BEST PROFIT TO NATURE AND BUSINESS
WITH GREEN INFRASTRUCTURE BY DEVELOPING AN ECOFRIENDLY
AND SUSTAINABLE HOUSING COMMUNITY
A CASE STUDY IN BENGALURU

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ABSTRACT

The context of my study is in Bangalore, India. India being one of the fastest growing economies in the 21st century but at the pace at which it is growing does not match up to the rate at which a truly sustainable environment should grow. Delhi, Mumbai and Bangalore are some of the metropolitan cities that have provided numerous opportunities for jobs, business and livelihoods. More jobs are directly proportionate to providing facilities such as houses, schools, hospitals, infrastructure and transportation. But at what cost? Innumerable trees cut down for the sake of development, construction of massive buildings that do not respond to the environment and local weather in any way, resulting in a drastic loss of biodiversity, increase in temperatures, air, water and soil pollution. These factors and many more have burdened capacity of an urban Indian city. Bangalore has gone from being known as the "Garden City" to a Garbage City. The outcomes are glaring: the adjustment in land-use with loss of water bodies and green spread are obvious. Obviously, the pattern isn't empowering.

The aim of this thesis is to explore the possibilities of an ecological gated community that is self-content in its requirement of natural resources. A community that creates a strong sense of belonging while also inculcating a shared sense of safety and responsibility. The attempt to blend traditional concepts with contemporary lifestyles using technology as an aide. How landscape and the unbuilt spaces take preference over the built. The importance on native species and creating an interactive landscape, which creates biodiversity. Low rise houses that are closer to the ground that promote sustainable city growth and to look at ways in which natural elements are not only used as an aesthetic but to create opportunities to conserve, recycle and preserve land, water and air. Importance of indigenous trees and plants for a sustainable environment will also be explored. To increase social interaction and induce mental peace with the help of natural and sustainable setup.

ACKNOWLEDGEMENT

I would like to thank the Hochschule Neubrandenburg for giving me an opportunity to study here. I will not forget to thank my first supervisor, Prof. Dr. Manfred Köhler whose guidance has helped my reach this far with my thesis. I would also like to thank my second supervisor Ar. Florian Betzler who encouraged me to give it my best shot with my Master Thesis.

Lastly, I would like to thank my parents for their never-ending support throughout my life.
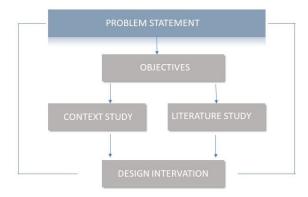
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INTRODUCTION

AIMS AND OBJECTIVES

- The aim of this thesis is to explore the possibilities of an ecological gated community that is self-content in its requirement of natural resources.
- A community creates a strong sense of belonging while also inculcating a shared sense of safety and responsibility.
- The attempt to blend traditional concepts with contemporary lifestyles using technology as an aide.
- How landscape and the unbuilt spaces take preference over the built. The importance on native species and creating an interactive landscape, which creates biodiversity.
- Low rise houses that are closer to the ground that promote sustainable city growth and to look at ways in which natural elements are not only used as an aesthetic but to create opportunities to conserve, recycle and preserve land, water and air.
- Importance of indigenous trees and plants for a sustainable environment will also be explored.
- To increase social interaction and induce mental peace with the help of natural and sustainable setup.

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RESEARCH QUESTIONS

-How is urbanization affecting Bangalore?

- What is the current context of housing demand in Bangalore?

- Can a housing community be self-sufficient and not burden Mother Nature?

- How important are the unbuilt spaces in comparison to the built-up spaces?

- Reduce heat island effect

- Study the advantages of rainwater harvesting, Bio swales, recycling units, green roofs, green walls, cross ventilation, natural lighting, local materials and various methods to make a house more liveable and sustainable.

CITY

"Around 54 percent of the world population currently live in urban areas which is forecast to rise to 66 percent by 2050". However, all cities spread under one percent of the world's surface.[1] What makes a city a happy city? Of course, good economy would be one of the primary aspects of a happy city but that's not the only factor. A good health care and education system along with housing facilities and well-functioning transportation system also play major role. But beyond all the factors noted above, the city planning, landscaping, the road networks, communal living, access to green spaces and efforts to maintain the city play a silent yet equally important role.

Figure 1 Major cities of the world (Desjardins, 2018)

Finland, Costa Rica, Norway, Denmark and Singapore are often considered to be the happiest places on this planet to reside.The UN World Happiness Report 2018 lists Finland as the world's happiest country.Although the country's GDP is smaller th an its neighboring northern nations, Finland is regarded to be the most stable, safest and best ruled nation as well as the least corrupt and socially progressive. [2]

It could be attributed to the fact that these countries give more importance to the people before anything. Wellbeing state is given more importance than welfare state. Basic amenities are of high quality. It would be a struggle to be happy if the basics are not in place.[3]

Urban cities in developing cities require sustainable growth as the population drastically grows (Fig 2) so does the burden on the cities. Housing being one of the

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[1] (Unknown, 2014)
[2] (Turbot, 2018)
[3] (Turbot, 2018)

primary requirements. Well-designed houses, clean air and water, greens spaces and a sense of community should be of prime importance.
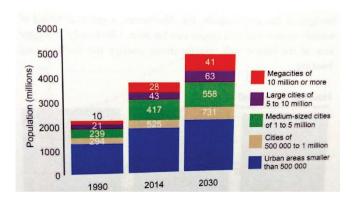

Figure 2 Rapid growth in Megacities

Access to jobs and fundamental needs are discovered in cities. Happiness and satisfaction are achieved by the realization of goals and good quality of life. It is possible to achieve this in cities compared to small towns. But, usually the possibility of good housing, wealth and amenities is usually restricted to only a few sections of the people.

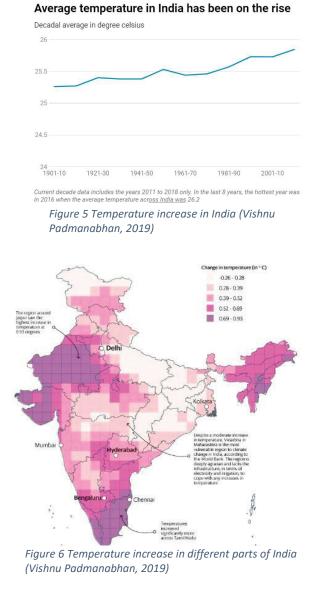**POPULATON RISE WORLD OVER**
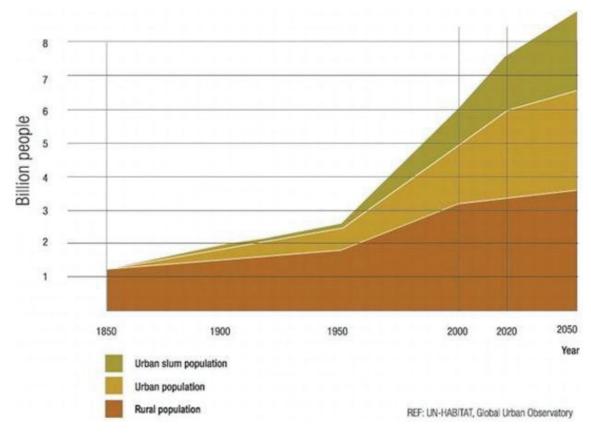
Figure 3Global population development

Urban population combined with the urban slum population has made biggest growth in the recent years (Fig 3). If the trend continues, we will have concrete jungles with very low quality of life. This will directly affect the biodiversity and nature will be abolished in these cities. The natural cycle of water will be affected, so will the quality of air and various living organisms. Which is why it's important for cities to grow sustainably. Every city should be able to accommodate blue green infrastructure within the urban fabric to maintain sustainable growth.[4]

Such situations will affect the city population and biodiversity. Urbanization can be a double-edged sword. Planners, architects and the government must work in tandem to sustainably develop cities that effect the environment as minimally as possible. If it's too late then we will be left with an extremely unbalanced environment. With people preferring bigger cities it is an urgent need to provide healthy neighborhoods to people from all social classes.

Average temperature in India has been on the rise

Decadal average in degree celsius

Current decade data includes the years 2011 to 2018 only. In the last 8 years, the hottest year was in 2016 when the average temperature across India was 26.2

Figure 5 Temperature increase in India (Vishnu Padmanabhan, 2019)

Figure 6 Temperature increase in different parts of India (Vishnu Padmanabhan, 2019)

India's cities are also getting hotter

Number of days when the maximum temperature exceeds 35° C

Figure 4 Rise in the number of hot days (Vishnu Padmanabhan, 2019)

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[4] (Julia Brandt, 2013)

INDIA AND CLIMATE CHANGE

There clearly has been a rise in the average temperature from the 1990s to 2000s (fig 4) the number days of when the maximum temperature is above 35 degrees has also been increasing(fig3). All major cities are examples of global warming and climate change. All the facts and figures imply that a change in the very basic planning of cities is the need of the hour. A holistic approach is required at every stage of planning in order to curb the obvious signs of climate change. The current state can be attributed to use of nonrenewable energies, pollution, cutting of trees, depletion of water bodies and lack of awareness which must be changed before it's too late.

Bangalore is the fifth biggest and one of india's fastest increasing towns with a population of over 9.6 million as of 2011.Bangalore city is the hub of hightech data, software, and biotechnology companies in india and a favored business process outsourcing location in the country of karnataka.It is india's hub of hightech information, software and biotechnology businesses and a favorite outsourcing place for business processes in karnataka .The city's financial operations are defined by the elevated concentration of smes across the economy in the different industries.[5]
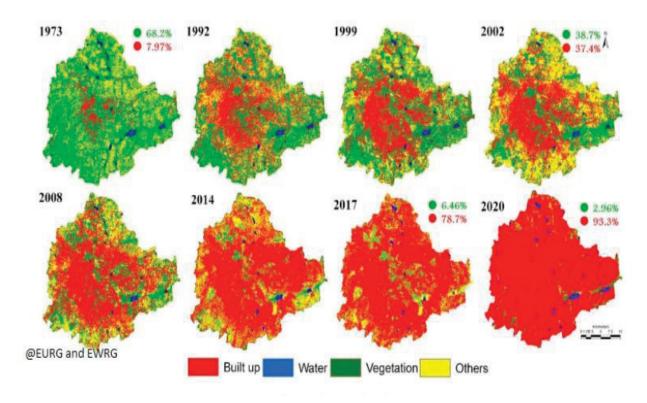

Figure 7 Change in tree cover in Bangalore

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[5] (Naomi Sunu)

LOSS OF GREENERY

All the development has led to constructions and development project. According to a Deccan Chronicle study, Bengaluru has already lost some 18,000 trees in the last nine years owing to distinct growth plans.Some 17,964 trees were trimmed between 2008-09 and 2016-17 for highway widening, building flyovers and other different projects.

[6]According to an abstract BBMP forest department, Namma Metro caused 2840 trees to fell, and various construction initiatives resulted in 15,124 trees to fell.[7] Such insensitivity to the importance of nature has led to the diminishing of green cover that Bangalore was once known for.

BANGALORE AND LOSS OF WATER BODIES

Much of the green cover loss is due to the fast land use shift.As the town grew over time and space, there was more crowding and congestion in the internal fields. Several roadside trees have been axed by projects to relieve congestion on highway networks.Many lakes have been transformed into residential buildings,bus stands, playgrounds and stadiums. [8]

	Bangalore City		Greater Bangalore	
	Number of Water bodies	Area (in ha)	Number of Water bodies	Area (in ha)
SOI	58	406	207	2342
1973	51	321	159	2003
1992	38	207	147	1582
2002	25	135	107	1083
2007	17	87	93	918

Figure 8 loss of water bodies in bangalore (Naomi Sunu)

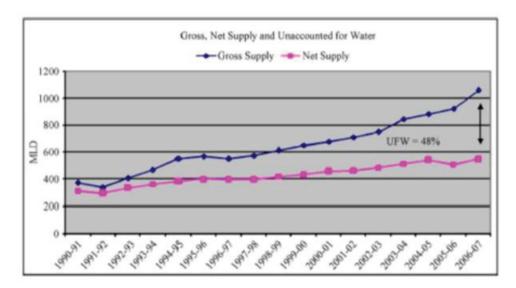[6] (G, 2017)
[7] (G, 2017)
[8] (Naomi Sunu)

Figure 9 Waste of water supplied (Naomi Sunu)

Added to the loss of water bodies, lack of rainwater harvesting, even the water that is supplied to the people is lost at a very high percentage of 48% which is almost half the entire amount of water received. Water leakages at the distribution mains, service pipes and valves, and water pilferage leads to loss of water.[9]
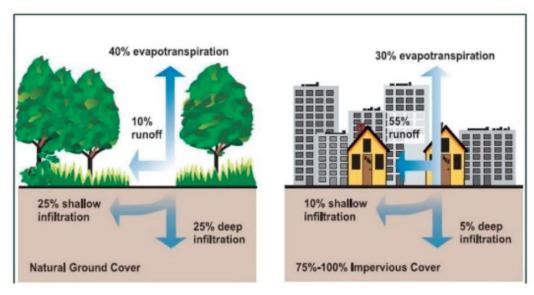
NEED FOR ECO-ARCHITECTURE AND SUSTAINABILITY

Figure 10 Forest vs cities water cycle((Kazemi, 2014)

When there is lack of infiltration in the environment, surface runoff increases, that in turn leads to drying up of ground water table because there isn't enough greenery such as trees, grass or bushes to absorb the rain water due to the trees being cut off and this leads to the lack of evapotranspiration which happens when the trees release the water in the

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[9] (Naomi Sunu)

environment to cool the surroundings . All this leads to the disruption of the water cycle that in turn effects the rain patterns.[10]

Added to that, concrete structures and asphalts in the form of streets and road make it almost an impermeable surface which acts as a barrier for the water to seep in. (Fig 810) In addition to that even the temperatures increase when concrete is used in abundance. [11]

Figure 11 Temperature rise in cities (Unknown, un.org, 2014)
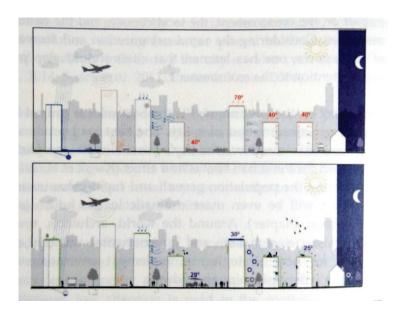

Figure 12 Difference in temperature with more greenery on built structures (Betzler, 2016)

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[10] (Kazemi, 2014)
[11] (Kazemi, 2014)

HOW GREENING A BUILDING HELPS THE ENVIRONMENT

Living walls that are Earth bound creepers when applied at 2m on the façade on a steel mesh. The overgrown creepers provide shade to in summer and in winter the plants shed leaves let in the warm sunshine Ground hedges add another layer of greening. It benefits the flora, fauna and the people indoors. Greening reduces the urban heat island and cools the building. Insulation and soundproofing are added advantages.[12]

PROJECT: Desy, Hamburg

19 selected building used for storage in Hamburg considered in possibilities of façade greening. Large building such as Desy, with even surfaces help in rainwater harvesting. The greening helps in evapotranspiration. The 19 buildings of a total of 36000m2 could collect 33.4 million litres of water per year and help in the normalizing of the water cycle by higher evapotranspiration.[13]
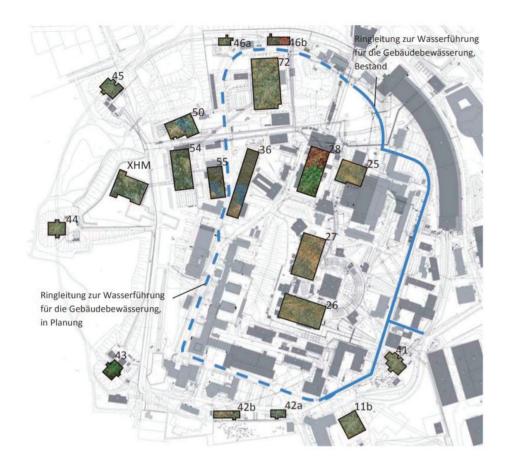

Figure 13 Buildings selected for study (Betzler, Sustainable Desy)

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[12] (Betzler, Sustainable Desy)
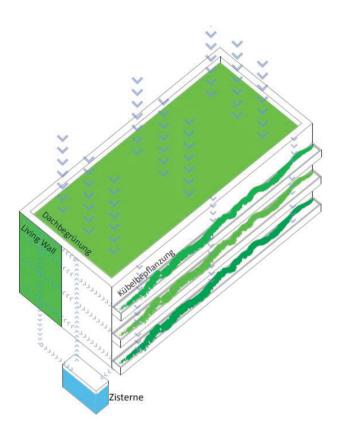[13] (Betzler, Sustainable Desy)

Figure 14 water circulation after rain (Betzler, Sustainable Desy)

Figure 15 Building elevation (Betzler, Sustainable Desy)

GREEN WINS PROJECT

Figure 16 3d view of the photosynthesis house (Artha krishna)

The project designed to create a photosynthesis house where plants and humans co-exist in a mutually beneficial setup. The concept of self-sufficiency was given importance by growing plants on the building utilizing rainwater to make it sustainable.
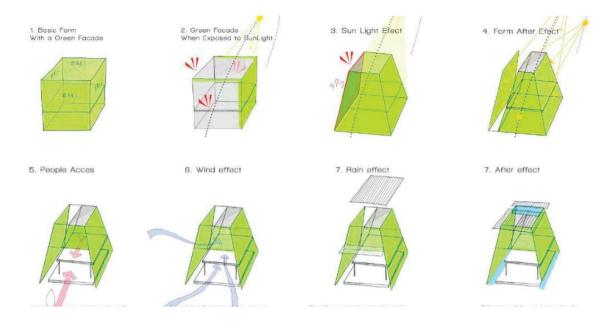

Figure 17 Form evolution (Artha krishna)

The development of the form after the sun path analysis show the importance given to climate architecture. This is done in order to maximise the sun light that

touches the plants so they can grow healthily. Therefore, the building slopes inwards on the top.[14]
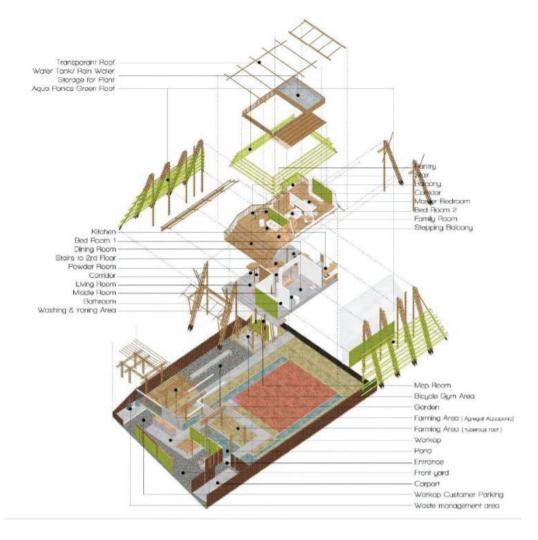

Figure 18 Building components (Artha krishna)

Figure 19 Materials used for construction (Artha krishna)

Using sustainable materials like bamboo and waste from construction sites such as clay tiles and paper waste, organic waste and plastic garbage to create eco friendly buildings reduces the carbon footprint greatly.

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[14] (Artha krishna)

LITERATURE STUDY

MASTER PLANNING AS THE START OF ECO SENSITIVE ARCHITECTURE

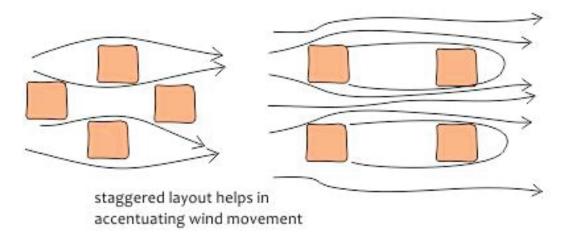

staggered layout helps in
accentuating wind movement

Figure 20 Placement of blocks is essential in planning (Kasinathuni, n.d.)

When building blocks are placed in linear methods it could mean that the wind would pass through it and not enter the building blocks. It is necessary to stagger them to create winds blocks so the wind would enter the blocks. While planning residential homes, the placement of the individual blocks play an important role in the way spaces are created, whether it's for cross ventilation, sunlight or to create lung spaces that include trees, shaded pathways, central courtyards. The ratio of the building height to the distance between the blocks could be 1: 2, 1:3.[15]
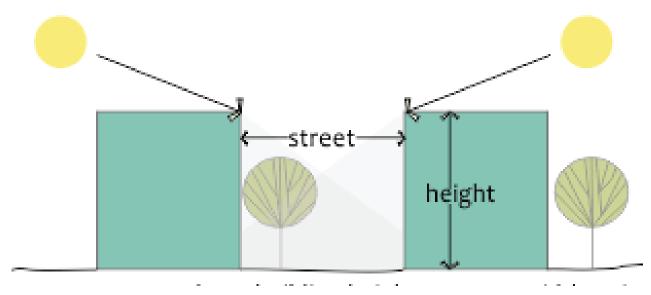

Figure 21 Distance between the buildings also play an important role in shading and ventilation (Kasinathuni, n.d.)
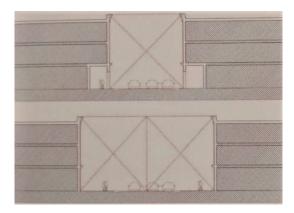
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[15] (Thadani, 2010)

Figure 23 Building spacing 1:1 and 1:2 (Thadani, 2010)

Figure 22 Building spacing to include buffer zones (Thadani, 2010)

Figure 25 Congested housing (Thadani, 2010)

Figure 24 Buffer zones using landscape (Thadani, 2010)

Multiples of well-proportioned spaces which are in scale with the height of the buildings can be used in order to create harmony. Placement of trees also enhances the wind penetration.[16] Such methods when strategically planned ultimately play huge role in reducing the total electricity costs as one would not need to use fans or ACs as much. Car parks, walkways, cycle tracks, landscaping could be used to enhance the planning in these buffer zones. These open spaces act as courtyards to create a stack effect for a group of houses and maintain the overall temperature.
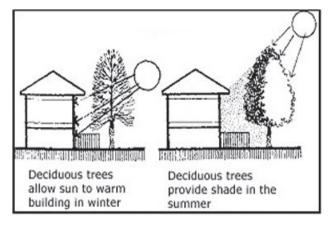

Deciduous trees allow sun to warm building in winter

Deciduous trees provide shade in the summer

Figure 26 Placement of trees plays an important role in Planning (Prowler, 2016)

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[16] (Thadani, 2010)

Placement of tress could play an important role in the usage of heating and cooling usages. In Figure 18 when deciduous trees are places on the east and western side. They protect and shade the house during the summertime as they grow in full bloom and they shed their leaves in winter and thereby letting in the sun to come into the house and keep it warm. This passive method of cooling allows the inhabitants to reduce the usage of fans and AC. Further, the size of fenestration and projections also help in shading the buildings.[17]
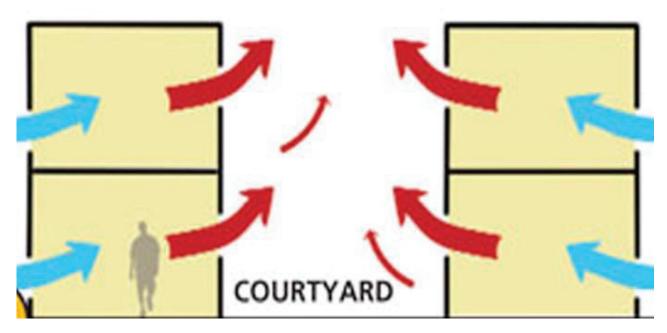
Figure 27 Courtyard acts as a bigger stack effect for a group of houses

Alternatively, Stack effect keeps the interior of the house cool by allow the warm air to rise and escape out from an outlet on the top.[18] Along with this cross ventilation is essential. Fenestration on opposite sides of the house create pressure difference so that helps in bring the wind in. As the air that enters warms up it gets less dense and rises to the vent on the top of the house and escapes from there. By doing so there is a continuous flow of cool wind and ejection of warm wind from the vents and window.[19]

[17] (Prowler, 2016)
[18] (Howard, 2019)
[19] (Howard, 2019)
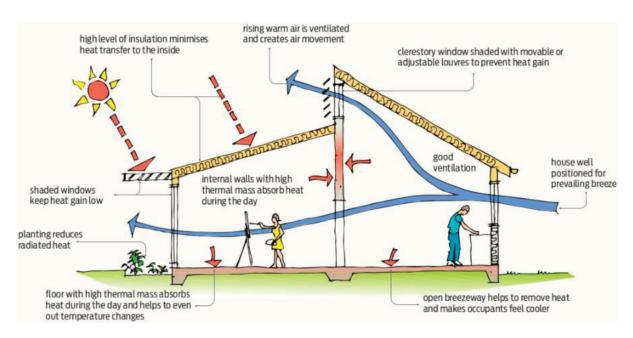
Figure 28 Stack effect to keep the interiors cool (Prowler, 2016)

SUSTAINABLE LANDSCAPE
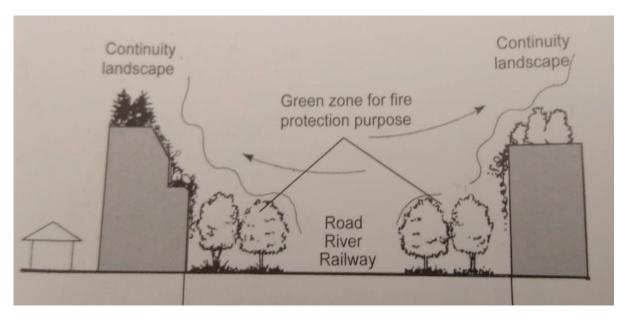
Figure 29 Greening at different levels (Yeang, 2008)

As we cut out trees and clear forests for urbanization it becomes imperative to create a balance in the environment by re introducing plants and trees to mitigate climate change. Different forms of greenery such as green roof, green screens, green façade and strategic placement of trees can create a mini green oasis that would keep its surroundings cool. Such methods could help in evapotranspiration and maintain healthy water cycles. Added to that it would help in harvesting water as the plants would slow down the flow of water and clean the water to an extent too.[20]

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[20] (Yeang, 2008)
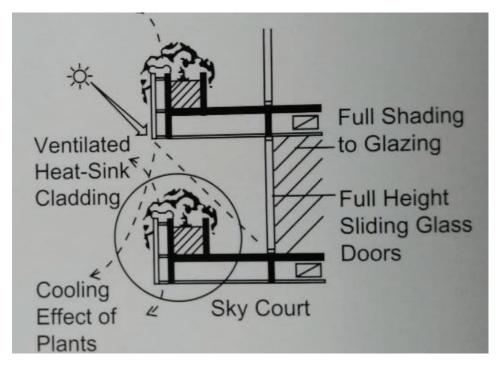
Figure 30 Projections with cooling effects of plants (Yeang, 2008)

Horizontal projections with green planters cool the air that flows inside the building and also add aesthetic feel to the façade of a building.
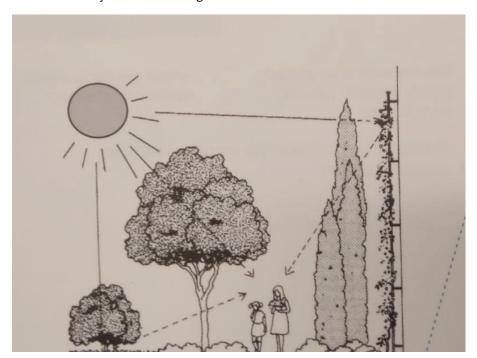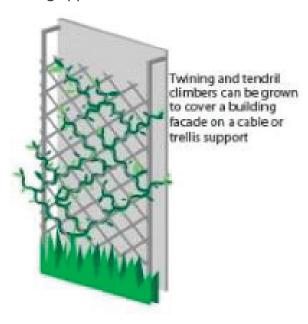
Figure 31 Shaded Pathways (Yeang, 2008)

Shaded pathways with Evergreen trees could always keep the walkway cool thereby reducing the need of creating built structures to shade it.

Wall creepers as a green element when allowed to be grown on the walls acts as a natural insulator. It also protects the external layer of the building and gives an very pleasing appearance.
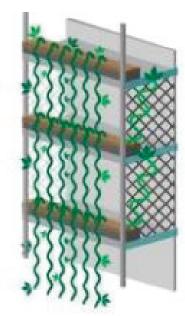
Figure 34 Bioswales and walkways (Thadani, 2010)

Figure 32 Creepers on metal mesh (Unknown, Green facade plants, Unknown)

Bioswales also play an important role in harvesting of rainwater. When rainwater flows in the green trench it retains the water that can be collected and treated to be used for landscaping purposes. Local water plants that can resist drought such as Indian grass should be used.[21]

These buffer spaces are not only aesthetic but also have a very functional purpose

Figure 33 Bioswales and walkways integration (Thadani, 2010)

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[21] (Thadani, 2010)

GOOD EARTH ORCHARDS

PROJECT OVERVIEW

- (Land: 7 acres
- Total built up area: 154000 sq.ft.
- Typology: Townhouses
- No of units: 57
- Plot areas 2400 sq.ft. to 4000 sq.ft.
- Location: Kengeri, Bangalore)[22]
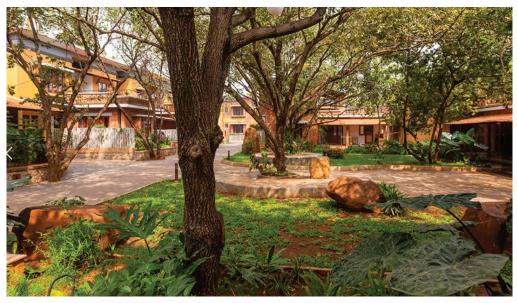
Figure 35 Existing trees included in the design (Unknown, Good Earth, n.d.)

Figure 36 Low rise housing closer to the ground (Unknown, Good Earth, n.d.)

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[22] (Unknown, Good Earth, n.d.)

Inception: The existing chikoo and coconut is the basis of fitting in built structure with nature to propagate green living[23]

Sustaining the community, the aim was to have a beneficial setup between nature and people. Neighborhood concept with organic landscape to create harmony was the intention. Sustainability was interwoven in ways that it was integrated in the daily lives of people.[24]

Figure 37 Green terrace in individual houses (Unknown, Good Earth, n.d.)

Figure 38 Verandah acting as a buffer space (Unknown, Good Earth, n.d.)

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[23] (Unknown, Good Earth, n.d.)
[24] (Unknown, Good Earth, n.d.)

Cluster planning
The idea was to create small clusters of independent houses around an organic lawn.[25]

Spaces
the built up is only one floor above the ground to keep the houses as close to nature, ground and open spaces. Courtyards, verandahs and open plans are blended with each other[26]

Figure 39 Coomon space in the form of a pond (Unknown, Good Earth, n.d.)

Figure 40 Common lawn for small cluster of houses (Unknown, Good Earth, n.d.)

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[25] (Unknown, Good Earth, n.d.)
[26] (Unknown, Good Earth, n.d.)
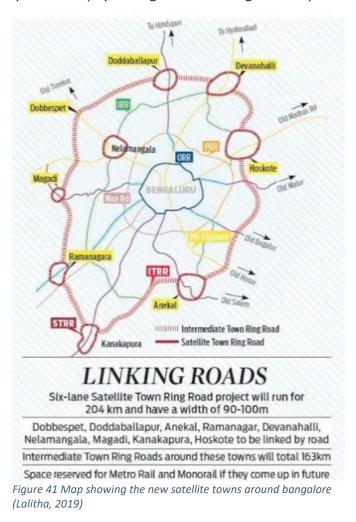
DESIGN

SITE

Owing to urban crawl and overpopulation the 'new town' concept, which came up a long time ago took grasp of things and attempted to conquer the intense urban rot of enormous metropolitan urban communities by making new arranged settlements around the mother city[27]. State governments have now started encouraging the real estate sector to come in and develop these towns. "Satellite Town Ring Road (STRR) project and Intermediate Town Ring Road Project (ITRR) are projects that are underway[28]". These ring roads plan to connect 9 new satellite towns around Bangalore.

Therefore, my site being chosen in one of the satellite towns of Devanhalli. As a matter of fact, housing is universally acknowledged as a fundamental human need that is basic in deciding personal satisfaction. It indicates extent of development since they affect the physical and psychological wellbeing of occupants.

Figure 41 Map showing the new satellite towns around bangalore (Lalitha, 2019)

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[27] (Satellite Town, n.d.)
[28] (Lalitha, 2019)

FUTURE DEVELOPMENT

- Five kilometer from international airport.
- It is the future IT hub of bangalore
- Devanahalli business park is expected to attract investment to the tune of $2.2 billion over the next five years. 104 acres of land has been reserved for various government agencies in the field of aviation, tourism, meteorology, and power.[29]
- The remaining 309 acreswill host 3 multi-speciality hospitals, 2 IT sezs, 2 non-sez offices, a manufacturing and assembly unit, a financial district, and a central business district (CBD) with hotels and malls.[30]
- Aerospace manufacturers like HAL, BEML & Dynamatic Technologies will set up units for making engine components, aircraft repair, and helicopter manufacturing at Aerospace SEZ. [31]
- IFCI (Industrial Finance Corporation of India) will set up a Global Financial District at Devanahalli to entice global financial players to set up an office here.[32]

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[29] (Unknown, Why plots in Devanhalli is good investment, 2018)
[30] (Unknown, Why plots in Devanhalli is good investment, 2018)
[31] (Unknown, Why plots in Devanhalli is good investment, 2018)
[32] (Unknown, Why plots in Devanhalli is good investment, 2018)
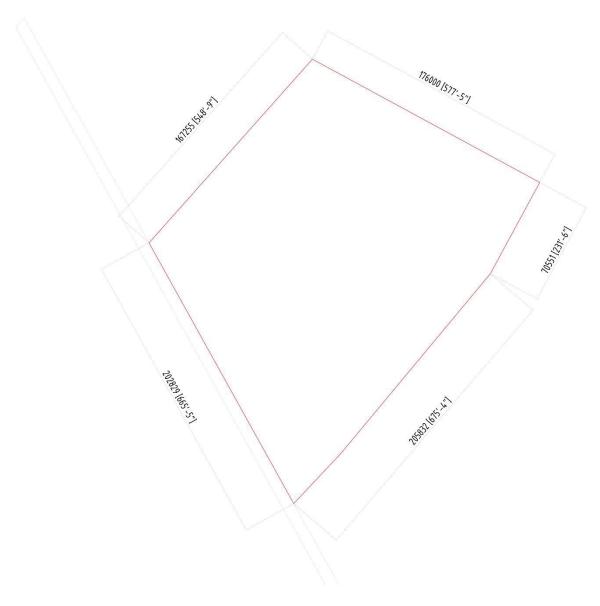
CURRENT CONTEXT OF SITE
- Currently the land has been converted to a layout with plots on sale.
- Surrounded by various other plotted communities for sale
- Landuse of the property is RESIDENTIAL
- Minimum trees.
- Current surroundings is less developed as the development in estimated to happen in coming years.

SITE SURROUNDINGS

-Area = 9 acres

- Opposite to Brigade Orchards
- Devanahalli Bus stand1km
- 1.5km from NH-7
- 15 Minutes to Nandi Hills
- 20 Minutes to Hebbal
- 30 Minutes to Bangalore city
- 5 Minutes to AeroSEZ, Hardware Park
- 40 Minutes to Whitefield
- 5 Minutes to International Airport
- Devanahalli Railway station 4km

1 Bioswales along the perimeter
   of the site boundary

2 Parking with bamboo shading structure
   integrated with bioswales

3 Evergreen woody trees to reduce urban
   heat island effect

4 Grass pavers in vehicular access to max-
   imise water absorption into the ground

5 Water restitant woody trees integrated
   with bioswale

6 Decidous Trees on east and west side of
   the house units

7 House units

8 Community farm

9 Courtyard for community gathering with
   water rentiontion landscaping

10 Individual house water retention planters

11 Amphitheatre

12 Porous pathways made of smoothened industrial
    glass waste

13 On site garbage management

MASTER PLAN

LVL 1 PLAN   LVL 2 PLAN   LVL 3 PLAN

Individual unit planned with open plan layout. East and Western facades shaded by projections, bamboo, planters and trellis covered in deciduous creepers. A central courtyard helps in stack effect and keeps the internal temperature cool. Terrace covered in green roofs to maintain indoor temperature and to harvest more volume of rainwater.

Single units when clubbed to create one mass but the ventilation, natural lighting and open spaces are not affected.

LVL 1 PLAN   LVL 2 PLAN   LVL 3 PLAN

DUAL UNITS

MAIN MATERIAL CHOICE AND ADVANTAGES

SL	ELEMENT	MATERIAL	ADVANTAGES	IMAGE
1	Foundation	Cadappah	Locally available Passive cooling Fire resistant Cheap	
2	Walls	Compressed stabilized earthBlocks	Biodegradable Local Cost efficient Energy efficient Eco friendly	
3	Beams	RCC	For stable structure	
4	Slab	Filler slab	Less concrete and steel	
5	Lintel	Stone Cadappah	Less weight of slab Locally available Passive cooling Fire resistant Cheap	
6	Mortar	Lime Mortar	Breathable Eco friendly	
7	Flooring 1	Caddapah	Locally available Passive cooling Fire resistant Cheap	
8	Flooring 2	Bamboo	Eco-friendly Inexpensive Less maintainance	

Front elevation of the house

Side elevation of the house comprises of various elements to keep the house well ventilated and cool. Trellis on the southern side, rain chains leading the water to the sump, Clay jaali along the internal courtyard and wall creepers for insulation.

GREEN ELEMENTS IN INDIVIDUAL HOUSE UNIT
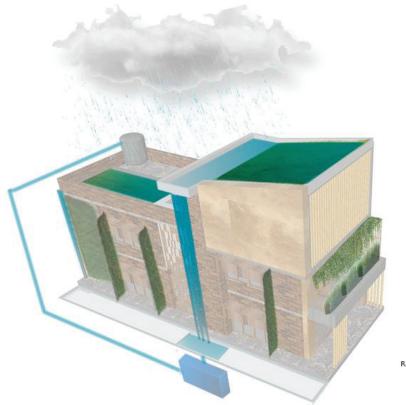
SL	ELEMENT	ADVANTAGES	IMAGE
1	Green Roof	Helps in evaporative cooling Increases amount of water retention Improves water quality Coserves energy and insulates Reduces urban heat island effect	
2	Planter boxes	Cools incoming air Helps in Shading Provides privacy	
3	Green Trellis	Low maintainance Cools incoming air Helps in evaporative cooling Decidous vines shed in winter	
4	Bamboo Screen	Natural shading device Aesthetic appearance Eco friendly	
5	Wall Creepers	Aesthically appealing Do not require extra structural support Provide an insulating barrier	
6	Jaali	Made of terracotta, eco friendly Allow for diffused sunlight from south side Courtyard and stack effect enhanced by Jaali	

Individual cluster 3d view. Each house covered in green roofs. Solar panels facing the western side to absorb maximum sunlight. Two water tanks for grey water and drinking water.

Extensive green roof

East side shadesed by
Level 1 - Chejja/planter
Level 2 - Planter and Trellis with
        decidous vines
Level 3 - Vertical Bamboo
        structure

Extensive green roof

Western side shaded
by double height volume
covered with trellis and vines

Decidous trees on east
and west side

Stack effect

SECTION THROUGH HOUSE

RAIN WATER HARVESTING FOR INDIVIDUAL HOUSE

Stack effect is necessary to keep indoor ventilated. The skylight court inside the house is enhanced with an indoor tree and vents on the side allow the warm air to rise up and keep the interiors cool.

GREEN DENSITY FACTOR

"The Green Density Factor compares the amount of building greenery with the footprint area of a building. A higher degree of vegetation is reflected in a higher GDF."[33]

GREEN DENSITY FACTOR

l, w (m) - Length and width of building
FP (m2) - Footprint area of building - lxw - 6.5 x 18 = 117
h (m) - Height of building - 3m
Total number of floor n - 3
H = h x n = 3 x 3 = 9
fr : Fraction of roof greenery = 0.5
GRA- Green roof area = fr x FP = .5 x 117 = 58.5
ff : Fraction of facade greenery -
GFA (m2) - Green facade area - ff x (l + w + w) H
$$\frac{- .3 \times (6.5 + 6.5 + 18)\, 9}{12}$$

GDF = GRA + GFA/FP - 58.5 +12/117 =.6

A value of 0.6 excludes the landscaping around the house. Therefore the value of each house can be assumed to be much higher than 0.6 as each house has the landscaped area offset by 3m minimum all around the house.

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[33] (Betzler, GDF - Green density factor and GCF- green cooling factor, 2016)

Area of Bioswale + Vehicular path = 8250 sq/m
Avg rainfall in Bangalore = 859

For calculation we take the following formula:
mean annual rainfall in mm x area in m² x runoff factor = collected rainwater in litres
= 859 x 8250 x .9
= 63,78,075 litres
(can be used for landscape maintenance and ground water recharge)

Individual house unit
=859x 117 x .9
90,000 litres

Type of need	Quantity (lpd)
Drinking	3
Cooking	5
Bathing	15
Washing utensils	7
House ablution	10
Total	40

A family of four requires 160-200 litres
Water saved by rainwater harvesting 200 x 365 days = 73,000 lts
Excess of 90,000 – 73,000 = 17,000 litres saved

Master Thesis

Part plan showing community garden

FRUIT ORCHARD

HERBS IN CONTAINER FARMING

TRADITIONAL FARMING

CONTAINER FARMING

GREEN HOUSE

VERTICAL FARMING

FRUIT ORCHARD

Part plan showing the eco courtyard

The eco courtyard acts like the space for stack effect and as a sponge for the rainwater to seep into. Excess rain can be stored in the mound temporarily and on most occasions, it acts as an open landscaped garden space. Each eco courtyard has no more than 8 units around it to keep the scale compact and promote social interaction amongst the house units.

Eco courtyards/Rain Gardens
Total area of four rain gardens 2000 sq/m
Avg rainfall in Bangalore = 859mm
For calculation we take the following formula:
mean annual rainfall in mm x area in m² x runoff factor = collected rainwater in litres
859x 2000x .9
15,46,200 litres

View of the eco courtyard

Relaxation space blended with the eco courtyard with an abstract deck cutting through it with benches along the walking deck.

TREES PLANTED ON SITE

SL	NAME	LOCATION	IMAGE
1	Decudious Trees Bauhinia purpurea L	East and west side of house	
2	Evergreen trees Saraca asoca (Roxb.) de Wilde Ashoka Tree	On the Periphery of the house clusters	
3	Michelia champaca L. Champa(grows 10m)	Periphery of site boundry	

[34]

PLANTS IN BIOSWALES AND ECO COURTYARDS

Figure 42 Ixora Figure

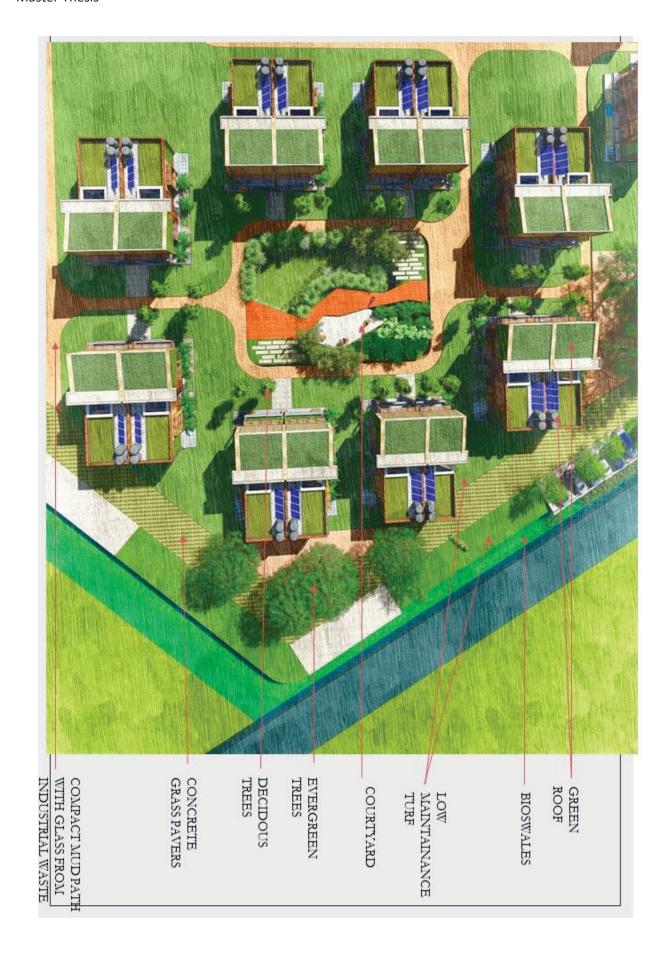*43 Taliparti Tiliaceum*

Figure 44 Thevetia peruviana

Figure 46 Ficus Celebensis

Figure 45 Pandamus Tectonius

[35]Plants names

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[34] (T.V. Ramachandra, n.d.)
[35] References for bioswale and eco courtyard from (Jean w H, 2010)

INDUSTRIAL WASTE
WITH GLASS FROM
COMPACT MUD PATH

CONCRETE
GRASS PAVERS

DECIDOUS
TREES

EVERGREEN
TREES

COURTYARD

LOW
MAINTAINANCE
TURF

BIOSWALES

GREEN
ROOF

CONCLUSION:

With growing population, it is the need of the hour to take steps in containing the global warming and climate change. Landscape architecture is not a separate entity from the built architecture, it must be blended with the building in order to create a balance and restore the greenery that we have been destroying over the last few decades. Innovating within the local context and using resources that's readily available will help in reducing the carbon footprint. It is necessary to keep the local climate and context to design better buildings. The ratio of built and unbuilt is important as we need to stop the overpopulated cities from degrading further. Developing sustainably and keep at least 40 percent reserved for landscape and adding different greening methods on the building is the need of the hour.

Rainwater harvesting might be an extra cost in the beginning but in the long run it saves a lot of expenses. It reduces the burden on the governments and authorities and creates a self-sufficient house. Similar with solar panelling, it reduces the dependency on electricity supply from government electric authority. The more self-sufficient the house is the lesser the carbon footprint is. Local plants and trees also playa vital role in reducing pollution and decreasing the urban heat island. Every design must include local vegetation as they are more weather resistant to the immediate climate.

When ecologically sensitive communities are designed it creates more awareness amongst people and as planners and architects it is our duty to design responsibly. As we design to build more eco communities the awareness also grows and that in in turn leads to more responsible way of living. Such planning to be done in every metropolitan city in order to offset the negative impacts of urbanization.

Therefore, future generations should be able to look forward to living in an environment that respects nature and its importance to living in a pollution free, sustainable and a healthy neighbourhood.

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