mounds and dykes can be regarded as hotspots for biodiversity, offering shelter from drought and flooding (Choosai et al., 2009).

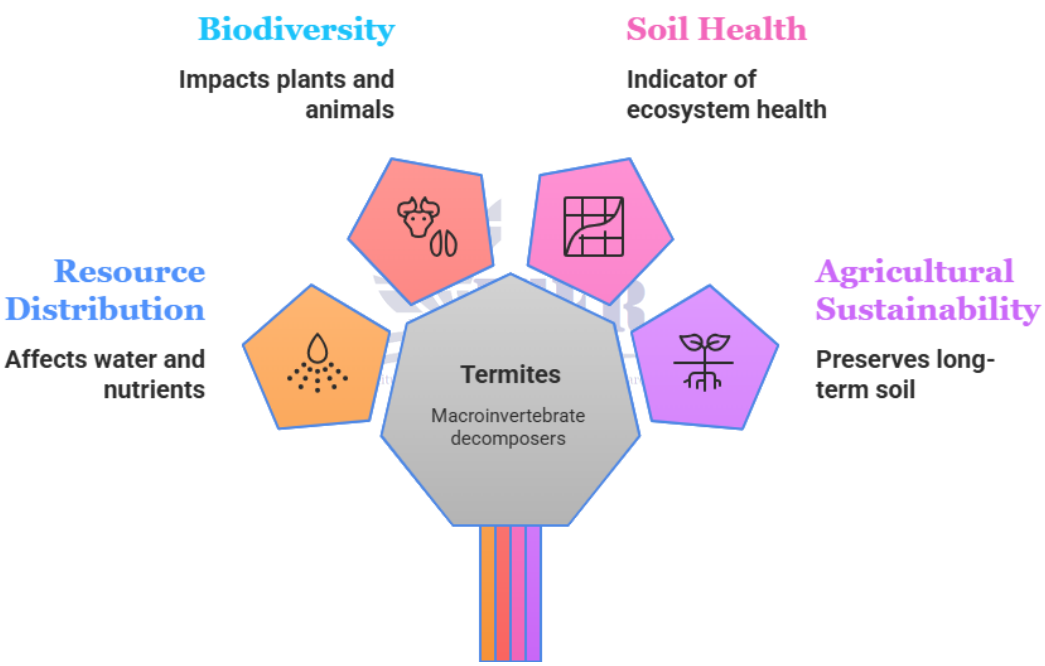

Fig. 01. Impact of Termites on Tropical Ecosystem

2. Termite`s taxonomy and global diversity:

Termites are a common and important soil organism on a worldwide scale. Although their role in ecosystems is becoming better known and appreciated, methods for accurately sampling termite populations across environments can be difficult and have not improved at the same rate as termite ecology research (Davies et al., 2021). Because there is a shortage of functional characteristic data on a worldwide scale, we investigate termite functional biogeography patterns in China. We investigate whether environmental factors influence termite taxonomy and functional geographic distribution on a global and within China scale, as well as how these compare across scales. Tropical locations are expected to have increased termite variety because to significant plant material turnover and diverse niche availability (Liu et al., 2022).

3. Termite caste system:

The neutering line produces laborers and soldiers throughout the year, whereas the sexual line develops during a certain season. After a few instars, larvae evolve into workers, with only minor morphological changes but a significant shift in physiology and behavior (Noirot, 1985). Termite societies have a diverse range remarkable patterns of polymorphism that only the most complex ant societies can match. When termite juveniles of either gender deviate away from the straight hemimetabolous route that connects the embryo as it develops to the winged imago, caste differences occur. There are two kinds of irreversible abnormalities seen in primitive termites: one contributes to the infertile soldier caste and other results in to neotenic reproductive systems. Immatures do social activities in a primitive manner that could prolong their development but allows them to continue developing (Roisin, 2000). Polymorphism takes place in the labor caste through sexual dimorphism, the existence of consecutive worker phases or both. Soldiers are distinguished from larvae and workers, with their origins clearly stated for each species. In most situations, they are all the same gender, either male or female determined by the species (Noirot, 1985)

4. Feeding groups of termites:

Termites' impact on the cycling of nitrogen and tropical soil development is determined by their eating behavior and material transformation. It is challenging to identify food sources since termite activity and nest development vary and alter (Siebers et al., 2015). Termite can feed on wood, dirt, or leaf litter. *N. macrocephalus* consumed around 49 mg of wood per gram of termite, which was greater than previous estimates (Martius, 1994).

5. Wood feeders:

In many tropical and subtropical environments, termites which originated as wood-eating cockroaches now dominate the saprophytic insect group. Their ecological role includes digestion of lignocellulose, which aids in the disintegration arm of the global carbon cycle, bioturbation, which combines organic and mineral elements in soil horizons, and communution (shredding) of dead organic material (Bignell, 2018). Xylophagous termites eat nitrogen deficient foods such as dry, solid wood or grass, as well as plant litter pieces with nitrogen amounts so low. Those wood-eating and grass-eating termites rely primarily on the parasitic bacterial colonies in their gut to supply the nitrogen through biological fixation (Majeed et al., 2012).

6. Soil feeders:

Termites aid in the humification of soil in the tropics, despite the fact that they are frequently regarded as a nuisance because of the harm they do to buildings and agriculture. This effect on the humification procedure that processes soil organic material is caused by soil feeding termites, who are the most significant eating habit in terms of species variety (approximately 200 species). In contrast to other termites, they consume mineral-containing horizons to obtain nutrients rather than lignocellulosic plant breakdown (Brauman, 2000).

7. Distribution and abundance in tropical ecosystem:

Environmental factors significantly impact the diversity of termite species in a given area. Rainfall, landscape climate, and altitude can impact termite point diversity (Eggleton, 2000).

Current local termite assemblages, as well as the geographic distributions of the many evolutionary clades, are the result of migration, radiation, and diversification processes, as well as the impact of contemporary environments. A corresponding framework of regional and worldwide biologically geography spanning the various biogeographical zones has developed as a result of termite ecology studies restricted to tropical forests and subtropical borders over the past forty years (Jones & Eggleton, 2010). Rainfall is expected to increase termite populations and species diversity in many tropical habitats, with rainforests exhibiting the greatest rates. (Clement et al., 2021).

8. Soil formation by Termites as a soil engineers

Because of their significant contributions to ecological processes such soil formation and control, decomposition, and nutrient cycling, termites are considered ecosystem engineers as explained in the Table 01 (Jouquet.et.,al. 2011,Bonachela.et.,al,2015).

9. Termites mound soil properties

Termites construct termite mounds, which are soil formations, in a variety of tropical environments (Jouquet et al., 2015). The aim of these trace fossils is to shield the colonies from a range of biological and environmental threats (Eze et al., 2020). These formations comprise clay and organic matter soil particles that have been cemented collectively (Harit et al., 2017; Jouquet et al., 2021; Cheik et al., 2022). Odontotermesobesus (Rambur), a species of termite that builds underground mounds, is primarily found in tropical regions of the entire globe, such as Africa and Asia. It is the most prevalent species in Assam with the capacity to build mounds (Ashraf et al., 2020; Liswas and Deka, 2019). The soil and the environment type encourage termite population expansion .

The mounds contain several distinct physico-chemical and biochemical characteristics, such as the pH level, organic matter, capacity for cation exchange, NPK that stands for Nitrogen (N), Phosphorus (P) , and Potassium (K) concentration, in comparison to the nearby soils because of termite activity. Because termite mound soil can give nutrients, numerous researchers have examined its effects on crop growth in paddies , corn (Barna & Ravindran, 2018), including tomatoes (Garba et al., 2011). These tests demonstrated that termite mound soil had a great growth effect on the crops mentioned above.

10. Termites mound fertility islands

By significantly changing the synthetic and structural features of the soil in contrast to neighbouring unaffected soils, termite mounds function as fertility islands, creating limited areas of enhanced quality of structure and nutrient availability, according to current research. By demonstrating increased macro-porosity, improved stability of the aggregate, and greater levels of naturally occurring carbon, available phosphorus, and essential cations compared to surrounding soils, evidence of termites project to enhance the fertility of the soil and structure mineral-poor landscapes (Duran-Bautista et al., 2025). In tropical paddy fields, termite structures can act as nutrient patches, enhancing physical and chemical characteristics like as pH in contrast to neighbouring grounds (Geoderma Regional et al., 2023).

The character of termite mounds as nutrient hotspots, particularly with regard to phosphorus cycling, is also highlighted by pedological syntheses. These biogenic structures have long been used as soil amendments due to their high nutritional content and potential benefits for crop development (Pedobiologia et al., 2023).

10.1. Termites as bioturbation

The capacity of soil animals to create soil-based cultivation biological forms, such as biotic bundle (e.g., Lavelle, 2000; Brussaard et al., 2007; Jouquet et al., 2009) or biopores (Vogel et al., 2021), is at the core of biological discompose, also known as bioturbation, and affects important ecological processes and environmental resources as explained in Table 01 (e.g., Adhikari and Hartemink, 2016).Even while termites frequently outnumber earthworms (King, 2016) and make up the majority of the soilmacrofauna population on tropical soil's (Eggleton et al., 1996; Bignell and Eggleton, 2000; Ellwood et al., 2002; Franco et al., 2016), little is known about how they affect soil structure.

There are two kinds of soil naturally occurring structures that termites can create. Termite infestation nests, which areone of the most noticeable aspects of humid ecosystems due to their size and complexity also their unique soil texture,ph and biodiversity characteristics, have been the subject of the majority of the composition on termite bioturbation that is currently available (Fagundes et al., 2021; Van Thuyne and Verrecchia, 2021). The unique characteristics of the associated soil give nests a very high stability if they are not disturbed through mammals (such as pangolins, bears, elephants, or anteaters) over periods of eras (Jouquet et al., 2004). This enables them to withstand the weathering action of rainfall (Erens et al., 2015). Termites are also capable of producing "soil sheeting" structures, which are tiny aggregates that are frequently formed on the ground and resemble earthworm casts. In certain tropical habitats, the chunk of earth involved can reach several tonnes per year (Mando, 1997; Rouland et al., 2003). This amount is similar to the amount of worm casts created in moderate and humid zone (e.g. Butt et al., 2015; Bottinelli et al., 2021). Clay particles along with organic matter hold soil particles together to form termite biogenic structures (Harit et al., 2017; Jouquet et al., 2021; 2022a).

96 termites had varying effects on soil coating stability, according to a recent that compared the characteristics of soil sheeting gathered over a large quantity of biotopes on 21 nations across every continent except Antarctica (Jouquet.et.al., 2022a). Two termite groups fungus-97 98 developing (FG: belongs within the Macrotermitinae subfamily) and other than fungus developing 99 termites (non-FG: other wood as well as foraging termites were distinguished using mound similarities.For non-FG growing termite species, soil sheets was as solid as the neighbouring soil particles , but for fungus-growing termite species, the strength of sheeting was variable 102, reaching approximately 60% of water durable aggregates, regardless of the security adjoining soil particles (Jouquet et al., 2022a).

In a different study, Harit et al. (2017) demonstrated a potential rake between fungus-growing agents that added clay particles to soil sheeting to those that did not alter soil appearance but instead added biomass within the shape of saliva, most likely to protect themselves from environmental threats. It has also been proposed that one of the elements determine the strength of sheeting is the substrate composition that is concealed by it (Jouquet et al., 2015; Harit et al.109 2017). Although, given the small amount of data available (n = 16 to 32 findings from 24 investigations in the systema review conducted by Harit et al., 2017), these claims must be regarded cautiously.

11. Role of termites in nutrient cycling

Termites are a major category soil containing animals in tropical and mild temperate regions. Nine termite species have been identified in the study region, with seven in total foraging on wood and two on grass and surface organic detritus; *Nasutitermes exitiosus* is the major wood feeder (Lee & Butler, 1977).

In tropical settings, termites act as ecosystem engineers via visual bionomic structures (mounds) that affect vegetation development, biodiversity, nutrient cycling, decomposition, and soil characteristics. In their natural temperate habitat, underground termites (Reticulitermes spp.) have an impact on nitrogen cycle explained in Table 01. Holarctic distribution by export of the fruit-bodies from woods to soils as larval galleries are lined by feces (frass). The total number of elements in frass was 14 higher compared to wood and only Cr and Fe were less concentrated (Myer & Forschler, 2019).

Fungus farming evolved a single time, in one of the termite sub family, the family Macrotermitinae. In the ancient world, this subfamily is now the most common decomposer, and insect enzymatic action following fungus/bacterial activity on a complex decomposition pathway, termites achieve almost total utilization of nearly any plant substrate (da Costa et al., 2019). Termites that grow fungus effectively degrade lignocellulose in tight symbiotic relationship with basidiomycete fungi cultivated in their nest (Ohkuma, 2003). Using a dead wood disintegration assay, we discovered that termites are the cause of 58-64% of overall mass loss, whereas microorganisms contributed 36-42%. These discoveries will assist to enhance the precision of Earth-system models and predictions for climate in the appearance of worldwide transformation, illustrated in Figure 02 (Griffiths et al., 2019).

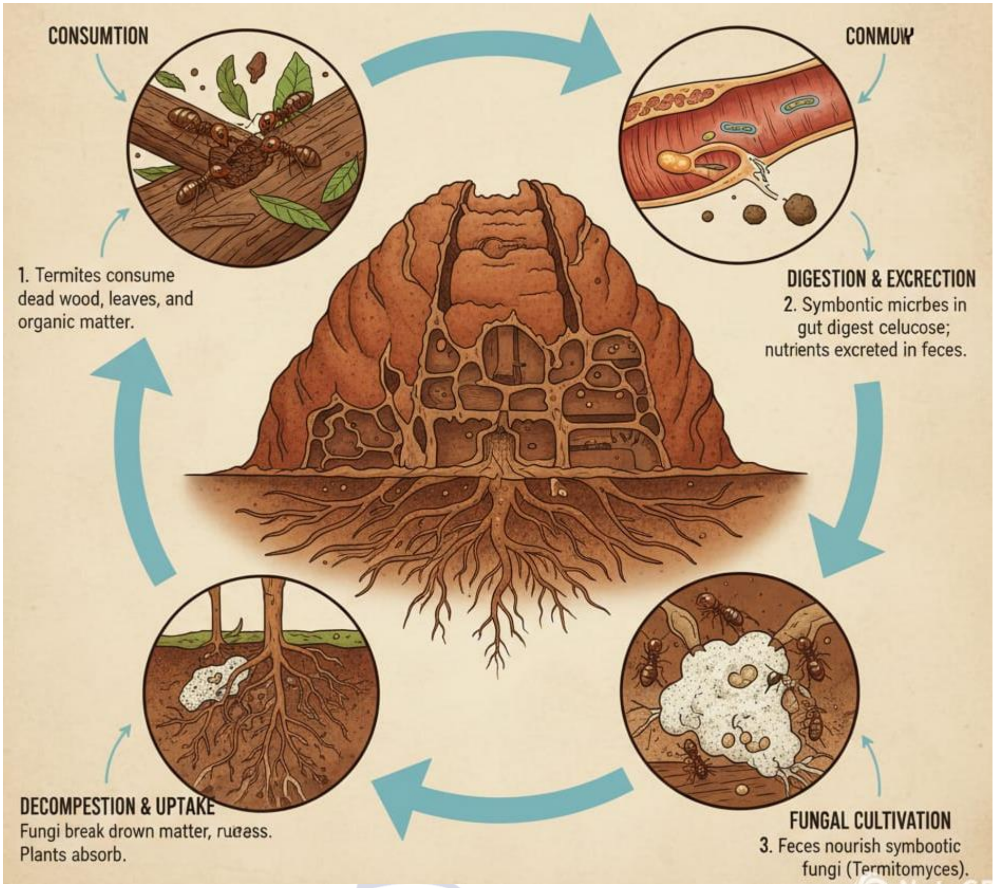

Fig. 02. The Nutrient Cycling of Termites

12. Termites gut microbiome

Termites rely on stomach microorganisms to breakdown polymers that are complex of hardwood into simpler ones. Wood contains cellulose, a main polymeric carbohydrate that is converted into simpler metabolites by hindgut bacteria during metabolic processes. During the cellulose breakdown process, termite gut microorganisms create gases, the most common of which is methane. Microorganism of the gut predominantly belong to three main categories i.e., bacteria, archaea, and protozoa. They are mutualistic, and in 24 hours can convert up to 95% of the cellulose into simple sugars explained in Table 01 (Maurice & Erdei, 2018).

Culture-independent methods were employed to explore the association between gut microbial community structure and termite diet habits and phylogenetic positions based on 16S means ribosomal RNA gene. V1-V3 the Variable regions 1 to 3 of the 16S rRNA gene. amplicons with high-throughput 454 pyrosequencing. Three colonies of higher termites (*Mironasutitermes shangchengensis* and fungus-feeding *Odontotermes formosanus*) and two wood-feeding lower termites (*Tsaitermes ampliceps*, *Reticulitermes flaviceps*) were analyzed. The gut microbiota consisted of 132 genera and unclassified OTUs known as Operational Taxonomic Units from 29 phyla. Spirochaetes (11%-55%), Firmicutes (7%-18%), Bacteroidetes (7-31%) and Proteobacteria (8%-14%) were the predominant phyla, with Treponema, TG5 a candidate bacterial group (not fully classified), *Dysgonomonas*, *Tannerella*, ZA29 that is likely a candidate or uncultured lineage, Lactococcus, Pseudomonas and SJA-88 as common genera in all four termite species. The gut microbial communities of *M. shangchengensis* (wood-feeding higher termite) were closer to those of the wood-feeding lower termites than to those of *O.*

formosanus (fungus-feeding higher termite). Despite their phylogeny, the wood-feeding termites were dominated by spirochaetes and nitrogen-fixing bacteria (Su et al., 2016).

The termite gut consists of one or more compartment that harbor mostly bacteria and protists called lower termites, some archaeal genera that includes both methanogenic and nonmethanogenic lineages, fungi, and bacteriophages as endosymbionts with the host termites in a mutualistic exchange to provide nutrients through degradation of recalcitrant plant biomass. Biotic, abiotic and dietary environmental factors are known to influence the physicochemical status of the different segments in addition to their microbiome diversity. Methanogenic substrate availability as a control factor for methanogen diversity in the gut (Kumar et al., 2020).

The efficacy with which three different species of mouna-building termites, *Amitermes vitiosus* Hill, *Drepanotermes perniger* (Froggatt) and *Tumulitermes pastinator* (Froggatt), were able to make available nutrients contained in plant material was investigated in a semi-arid tropical woodland at Charters Towers, north-eastern Queensland. Several chemical properties of the red and yellow earth soils, which were found to have poor in situ fertility and remained unmodified by past termite activity, are contrasted with the mounds produced by the three termite species, along with the underlying soil as modified by termites. 21 Mg ha-I of soil, at only l o% of the total soil mass in the Al soil horizon, but 5-71% of plant nutrients in this system. Soil nutrients in termite mounds are temporarily withheld from plant growth, before being released to the soil surface due to erosion of abandoned mounds. Termites are able to turn over 300-400 kg ha-1 of soil material with N concentrations that are 2-7 times higher than those measured in the Al soil horizon (Coventry et al., 1988).

13. Termites and Carbon Cycling & Climate Change

Due to their enormous biomass and abundance, social insects are very visible in many ecosystems on earth, which has significant effects on ecological processes. Ants and termites certainly outnumber the other macro arthropods, but they also do so rather frequently. Their well-known, yet still very pertinent, research of the central Amazonian rainforest revealed that termites and ants together accounted for about 15% of total animal biomass. There is evidence that termite colonies generate a variety of traces of gases that may have an impact on the composition of the air or balance of the earth. These gases include carbon dioxide, methane, nitrogen dioxide, carbon mono-oxide, and chloroform, yet only Carbon dioxide and methane are produced in large enough quantities to be of concern to global budgets (Bignell, 2010).

The only elements that were less prevalent in frass were Cr the chromium and Fe iron than in wood, while the other 14 elements became more concentrated in frass. Termites increase C carbon along with Ca calcium in soil while decreasing Al aluminium, Co cobalt, as well as Cr chromium levels, according to the contrasts between the soil and the shelter tube. Thus, it is likely that Reticulitermes regulate element fluxes by replenishing the weathered, acids and Ultisols of the southeast US woods with organic C & base cations (Myer & Froschler., 2019).

13.1. Termites Carbon Cycling

It is hypothesized that termite activity divides litterfall among neighbouring, rival colonies in an exhaustive manner, decomposing it to the point where little or no organic carbon is added to the soil. It appears that carbon is released from the mounds as CO_2 and CH_4 while accompanying N, P, & cations accumulate in the mounds. Although the data is insufficient to compute nutritional fluxes through termites, it does corroborate the notion that termites perform an important role in atmospheric CO2 and CH4 fluxes illustrated in Figure 03. Additionally, they propose that the global carbon constraint and regional soil formation processes are coupled (Jones, 1990).

By mediating degradation and other facets of soil function, termites are acknowledged as ecosystem architects. Consequently, termites could be quite important in the biochemical cycles of earth, particularly the carbon and methane cycles. In fact, termites can account for as much as 2% of the natural CO_2 emissions from land-based sources which is a significant contribution for just a single taxon but a minor one when considered globally. We observe that errors regarding termite biomass distribution continue to interfere with estimations for CH_4 (Sugimoto et al., 2000).

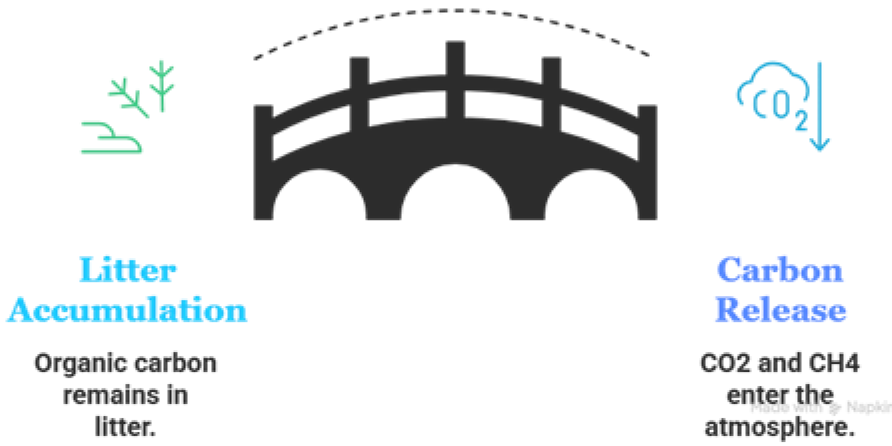

Fig. 03. Role of Termites in Carbon Cycling

13.2. Termite Methane Emission

There has been substantial discussion over the past 40 years over termites' contribution to the worldwide methane budget. Termite emissions, which make up around 4% of emission from natural sources (apart from wetlands), are estimated to be between 9 -15 trillion grams of CH_4 per year (Law et al., 2024). An estimated 14.8 ± 6.7 Tg CH_4 per year was released globally in 2020, primarily within tropical and subtropical habitats, suggesting that upland areas were a key natural source. The estimating methods' uncertainties were evaluated (Ito, 2023).

Two methods were used to assess termites' contribution to the ecosystem's CH_4 budget. When local mound density figures were paired with termite mound emission data, the average amount of CH_4 emitted by termite mounds was estimated to be between 0.15 and 0.71 nmol m 2 s1. Furthermore, termite-emitted CH_4 was estimated to be 1.0 nmol m 2 s 1 after the termite CH4 output factor from this investigation was merged with termite biomass numbers. We anticipate that termites have a significant impact on the CH_4 economy of this terrestrial firm ecosystem, given the comparatively low net emission levels of CH_4 that have been previously recorded at this ecosystem (van Asperen et al., 2021).

13.3. Termite Climate Change

CO_2, CH_4, and N_2O are the primary gases linked to rises in greenhouse gas emissions and global warming (Khalil et al., 1990). Prior research has examined the variation in CO_2 levels between termite mounds and the surrounding foraging areas. The findings indicate that low CO_2 emissions are caused by insect respiration rates and organic matter decomposition rates that are proportionate to the abundance of macro invertebrates. Between late 1990s and 2006, the amount of CH_4 in the atmosphere remained constant before beginning to rise once more. The total estimated contribution of termites to the CH_4 balancing is 11 trillion grams of CH_4 per year, or 0.02% of world emissions. Termites' full contribution to the nitrogen cycle requires in situ emission studies because N_2O is a potent greenhouse gas that may be created in the stomach of macroinvertebrates (Quevedo et al., 2021).

13.4. Lignocellulose Degradation in Termites

The most plentiful renewable energy source available for use in the manufacturing of biofuel is lignocellulosic biomass. It`s complicated structure and stubborn character, however, limit its use in the generation of biofuel. An effective method of improving the decomposition of anaerobic biomass is to use termite gut microorganisms, which are a potential source of appropriate bacteria with productive enzyme systems (Bhujbal et al., 2021). The intestinal bacteria of termites are crucial for nitrogen fixation, microbial defense, and lignocellulosic breakdown. Lower termites use protozoa and cellulolytic organisms to break down wood, while higher termites have hindgut microbes that coexist symbiotically with fungi called Basidiomycetes. Enhanced lignocellulosic breakdown has resulted from higher termites' total lack of cellulolytic protozoans as a result of evolution and the acquisition of new bacteria that thrive in their gut (Mathew et al., 2022).

Termites' gut microbiome is made up of bacteria, archaea, and flagellated protists. The midgut and foregut contain less germs than the hindgut, which has a higher concentration of microbes. Foods high in cellulose are consumed by termites, and both the host & its gut bacteria are involved in digestion. In the termite gut, partially digested plant matter is combined with salivary gland enzymes, and the gut microbiota hydrolyzes the polysaccharides by releasing enzymes. Enzyme released by the gut microbiota include lignin modification enzymes, cellulases, and hemicellulases (Ahmad et al., 2021).

14. Search for habitat

Researchers, farmers, and policymakers around the world are currently very concerned about identifying energy-efficient, diverse, low-input, self-sustaining agricultural systems (Foley et al., 2005). Because of its well-established benefits for nutrient cycling, controlling pest populations, and promoting plant growth, biodiversity preservation is one of the main goals of sustainable agriculture (Matson et al., 1997).

15. Natural habitat

Termite mounds are a significant contributor to landscape variability in Sub-Saharan West Africa and are rich, highly diverse microhabitats in tropical savanna settings. The floral content, density, structure, and zonation of plant cover of Northern Benin's mounds were analysed and compared to the surrounding savanna vegetation (Ville de Geneve, 2011).

16. Ecosystem engineers

As ecosystem engineers, termites are essential to preserving biodiversity (Jones & Gutiérrez 2007). These soil-dwelling organisms alter the biological, physical, and chemical features of the soil by relocating organic and mineral substances and creating biogenic structures such as macropores like galleries, chambers and organo-mineral aggregates such as feces, heaps, aggregates, and gallery exteriors (Lobry & Conacher, 1990).

17. Soil fertility

Termites, especially the fungus-growing, mound-building in arid tropical African soils, Macrotermitinae can grow up to 400 (Anderson & Coe, 1974). Although it has been demonstrated that Macrotermitinae improve some soil nutrients in mounds compared to neighbouring soils, the connection between termite litter harvesting, soil fertility, and global carbon cycling has not been studied (Arshad, 1982).

Litterfall is said to be completely dispersed by termite activity across nearby competing communities, where it is decomposed to the point that the soils receive little to no organic carbon. The mounds seem to emit C as CO_2 and CH_4, but they also accumulate related N, P, and cations (Basalingappa, 1970). This information provided supports the claim that although calculating nutrient fluxes through termites is insufficient, termites significantly contribute to atmospheric fluxes of CO_2 and CH_4 (Anderson & Coe, 1974).

18. Agricultural benefits

Major soil macrofauna, termites are either portrayed in literature as "pests" or as crucial markers of environmental resilience. It's important to know how termites can be controlled to prevent crop damage while enhancing the sustainability of farming systems. It is important to know how termites can be controlled to prevent crop damage while enhancing soil quality (Giller et al.,2009). On the other hand, nothing is understood about how termites are affected by intricate farming systems. It is unclear how biophysical and organizational factors affect termite activity, variation, and abundance (Kladivko, 2001).

Table. 01. Comparative summary of termite`s role in the ecosystem

Role	Activity	Importance	Effect	References
Soil Engineers	Soil mounds formation	Formations comprise clay and organic matter soil particles that have been cemented collectively	Soil fertility.	Harit et al., 2017 Jouquet et al., 2021, 2022
Nutrient cycling	Transferring components from wood to soil by coating their biogenic structures with frass (faeces)	Habitats	Nutrients recycling in ecosystem	Myer & Forschler, 2019
Termites gut microbiome	Mutualistic interaction to gut microbiome	Rely on stomach microorganisms to breakdown polymers	Food and shelter for gut microbiome	Maurice & Erdei, 2018
Climate Change	Full contribution to the nitrogen cycle	CH4 from gut microbiome.	CO2, CH4, and N2O are the primary gases linked to rises in greenhouse gas emissions and global warming	Khalil et al., 1990, Qu evedo et al.,2021
Bioturbation	Soil organisms to create soil-based cultivation biostructures, biogenic aggregates	Clay particles along with organic matter hold soil particles together to form termite biogenic structures	Capable of producing soil sheeting structures	Mando, 1997; Rouland et al., 2003; Lavelle, 2000; Brussaard et al., 2007; Jouquet et al., 2009

19. Future research directions:

Despite the fact that termites are widely recognized for their role in maintaining ecosystems, there are still many unanswered questions and areas that need more study. No research has projected the possible global distribution of invasive termites under climate change, despite their ecological and economic significance. In most tropical ecosystems across the world, termite`s cryptic social insects play a crucial role as ecosystem builders and in the carbon cycle (Buczkowski & Bertelsmeier., 2017).

In tropical settings, termites are regarded as important ecosystem engineers. However, particularly in grassland environments, they are frequently overlooked and poorly researched. One illustration of this is the relationship among termites and fire ecology. Considering Given the significance of both termites and fires in savanna systems, a deeper ecological knowledge of savanna biodiversity depends on a better understanding of how they interact (Davies & Janse, 2010).

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