NATURAL WORLD HABITAT NETWORKS AND LAND MANAGEMENT:

A STUDY BASED ON NETWORK THEORY

Report of the

Minor Research Project

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Principal Investigator

Sri. Jijo Joy

Assistant Professor

Department of Mathematics

jijo.stcpala@gmail.com

Name of the Institution

St. Aloysius College, Edathua

Alappuzha, Kerala -689573

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Declaration

I, hereby declare that the Minor Research Project entitled **'Natural World Habitat Networks and Land Management: A Study Based on Network Theory'** is an authentic record of the Minor Research Project carried out by me under the financial assistance of University Grants Commission with approval No. 1887 -MRP /14-15/KLMG019/UGC-SWRO dated 4th February 2015. The work presented in this project has not been submitted anywhere before.

Place: Edathua

Date: 1/06/2017   Sri. Jijo Joy

Counter Signed

Principal

AKNOWLEDGEMNT

A Minor Research Project of this magnitude would not have been possible without the expertise and co-operation of well-wishers. I take this opportunity to express my sincere gratitude to several persons who have helped me in this endeavour.

First of all I thank **Almighty God** for his mercy and love for keeping me in good health and sound mind and helping me to complete this project successfully.

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CHAPTER I

INTRODUCTION

> Without mathematics there's nothing you can do.
> Everything around you is mathematics.
> Everything around you is numbers.
> -Shakuntala Devi

Mathematics exists all around us in the natural world. As Galileo puts it

> The laws of Nature are written in the language of mathematics... the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word.
>
> (Galileo Galilei)
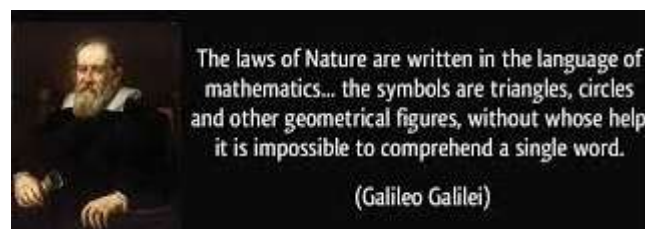
Mathematics is everywhere in the universe. While going deep into the patterns of each and every object in the universe, there unravel a number of Mathematical principles. There are a variety of places in nature where we can find Mathematics. There underlies Mathematical principles in the structure of a leaf or a cob web etc.

Fig: 1.a- Structure of a leaf.

Fig: 1.b- A cob web

Mathematics can put forward solutions to different problems in the universe as well. While the problems have deep roots, major transformation of society have always caused and been helped along by revolution in Mathematics. Mathematics is helpful in analysing the inextricably interconnected environmental problems. It also helps in finding immediate solutions to the various environmental problems.

Demographic pressures i.e, over population and over consumption has decreased the amount of natural resources to each individual in the universe. Rising population combined with unsustainable land use practices leads to environmental degradation and further scarcity.

This project analyses various habitat networks in the insect world using, a sprawling field of study Network Theory in Mathematics. This project tries to unravel certain Mathematical facts behind a number of natural insect household. Thus this project is relevant when concern with conservation biology and land management.

This project is divided into five chapters whereas the first chapter is introduction and it discusses about the relationship between Mathematics and Nature. The second chapter provides a description of the Mathematical Networks in general which are used as interpretative tools for analysing the natural habitats. The third chapter includes the methodology of the work done. The fourth chapter comprises details about natural habitats of some social insects; Mathematical Modelling of the above mentioned natural habitats; human buildings inspired

from animal world. The final chapter conclusion, tells how conservation and land management is possible by simply imitating the bionic method.

CHAPTER TWO

INTERPRETATIVE TOOLS

CHAPTER TWO

INTERPRETATIVE TOOLS

2.1 Network Theory

Network Theory is the study of graphs as a representation of either symmetric relations or asymmetric relations between discrete objects. In computer science and network science, network theory is a part of graph theory.

Network theory has applications in many disciplines including statistical physics, particle physics, computer science, electrical engineering, biology, economics, finance, operations research, climatology and sociology. Applications of network theory include logistical networks, the World Wide Web, Internet, gene regulatory networks, metabolic networks, social networks, epistemological networks, etc.
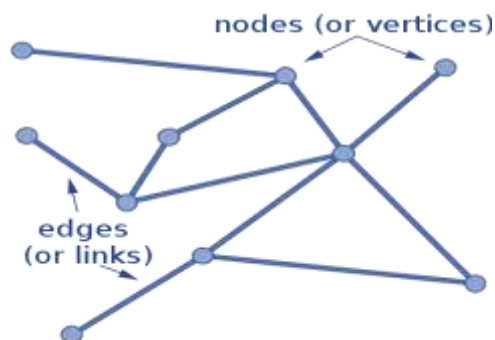
Fig 2.a- A network with vertices and edges.

Kinds of Networks

A network can be defined as a graph in which nodes and/or edges have attributes. A network is a set of objects, called nodes or vertices that are connected together. The connections between the nodes are called edges or links. In mathematics, networks are often referred to as graphs.

In terms of randomness, heterogeneity and modularity there are Random, Small World, Scale free and Planar Networks. The topology of any given network may fall into one or more non-exclusive categories Planar, Regular, Random or Complex- which includes Small world and Scale free topology.

2.1.1 Planar Networks

Planar Networks are two dimensional. The edges do not cross each other. In other words a node may only be connected directly to its geographical neighbours or adjacent nodes and must connect to more distant nodes by passing through stepping-stone nodes. When A graph that can be drawn on a plane without edges crossing is called planar.
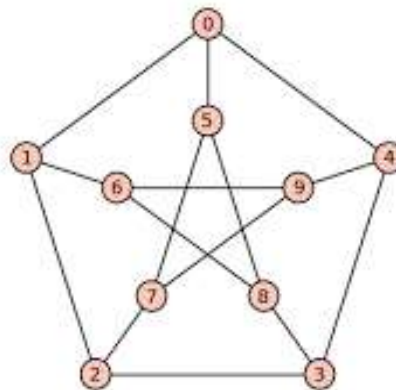
Fig 2.b-Example of planar network.

In graph theory, a planar graph is a graph that can be embedded in the plane, i.e., it can be drawn on the plane in such a way that its edges intersect only at their endpoints. In other words, it can be drawn in such a way that no edges cross each other. Such a drawing is called a plane

graph or planar embedding of the graph. A plane graph can be defined as a planar graph with a mapping from every node to a point on a plane, and from every edge to a plane curve on that plane, such that the extreme points of each curve are the points mapped from its end nodes, and all curves are disjoint except on their extreme points. Every graph that can be drawn on a plane can be drawn on the sphere as well, and vice versa .Plane graphs can be encoded by combinatorial maps. The equivalence class of topologically equivalent drawings on the sphere is called a planar map. Although a plane graph has an external or unbounded face, none of the faces of a planar map have a particular status.

A real world example of this kind of network is an urban street network with intersections as nodes and streets as edges. The air transportation network is not planar in that one can board a plane and arrive at one's destination without passing through every city in between. Planar network are suitable models in landscape connectivity.

2.2.1   Small-World Network

A small-world network is a type of mathematical graph in which most nodes are not neighbours of one another, but the neighbours of any given node are likely to be neighbours of each other and most nodes can be reached from every other node by a small number of hops or steps.
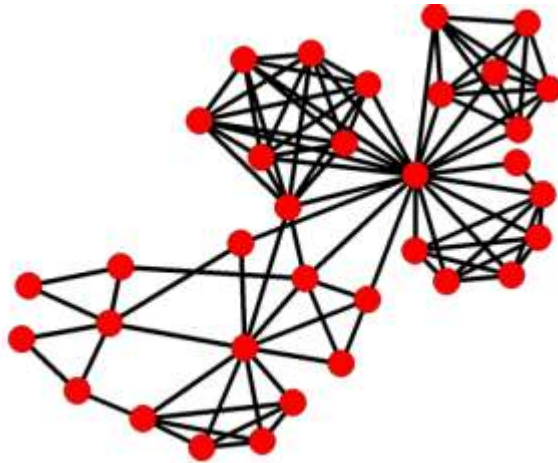
Fig 2.c. Example of small world network.

Specifically, a small-world network has a high clustering coefficient. Secondly, most pairs

of nodes will be connected by at least one short path. This follows from the defining property

that the mean-shortest path length be small. Several other properties are often associated with

small-world networks. Typically there is an over-abundance of *hubs* – nodes in the network

with a high number of connections, known as high degree nodes. These hubs serve as the

common connections mediating the short path lengths between other edges.

Small-world properties are found in many real-world phenomena, including websites

with navigation menus, food webs, electric power grids, metabolite processing

networks, networks of brain neurons, voter networks, telephone call graphs, and social

influence networks.

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networks, networks of brain neurons, voter networks, telephone call graphs, and social influence networks.

2.2.2. Random Networks

Random graphs were first defined by Paul Erdős and Alfréd Rényi in their 1959 paper "On Random Graphs" and independently by Gilbert in his paper "Random graphs".

In Mathematics, Random Networks consists of nodes with randomly placed connections. In these networks, a plot of node degree distribution is often bell shaped, with most nodes having approximately the same number of edges. They typically do not display clustering and may or may not be planar.
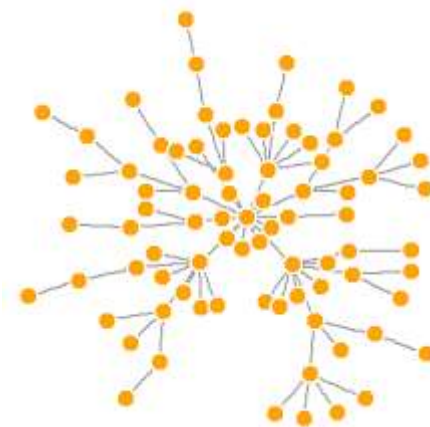
Fig 2.d. Example of Random graphs

From a Mathematical perspective, random graphs have practical applications are found in all areas in which complex networks need to be modelled – a large number of random graph models are thus known, mirroring the diverse types of complex networks encountered in different areas. In other contexts, any graph model may be referred to as a *random graph*.

2.2.3. Scale Free Networks

A scale-free network is a [connected graph](#) or [network](#) with the property that the number of links k originating from a given node exhibits a power law distribution $P(k) \sim k^{-\gamma}$.
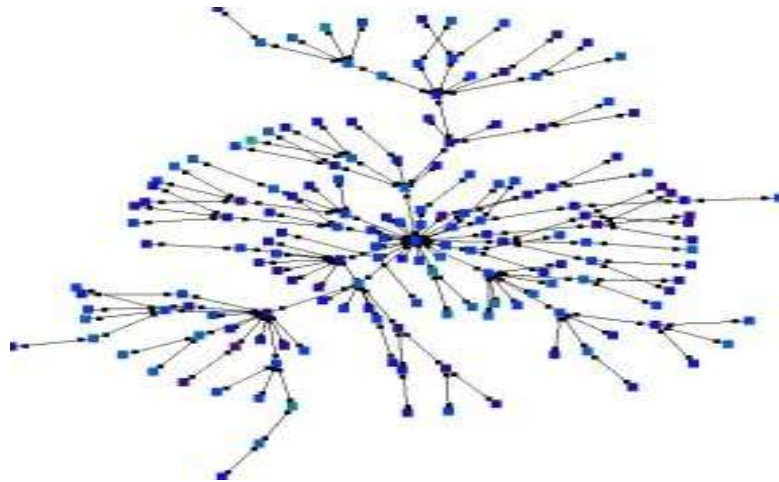
Fig.2.e : Example for a scale-free network

A scale-free network can be constructed by progressively adding nodes to an existing network and introducing links to existing nodes with preferential attachment so that the probability of linking to a given node i is proportional to the number of existing links k_i that node has, i.e.,

$$P(\text{linking to node } i) \sim \frac{k_i}{\sum_j k_j}.$$

Scale-free networks occur in many areas of science and engineering, including the topology of web pages. In the context of networks, if the degree distribution has a scale, that typically means that nodes with degree greater than that scale are very rare. In contrast, if the degree distribution is scale-free, it's relatively likely that nodes with very high degree will form, and these are the hubs

CHAPTER THREE

METHODOLOGY

CHAPTER THREE

METHODOLOGY

Graph Theory, a well-established mainstay of information technology is concerned with highly efficient network flow. It employs algorithms and compact data structures that are easily adapted for analysing and finding solutions to real life problems. Here it is demonstrated how the use of graph theory especially network theory can be applied in real world context.

The following standard methods were used for the collection of data and detailed study.

- The primary data has collected by field observation and the samples were selected. As bees, ants, termites and wasp are social insects that live in colonies and have some characteristics common to human beings, they were selected for the particular study.

- The selection was followed by close observation of their habitats.

- After the above mentioned process, referred books and journals related to the selected insect groups by visiting various education centres of excellence.

- Consulted with research scholars and experts provided a new light to the field of study and opened up new avenues.

- After the data collection from the primary and secondary sources the biological problem was studied by applying mathematical theory especially network theory.

The analysis was recorded under five heads such as introduction, interpretative tools, methodology, analysis of data and conclusion. In the first session introduction the statement of the problem is given. The second session is a detailed analysis of mathematical network theory and the third session methodology gives an idea about the total work done. The fourth session is the actual analysis of the problem on the basis of network theory in which details about the social insect households, their particular structure, the mathematical modelling of the

structures, the uses of or specialities of these structures, the insect household like human buildings and their characteristic features are given. Finally the session conclusion explains how human beings can utilize their space in an era of unsustainable land use and population growth.

CHAPTER FOUR

NATURAL HABITATS AND LAND MANAGEMENT; AN ANALYSIS

CHAPTER FOUR

NATURAL HABITATS AND LAND MANAGEMENT;
AN ANALYSIS

By the term, Social insects, it is meant that any of numerous species of insects that live in colonies and manifest three characteristics: group integration, division of labour, and overlap of generations. The eusocial, or most social of the insects, are the bees, wasps, ants, and termites.

4.1 Certain traits characterize the eusocial insects are:

(a) Reproductive division of labor, this means that the queen reproduces almost exclusively while other members of the colony specialize on different tasks.

(b) Cooperative brood care: Social insects are organized into different 'castes', these are characterized by specialized roles -queen, soldiers, workers- and such. Usually there is a queen that produces a lot of offspring and apart from her, many other sterile daughters –workers- that depending on their age or structure carry out specific tasks in or around the colony.

(c) Social insects are able to communicate mainly through pheromones; bees are also able to communicate through elaborate 'dances' to convey the direction and distance of food sources.

(d) Social insect colonies have many of the properties of adaptive networks: Social insect colonies -ants, bees, wasps, and termites- show sophisticated collective problem-solving in the face of variable constraints. Individuals exchange information and materials such as food. The resulting network structure and dynamics can inform us about the mechanisms by which the insects achieve particular collective behaviours and these can be transposed to man-made and social networks.

4.2 Social insects-selected for study

Social insect colonies -ants, bees, wasps, and termites-are selected for the study as they lead social life and has some characteristics common to human beings.

I.   Honey Bees

Fig.4.a-Honey Bees

Honey bees are social insects who live in colonies. For different purposes they communicate within the group through the process networking. Bees collect food from sources distance up to 10 km from the hive. The colony uses simple rules to dispatch bees towards the best nectar source available. In this process of foraging the bees return with nectar and the information about its source. Important role in the process of communication plays a waggle dance.

II. Ants

Fig.4.b-Ants

Ants are eusocial insects of the family Formicate. The colonies are described as super organisms because the ants appear to operate as a unified entity, collectively working together to support the colony. Ant colony is the basic unit around which ants organize their lifecycle. Ant colonies are eusocial, and are very much like those found in other social Hymenoptera, though the various groups of these developed sociality independently through convergent evolution. The typical colony consists of one or more egg-laying queens, a large number of sterile females and, seasonally, a large number of winged sexual males and females. In order to establish new colonies, ants undertake nuptial flights that occur at species-characteristic times of the day. Swarms of the winged sexuals depart the nest in search of other nests. The males die shortly thereafter, along with most of the females. A small percentage of the females survive to initiate new nests.

III. Wasps

Fig.4.c-Wasps

Social wasps such as the hornets, yellowjackets and paper wasps live in colonies in a fashion similar to the honey bees and ants. Most of the wasps in a colony are workers; i.e., the nest queen's nonreproductive daughters that build the nest, gather food and care for the queen's offspring. 'Yellowjackets' are honey bee size and black with bright yellow markings. Yellowjackets build paper nests similar to hornets but either in the ground, a log or landscape

timber or building wall or attic. Yellowjackets are commonly observed hovering back and forth at the small nest opening or around garbage cans and other areas where they forage for food. Nests of Yellowjackets contain up to 5,000 workers, most of which never travel more than a few hundred yards from the nest while looking for food.

'Hornets' build the familiar large nests of a paper-like material made from chewed wood mixed with saliva. Nests contain many tiers of cells covered by the outer shell with a single opening at the bottom. Hornet nests contain only a few hundred workers that are about an inch long and dark with white, light yellow or cream colored markings on the abdomen, thorax, and face.

'Paper wasps' build the familiar umbrella shaped nests found hanging by a short stalk on the undersides of building eaves. Only a single tier of cells is constructed and there is no external covering over the nest. Each colony normally contains fewer than 25 wasps, but late in the season, the number may swell to over 100. Paper wasps are slightly longer and more slender than yellowjackets, and color is variable among the many species.

IV.Termites

Fig.4.d-Termites

Termites are social insects. This means that they live in colonies. Scientists think that the termite social structure is a big reason they have thrived in almost every part of the world.

A colony of termites contains three forms of termites. The forms are called castes. Members of each caste look very different from the other castes. Each caste has a different role or job in the colony. The three castes are workers, soldiers, and reproductives.

The above mentioned social insects use networking for different needs such as collecting food, reproduction and making nests. But the very shape of their nests help them a lot in the process of networking or networking among the members becomes easier because of the distinctive shape of their nests. An analysis of the natural habitats of these social insects and corresponding mathematical modelling is provided here.

4.3 Natural Habitats of different Social Insects

Bee hive:

Fig.4.e -A Beehive

Specialities of Beehive Structure

The hive and comb of the bees are formed mainly by workers. A comb is a vertical sheet of wax, composed of a double layer of hexagonal cells projecting in both directions from central wax-sheet. Comb hangs vertically downward, while cells are horizontal in position. The hexagonal shape of cells accumulates maximum space in minimum use of wax and labour. The cells of the comb are of various types. The "Storage cells", which contains honey and pollen are generally built on the margin and at the top of the comb. The "brood cells", which contains

the young stages, are built in the centre and the lower part of the comb. Brood chamber is further divided into three types, namely Worker-chamber, where developing workers are reared; Drone-chamber, where developing drones are reared and the Queen-chamber, which is larger than other and where the larvae developing into queens are reared. There is no special chamber for adults. They move on the surface of the comb.

Mathematical modelling of a Beehive
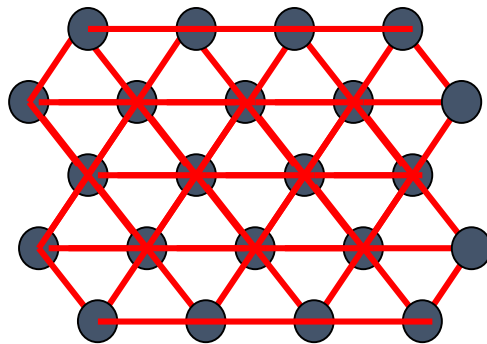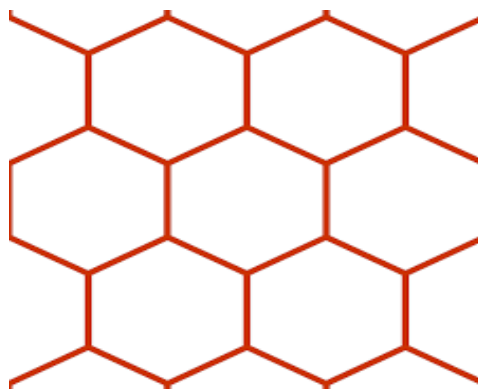

Fig.4.f-Hexagonal structure of a beehive

- Assume the nodes of the network are vertices of a graph. Simple geometrical "points"

- The relation between two vertices is simply an undirected unweighted edge between the vertices

- Graph $G=(V(G),E(G))$, with vertex set $V(G)$, the nodes of the network and an edge list $E(G)$.

- Here the junctions represent vertices and lines as edges.

Honey bee model structure exhibits planar structure, its properties are

- It is also a three regular graph.

- Degree of each vertex is 3.

- Here the average path length is high.

Ant-hill

Ant hill in its simplest form, is a pile of earth, sand, pine needles, or clay or a composite of these and other materials that build up at the entrances of the subterranean dwellings of ant colonies as they are excavated.

Fig.4.g-An Ant Hill

A colony is built and maintained by legions of worker ants, who carry tiny bits of dirt and pebbles in their mandibles and deposit them near the exit of the colony. They normally deposit the dirt or vegetation at the top of the hill to prevent it from sliding back into the colony, but in some species, they actively sculpt the materials into specific shapes and may create nest chambers within the mound.

Specialities of Ant Hill Structure

Ant nest architecture is likely as variable as the number of ant species on the planet but they share some common features across species. For one, most ant nests are modular and

consist of chambers connected by shafts, which are similar to our rooms and hallways. These chambers may serve as nurseries for developing larvae, storage rooms for seeds and other food, or royal chambers for protecting the colony's queen.

Central air and heating allow us to keep our homes at a moderate temperature year round, and ants have this ability too. Some, like fire ants, build mounds to capture heat from the sun, and workers move larvae inside to track their preferred temperature. Others, like thatch ants, live near the Arctic Circle and build heaping piles of compost that release heat to keep the colony warm over winter. In the tropics, where too much heat is the problem, army ants build nests out of their own bodies and change their position to help cool the nest during the hottest part of the day.

Colonies of leaf-cutter ants are massive. They house tens of thousands of workers. Inside, the ants grow fungus to feed their larvae, and the combined mass of the ants and their fungus gardens produces a huge amount of CO2. Ants need oxygen to breath, so they build chimneys to circulate fresh air. As wind travels across the surface, air blows in through the chimneys on the side of the nest, and stagnant air escapes from the chimneys on top.

Leaf cutter ants maintain huge garbage chambers, and when workers shift to garbage duty, they're never allowed back inside the main nest. They are the "untouchables," individuals abandoned by society in order to prevent disease.

Ants are skilled gardeners. Some grow crops of fungus, but others show off another gardening skill: weeding. Harvester ants clear crop-circles around their nests, which are visible from Google Earth. Others, like the lemon ants of Amazonia, weed some plant species while preserving others to create what locals call Devil's Gardens. Ants may even collect certain seeds deliberately and plant them around their nests to create their own landscaping.

Ants communicate through scent, and they recognize their family members by smell. Each nest has a distinctive odour that might be related to what a colony's been eating, their genetics, what type of soil they nest in, or factors still unknown. There is also evidence that humans communicate through pheromones, though this is one of the many cases in which we know more about "them" than we do about us.

All ant nests have an entrance patrolled by guards. Some species take this a step further, like the turtle ants. Turtle ants have soldiers with disc-shaped heads that fit perfectly into their nest entrances. These soldiers serve as living doors, and they control who enters and who stays out.Ant workers may differ in size by 100-fold, and there are tiny species, like thief ants, that specialize in robbing food from larger species.

Mathematical Modelling Ant hill Structure

The Small World concept in simple terms describes the fact despite their often large size, in most networks there is a relatively short path between any two nodes.
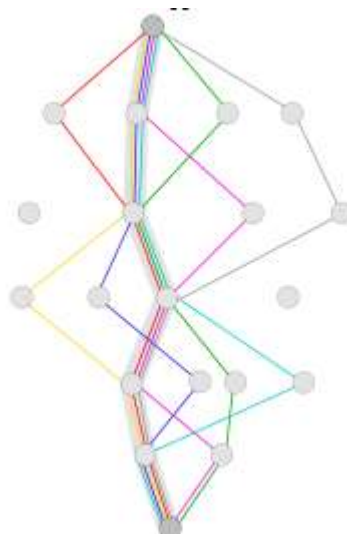

Fig.4.h-Mathematical Modelling Ant hill

- Assume the nodes of the network are vertices of a graph . Simple geometrical "points"

- The relation between two vertices is simply an undirected unweighted edge between the vertices

- Graph $G=(V(G),E(G))$,with vertex set $V(G)$,the nodes of the network and an edge list $E(G)$.

- Here the junctions represent vertices and lines as edges.

Analyzing Ant Hill Model

Ant hill model exhibit small world network structure.

Three main attributes used to analyze Small World Graphs :

- high clustering
- small diameter
- almost regular

Wasp nest

Fig.4.i-Wasp nest

all make paper nests, though the size, shape, and location of their nests differ. Paper wasps build umbrella-shaped wasp nests suspended underneath eaves and overhangs.

Specialities of Wasp Nest Structure

Bald-faced hornets construct large, football-shaped nests. Yellowjackets make their nests underground. Regardless of where a wasp builds its nest or what shape the nest is, the process wasps use to construct their nests is generally the same.

Wasps are expert paper makers, capable of turning raw wood into sturdy paper homes. A wasp queen uses her mandibles to scrape bits of wood fiber from fences, logs, or even cardboard. She then breaks the wood fibers down in her mouth, using saliva and water to weaken them. The wasp flies to her chosen nest site with a mouth full of soft paper pulp.

Construction begins with finding a suitable support for the nest – a window shutter, a tree branch, or a root in the case of subterranean nests. Once she has settled on a suitable location, the queen adds her pulp to the surface of the support. As the wet cellulose fibers dry, they become a strong paper buttress from which she will suspend her nest.

The nest itself is comprised of hexagonal cells in which the young will develop. The queen protects the brood cells by building a paper envelope, or cover, around them. The nest expands as the colony grows in number, with new generations of workers constructing new cells as needed.

Mathematical modelling of a wasp nest

- Assume the nodes of the network are vertices of a graph . Simple geometrical "points"

- The relation between two vertices is simply an undirected unweighted edge between the vertices

- Graph $G=(V(G),E(G))$, with vertex set $V(G)$, the nodes of the network and an edge list $E(G)$.

- Here the junctions represent vertices and lines as edges.

Analysing Wasp Nest Model

Wasp Nest Model Exhibits Random network structure. Their features are

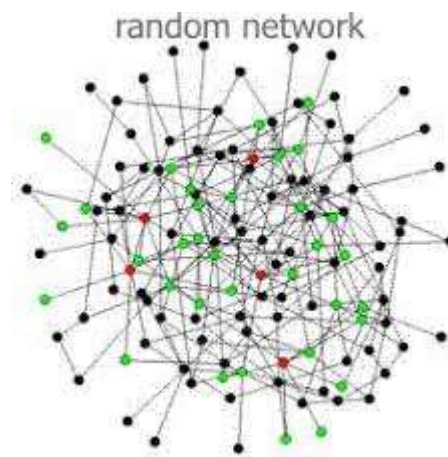- small *clustering*
- small diameter

Fig.4.j-Mathematical modelling of a wasp nest

Termite mound

Fig.4.k-Termite mound

All species locate their colonies underground, where they cultivate fungi that aid in cellulose digestion. The mounds enclose a ramifying network of tunnels that forms a respiratory gas exchange system for the nest. Some species may build open chimneys or vent holes into their mounds, while others build completely enclosed mounds that exchange gas through porous thin-walled tunnels. Even within populations, the variation of mound structure is prodigious. Outwardly, the mound consists of three parts:

(a) columnar spire atop a conical base. The spire reaches on average about 3 meters high,   but it can reach as high as 9 meters.

(b) (b)conical base, roughly 4-5 meters in diameter and roughly 1.5 meters tall

(c) broad outwash pediment, roughly 10-20 meters in diameter, consisting of soil eroded from the mound.

A distinctive feature of these mounds is the northward tilt of the spire. Mounds are also often built around trees. A foundling colony's chance of survival to maturity may be enhanced when the founding king and queen land in the shelter of a tree, rather than in the harsher environments between trees. The tree is not harmed by this - indeed it thrives. The termite is one of nature's more accomplished builders, erecting the tallest structures on our planet -when

measured against the size of the builder-, and maintaining a constant temperature inside despite wide temperature swings outside. The structure of the mounds can be very complicated. Inside the mound is an extensive system of tunnels and conduits that serves as a ventilation system for the underground nest. In order to get good ventilation, the termites will construct several shafts leading down to the cellar located beneath the nest. The mound is built above the subterranean nest. The nest itself is a spheroidal structure consisting of numerous gallery chambers. They come in a wide variety of shapes and sizes. The mounds that they build are extremely durable structures of mud, often employing sophisticated buttressing and, in the case of so-called compass mounds, a precise shape and siting that optimize the effects of the sun.

Termites, like many social insects, build nests of complex architecture. These constructions have been proposed to optimize different structural features. Here we describe the nest network of the termite *Nasutitermes ephratae*, which is among the largest nest-network reported for termites and show that it optimizes diverse parameters defining the network architecture. The network structure avoids multiple crossing of galleries and minimizes the overlap of foraging territories. Thus, these termites are able to minimize the number of galleries they build, while maximizing the foraging area available at the nest mounds.

Mathematical Modelling Termite Mount structure

Each node is connected to at least one other; most are connected to only one, while a few are connected to many.
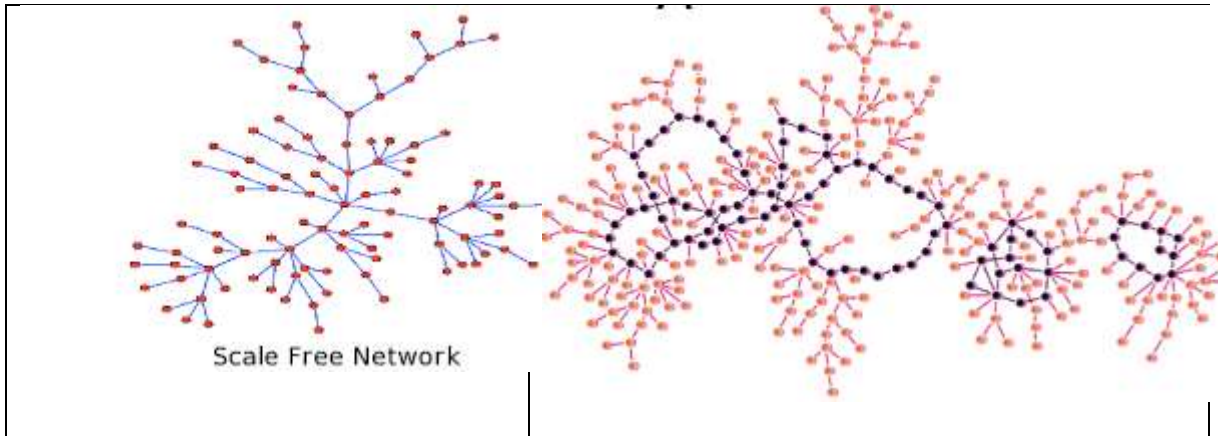
Fig -4 l Scale free network

- Assume the nodes of the network are vertices of a graph . Simple geometrical "points"

- The relation between two vertices is simply an undirected unweighted edge between the vertices

- Graph *G=(V(G),E(G)),with v*ertex set *V(G),th*e nodes of the network and an edge list *E(G).*

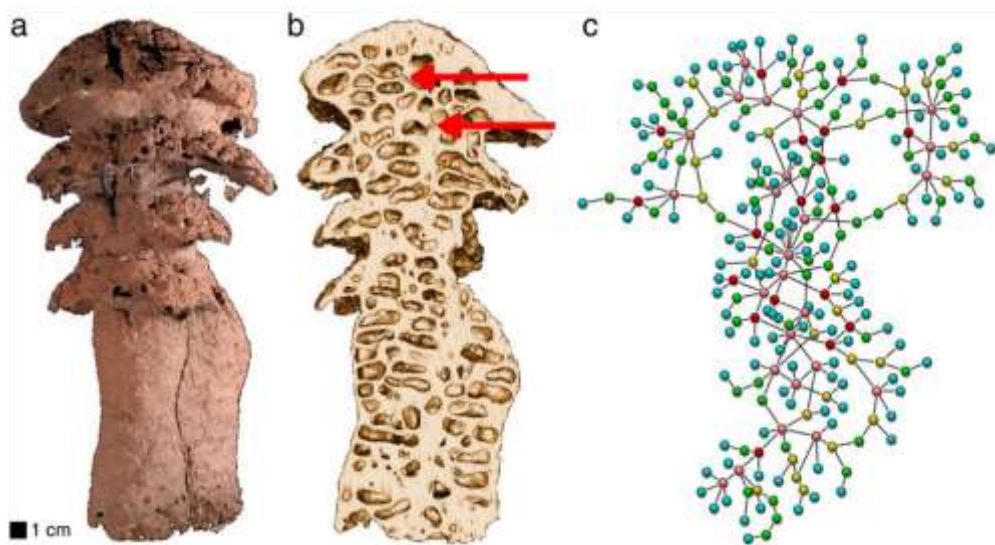- Here the junctions represent vertices and path as edges.

Fig.4.m-Mathematical Modelling Termite Mount Structure

Analysing Termite Mound Model

Termite mound model exhibits scale free network structure, its features are

- Here the graph is not regular

- The average path length is high

4.4 Human Buildings Inspired by Insect Habitats

Honey Comb Building Model

Eg;Honeycomb Housing

The honeycomb Layout may be said to be inspired from the structure of beehives. In "honeycomb housing" small courtyard neighbourhoods of 5 to 16 cluster houses , which in turn form part of a larger neighbourhood of up to 300 houses. The honeycomb concept was first introduced in Malaysia as an alternative to terrace houses and the predominantly rectilinear form of residential layouts. It seeks to offer a community lifestyle that many Malaysians used to enjoy in their childhood but in an urban setting.

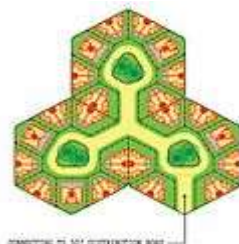Fig.4.n-A small courtyard neighbourhood

Fig.4.o-A cul-de-sac community composed from three connected courtyards.
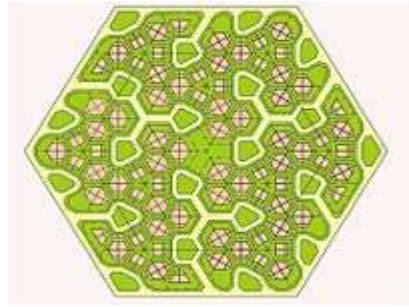
Fig.4.p-A honeycomb neighbourhood.

Fig.4.q-A honeycomb neighbourhood

iv. Ant hill Building Model
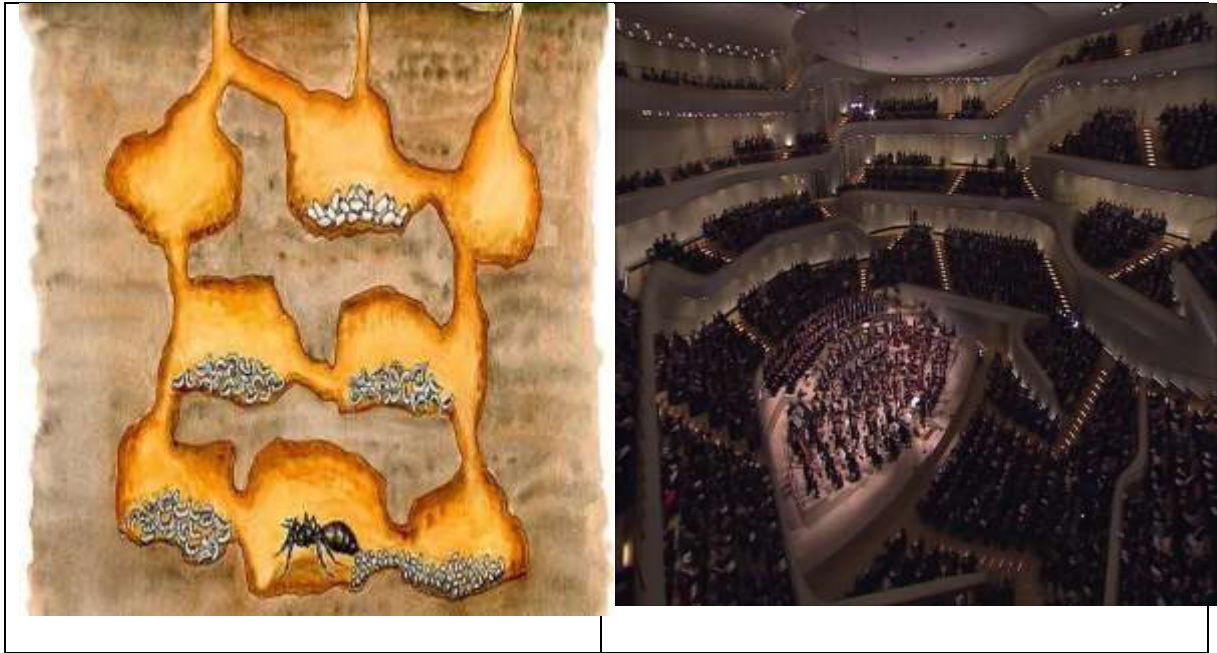
Fig.4.r-Example for a Ant Hill Building Model

Ant nests like human buildings are modular and consist of chambers connected by shafts, which are similar to our rooms and hallways. Ants are skilled gardeners so Ant model houses have good landscape. They are temperature controlled. Some feature ventilation ducts and garbage dumps etc.

iii Wasp nest building model

Wasp nest model building commonly evolved architectures for the: Agelaia or Parapolibia, Parachartergus, Vespula or Stelopolybia, and Vespa wasp families. They are less expensive and economic.

ii. Termite Mount Housing Model

eg; Green Building- The Eastgate Centre in Harare, Zimbabwe

The Eastgate Centre in Harare, Zimbabwe, typifies the best of green architecture and ecologically sensitive adaptation. The country's largest office and shopping complex is an architectural marvel in its use of biomimicry principles. The mid-rise building, designed by architect Mick Pearce in collaboration with Arup engineers, has no conventional air-conditioning or heating, yet stays regulated year round with dramatically less energy consumption using design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termite.

Fig.4.t-Example 1for a Termite Mount Housing Model

Fig.4.u-Example2 for a Termite Mount Housing Model

The complex is actually two buildings that shelter an interior atrium (right). Heat gain is reduced by limited glazing, deep overhangs, and building mass, and the architect took advantage of night cooling, thermal storage and convective air currents to moderate temperatures.

During the day the heavy building mass and rock storage in the basement absorb the heat of the environment and human activity. At night, cool air is allowed into the bottom of the building and starts the convective flow that vents the hot daytime air through roof vents. This cool air is also stored and then distributed the next day into offices via hollow floors and baseboard vents.

CHAPTER FIVE

CONCLUSION

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By analysing insect habitat networking using network theory provides a new outlook to human beings about maximum utilization of landscapes. A specific branch of engineering-biomimicing has evolved from such imitation from the animal world .the following things inspire human beings to imitate the natural insect habitats.

i.**The beehive structure**

The beehive structure follows the shape of hexagons and they are very useful shapes. For bees they are the perfect design in economizing labor and wax. Pizhong Qioa, an engineer and professor at WSU says "We learned it from the bee," "Hexagons apply to almost everything you can build." they build hexagons that are the strongest, most useful shape. The hexagon might just save bees some time and energy. They can use the energy to do another really important job. The structure is important to hold all this weight and protect the honey, especially during winter. A hexagonal honeycomb has the smallest total perimeter and therefore it needs less wax to be built and is a more compact structure. Hexagons and honeycomb shapes are also useful for building things humans use, too, like bridges, airplanes, and cars. It gives materials extra strength. After all, materials made with hexagon shapes can also handle a lot of force, even if they are made out of a lighter material.

The honeycomb housing, the biomimicing model by human beings also have certain qualities. They are;-

- Less expensive
- Each house still retains a public access.

- Since houses are built around a small park with plentiful shady trees, this communal garden is easily accessible to all in the cul-de-sac, allowing it to act as a social focus that can encourage social interaction and neighbourly spirit.

- The courtyard area is a "defensible space" as well, as it acts naturally to reduce crime in the sense that strangers are quickly spotted. The short winding roads put a stop to speeding traffic, and certain to dissuade snatch thieves on motorcycles - therefore becoming safe for children, pedestrians and cyclists.

- Apart from the social advantages, it is also claimed that compared to the terrace house layout, the honeycomb layout uses land efficiently and offers savings in the cost of infrastructure.

ii. The Ant Hill Building Structure

- Ant nests like buildings have rooms and hallways.

- They are temperature controlled.

- Ant hill buildings feature ventilation ducts.

- Ant hill buildings have garbage dumps (and garbage workers!).

- Ant hill like buildings have landscape.

- Ant hill buildings have a "smell."

- Ant hill buildings use anti-microbial cleaners.

- Ant hill buildings have doors.

- Even with doors, they still get unwanted guests.

- Ant hill like houses are also infested by ants.

iii The Wasp Nest Building Structure

- Less expensive

- uses land efficiently and offers savings in the cost of infrastructure.

- act as a social focus that can encourage social interaction and neighbourly spirit.

iv. Termite Mount Building Structure - Green building

- The Eastgate Centre in Harare, Zimbabwe, which follows termite mound structure typifies the best of green architecture and ecologically sensitive adaptation.

- The mid-rise building, designed by architect Mick Pearce in collaboration with Arup engineers, has no conventional air-conditioning or heating, yet stays regulated year round with dramatically less energy consumption using design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termites

- The "night purge" vents the warmer air directly from the office and shop spaces and cools down the overhead mass of concrete. The warm air rises up to openings in the ceiling and then travels through hollow floors to a vertical shaft and eventually to roof vents. This passive treatment alone is enough to keep the spaces comfortable for a part of the day. Cooled fresh air rises up through floor registers throughout the day.

- This building also uses thermal mass to absorb heat, reduces heat gain by a strategic placement of glazing, and produces power and heat by photovoltaic and thermal solar panels and a gas-fired cogeneration plant. It also hosts an equivalent amount of plant leaf surface to the site, which oxygenates the air indoors and out. The building receives a fresh air change every half hour.

In conclusion the peculiar structures of the insect's household help them in communication among its members. By studying different types of insect habitats and their networking patterns rendered a new vision in conserving energy and space

management. The study on networking and land management surely has fruitful effects in this era of over population and over consumption.

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