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Assessment of Dense Settlement to Improve its Scenario through GI Retrofit - A case of Chakupat, Lalitpur

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Abstract

This paper focuses on the benefits on the air quality, building energy saving and urban heat island resulting from green infrastructure retrofit. The main objective of research is to assess and study of settlements to develop strategic planning for green infrastructure retrofit and exploring its multiple benefits and sustainability impact. Green infrastructure plays a critical role in environmentally sustainable urbanization in developing countries. The urban open space design in contemporary urban development of Kathmandu Valley demonstrates numerous problems starting from lack of open spaces itself to their poor design, improper or lack of use and lack of maintenance. As population and urban development increase rapidly in Kathmandu valley, conversion of open space, unplanned housing and added imperviousness are closely related to growth of dense settlements, increase urban heat island effect, energy consumption for heating/cooling and poor air quality. Green Infrastructure Retrofit approach will address issues with least possible disturbance to existing urban scene. There is a lack of empirical research assessing specific dimensions of green infrastructure retrofit and the balance between green infrastructure and urban development. Also, little research has been conducted on feasibility study and the potential benefits of green infrastructure to reduce related issues.

Keywords

Green Infrastructure, Urbanization, Green roof, Green wall, Urban heat island effect, Air quality, Energy

1. Introduction

Urbanization in Nepal has been observed since 1970. In last few decades, Nepal has been among those countries with the highest urbanization rates with an annual increase of 3.0%. This trend is expected to continue until 2050. The areas with the greatest urbanization rates were in the Kathmandu Valley which comprises 24.02% of the total urban area. Kathmandu's metropolitan municipality contains approximately 9.72% of the valley's total urban population. Kathmandu is a major urban centre with a population exceeding three million people [1].

As population and urban development increase rapidly in Kathmandu valley, conversion of open space, unplanned housing and added imperviousness are closely related to growth of dense settlements, increase urban heat island effect, energy consumption for heating/cooling and poor air quality.

There is a lack of empirical research assessing specific dimensions of green infrastructure and the balance between green infrastructure and urban development. Also, little research has been conducted on feasibility study and the potential benefits of green infrastructure to reduce related issues. The goal of this study is to access and investigate community and neighborhood scale of green infrastructure retrofit to examine the potential effects of it on reducing energy consumption, heat island effect and improving air quality.

2. Research Objectives

Main Objective:

- To access and investigate the settlement to create sustainable neighbourhood through Green Infrastructure intervention/retrofitting.

Specific objectives:

- To explore social, economic and technical challenges/opportunities while planning, designing and adopting the intervention of green infrastructure on case area.

- To analyse benefits of Green Infrastructure in terms of energy, air quality and urban heat island effect.

- To explore economic and social benefits through Green infrastructure intervention

3. Methodology

Method of this study is descriptive-explorative method and descriptive-comparative method.

- The descriptive-explorative method used to identify the area study on physical, social, economic, and culture aspects. That method may use to identified some indicators on manage small perimeters of dense settlements in Kathmandu valley with in literature review technique.

- The descriptive-comparative method is used to analyze the existing condition based on some indicators that found before. This method can lead to find the potentials and problems on area study. Based on that result, the strategic program would be formulated.

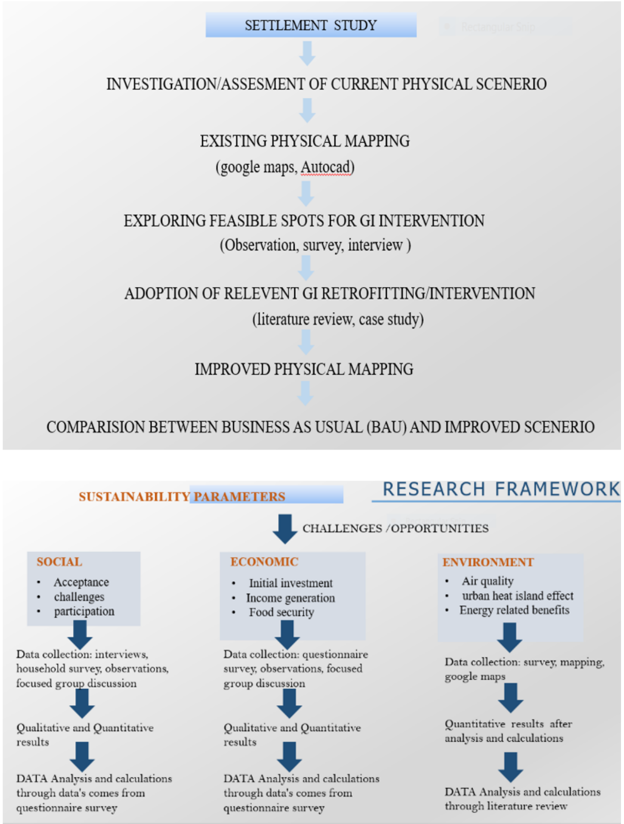


Figure 1: Methodology Chart

- Methods of data collection & Research framework: This process is conducted in multiple steps. At first, current physical aspect of settlement is investigated/assessed. The existing physical mapping is traced out through google maps/ACAD. All the physical characteristics of settlement which are important for GI (Green Infrastructure) retrofit are explored in quantified data. Exploration of physical spots for GI retrofit through observation, survey or by interviewing community. Relevant Green Infrastructure (literature review/case study) on case area are adopted. And improved physical scenario of settlements after retrofit is explored through mapping. There is Comparison of current physical scenario (Business as usual) and improved scenario after green infrastructure retrofit exploring benefits in terms of air quality, reduced urban heat island effect and energy consumption.

Exploring challenges/opportunities of green infrastructure retrofit in terms of social, economic and environment aspect through sample questionnaire survey and interview.

4. Limitation of the study

• Study is carried out on small segments of chakupat area having 80 households in total.

• Quantified data on Green infrastructure benefits on case area in terms of air quality, energy and urban heat island is depends on literature review.

• Study mostly based on observation and sample questionnaire survey for extracting physical data of case area.

• Quantified data are extracted from different cases around the world which has similar climatic characteristics as Kathmandu valley. This is only validation of references data extracted from literature review.

5. Problem Statement

In last few decades, Nepal has been among those countries with the highest urbanization rates with an annual increase of 3.0%. This trend is expected to continue until 2050 The areas with the greatest urbanization rates were in the Kathmandu Valley which comprises 24.02% of the total urban area. Kathmandu's metropolitan municipality contains approximately 9.72% of the valley's total urban population. Kathmandu is a major urban centre with a population exceeding three million people. [2]

Air Quality

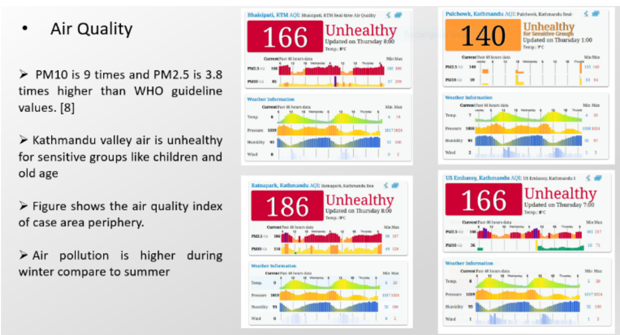


Figure 2: Air Quality in Kathamndu

Urban Heat Island

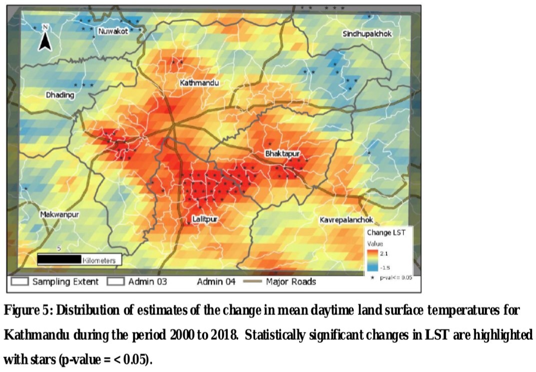


Figure 3: Day time land surface temperature

Areas colored red represents a relative annual increase of 0°C to 2°C and areas colored blue represents an annual decrease of 0.0°C to 2.5°C [2].

Energy consumption

Heating and cooling consume 60% of total energy consumption in contemporary building [1]. The final energy demand in BAU will increase at the rate of 4% per annum from base year value [3].

6. Rationale

Due to unplanned settlement and unmanaged urbanization, life in the city area is degrading. The urban open space design in contemporary urban development of Kathmandu Valley demonstrates numerous problems starting from lack of open spaces itself to their poor design, improper or lack of use and lack of maintenance. Rapid urban development with its concomitant conversion of open space and added imperviousness increases the potential for stormwater runoff and flooding, resulting in increases in potential for adverse hazard impacts such as economic damage. Given these circumstances, the benefit of green infrastructure has become an emerging topic of study, and its potential use as a hazard mitigation tool is receiving more attention in the urban planning discipline [4].

7. Case Studies

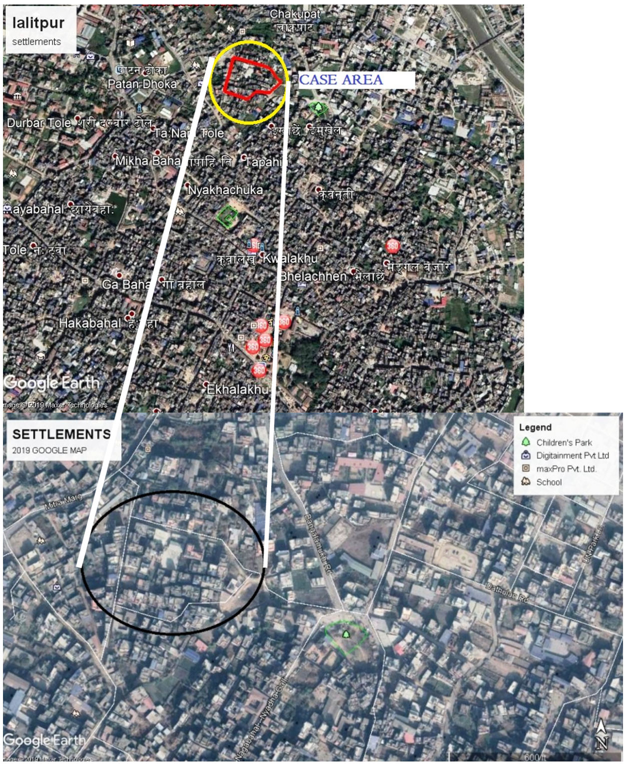


Figure 4: Chakupat in Map

Chakupat is located at central urban sprawl which is newly formed settlements without having proper land management. Study area is emerged from the fragmentation of land in small pieces without open space, proper width road networks, proper setback and vegetation which is ultimately in the form of urban sprawl.

Building Typology Most of the buildings are modern with flat roof. Building materials used for construction are cement, brick, reinforcement bar etc. Average height of buildings is 3 storeys.

Settlements pattern building typology Settlements are in compact form having Narrow Street. Absence of public open spaces and green vegetation.

Road networks Brick paved narrow streets (width: 4-6') within a settlement. Peripheral asphalt roads (width: 10-13").

Socio-Cultural character of site Peoples from different socio-cultural background are present there. Most of them are from newar community migrated from nearby traditional settlements. Social cohesion is very less within settlements as seen from the observation. Layout of settlements discourages community to interact to each other. There are no open spaces for communal activities.

Figure 5: Site Photos

8. Result and Discussion

The results of this study are explained in comparison between existing scenario of settlement and improved scenario after GI retrofit. The comparison is expressed in energy terms (kwh). The benefits of having planting trees, green wall and green roof are quantified in (kwh) so that the comparison will be more visualized between existing scenario and improve scenario and its impacts on reducing air pollution and reduced urban heat island.

8.1 Existing Scenario

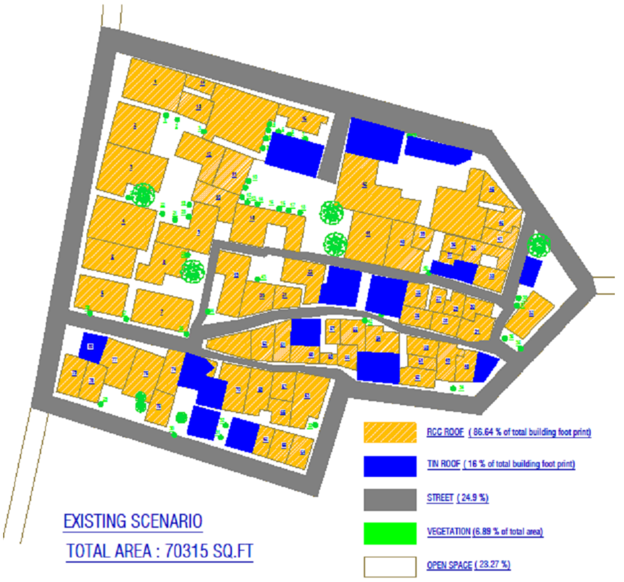


Figure 6: Existing Scenario

This map shows the existing physical scenario of settlement in which yellow patches indicates building footprints (occupy 86.64% of total area) having RCC flat roof which have potential for green roof, blue indicates building with teen roof (16%) which is not feasible for green roof, green indicates overall vegetation(6.69%) present on settlements. Benefits of vegetation on existing condition in terms of CO2 sequestration, Air pollution and energy.

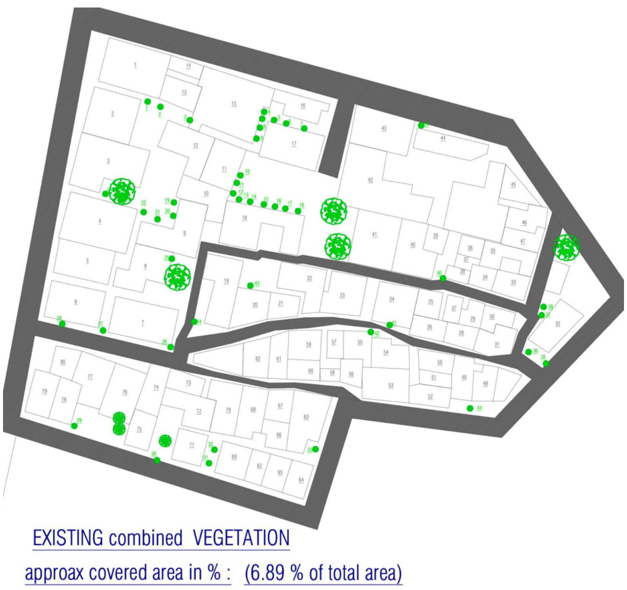


Figure 7: Existing scenario with Vegetation

AIR related benefits on existing scenario

Annual pollutant uptake

• NO2 uptake (0.37 lbs/tree) = 0.37 lbs/tree x 8 = 2.96 lbs

• SO2 uptake (0.40 lbs/tree) = 0.40 lbs/tree x 8 =3.2 lbs

• O3 uptake (0.29 lbs/tree) = 0.29 lbs/tree x 8 = 2.32 lbs

• PM-10 uptake (0.33 lbs/tree) = 0.33 lbs/tree x 8 = 16.17 lbs

• CO2 uptake (250 lbs /tree) = 250 lbs /tree x 8 = 2000 lbs

ENERGY related benefits on existing scenario

The indirect CO2 emission factors for reduced electricity use (1.13907 lbs/kWh)

CO2 uptake (250 lbs /tree) = 250 lbs /tree x 8= 2000 lbs

= 2000 lbs *1.13907 lbs/kWh

= 2278.14 kWh

8.2 Mapping for GI retrofit

Planting Tress

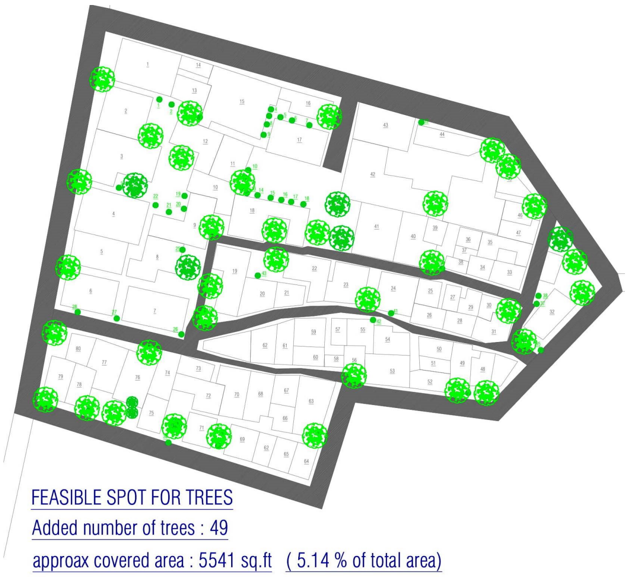


Figure 8: Feasible Spots for Trees

AIR related benefits

Annual pollutant uptake

• NO2 uptake (0.37 lbs/tree) = 0.37 lbs/tree x 49 = 18.13 lbs

• SO_2 uptake (0.40 lbs/tree) = 0.40 lbs/tree x 49 =19.6 lbs

• O_3 uptake (0.29 lbs/tree) = 0.29 lbs/tree x 49 = 14.21 lbs

• PM-10 uptake (0.33 lbs/tree) = 0.33 lbs/tree x 49 = 16.17 lbs

• CO_2 uptake (250 lbs /tree) = 250 lbs /tree x 49= 12250 lbs

ENERGY related benefits

The indirect CO_2 emission factors for reduced electricity use (1.13907 lbs/kWh) CO_2 uptake (250 lbs /tree) = 250 lbs /tree x 49= 12250 lbs

= 12250 lbs *1.13907 lbs/kWh

= 13953.60 kWh

Green Roof

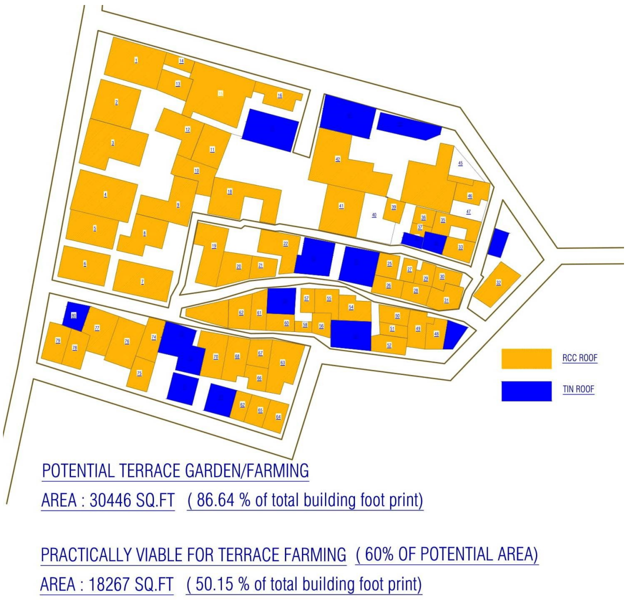


Figure 9: Potential Terrace Garden Farming

Practical area for green roofing (terrace gardening / terrace farming)

PRACTICAL AREA: 18267 sq.ft

• ENERGY related benefits

• 0.2244kWh/SF = annual cooling savings

• 2.11 kWh/SF = annual heating savings

Annual Cooing Savings: 0.2244kWh/SF x 18267 SF = 4099.11 kWh

Annual Heating Savings: 2.11 kWh/SF x 18267 SF = 38543.37 kWh

AIR related benefits

Annual pollutant uptake

• NO_2 uptake (0.0004770 lbs/SF) = 0.0004770 lbs/SF x 18267 SF = 8.713 lbs

• SO_2 uptake (0.0004060 lbs/SF) = 0.0004060 lbs/SF x 18267 SF = 7.416 lbs

• O_3 uptake (0.0009200 lbs/SF) = 0.0009200 lbs/SF x 18267 SF = 16.80 lbs

• PM-10 uptake (0.0001330 lbs/SF) = 0.0001330 lbs/SF x 18267 SF = 2.42 lbs

The average amount of annual carbon sequestered from green roofs (0.0338 lbs C/SF) and the indirect CO_2 emission factors for reduced electricity use (1.13907 lbs/kWh)

• CO_2 sequestration = 0.0338 lbs. C/SF *18267 SF = 69.41 lbs.

• Reduced Energy = 69.41 lbs. * 1.13907 lbs./kWh = 79.06 kWh **Green Wall**

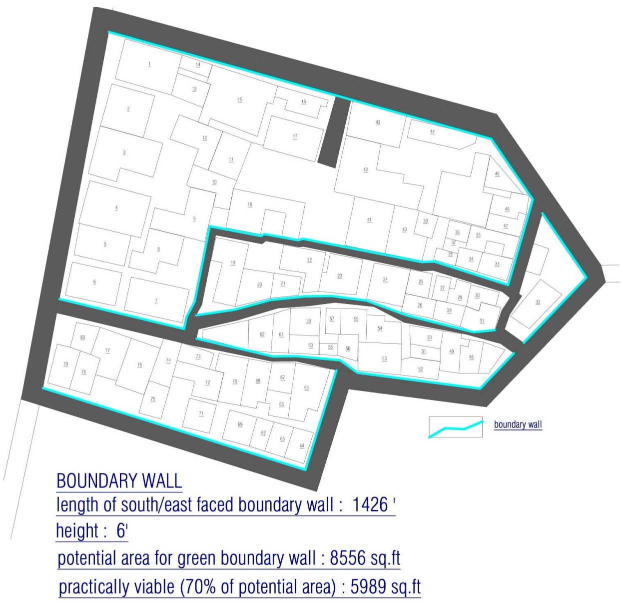


Figure 10: Potential Green wall Space

AIR related benefits

Annual pollutant uptake

• NO_2 uptake (0.0004770 lbs/SF) = 0.0004770 lbs/SF x 5989 SF = 2.85 lbs

• SO_2 uptake (0.0004060 lbs/SF) = 0.0004060 lbs/SF x 5989 SF = 2.43 lbs

• O_3 uptake (0.0009200 lbs/SF) = 0.0009200 lbs/SF x 5989 SF = 5.50 lbs

• PM-10 uptake (0.0001330 lbs/SF) = 0.0001330 lbs/SF x 5989 SF = 0.79 lbs

ENERGY related benefits

CARBON sequestered from green roofs (0.0338 lbs CO_2 /SF) = 0.0338 x 5989 = 202.42 lbs

The indirect CO2 emission factors for reduced electricity use (1.13907 lbs/kWh) CO2 uptake (202.42 lbs)= 202.42 lbs x 1.13907 lbs/kWh = 230.57 kWh

8.3 Quantitative Benefits on Existing Scenario

BENEFITS	CO2 SEQUESTERATION	ENERGY RELATED BENEFITS	URBAN HEAT ISLAND
GREEN INFRACTURE PRACTICES		Indoor Heating/cooling energy	
1. GREEN ROOF	-	-	-
2. PLANTING TREES	2278.14 kWh	-	Negligible effect
3. GREEN WALL	-	-	-
ANNUAL MONETARY VALUE	Nrs . 18544.05	-	-

Figure 11: Quantitative Benefits on Existing Scenario

8.4 Quantitative Benefits on Improved Scenario

BENEFITS	CO2 SEQUESTERATION	ENERGY RELATED BENEFITS	URBAN HEAT ISLAND
GREEN INFRACTURE PRACTICES		Indoor Heating/cooling energy	
1. GREEN ROOF	79.06 kWh	42642 kWh	Decrease indoor temperature by : 2 deg.c
2. PLANTING TREES	13953.60 kWh	-	Decrease outdoor temperature by : 2 deg.c
3. GREEN WALL	230.57 kWh	-	-
ANNUAL MONETARY VALUE	Nrs . 111,102	Nrs . 347,105	

Figure 12: Quantitative Benefits on Improved Scenario

8.5 Comparison

Business-as –usual (BAU)	Improved scenario
• Carbon sequestration on existing vegetation is 2000 lbs • Poor communal activities • Minimum green vegetation • Existing vacant land will be occupied for housing	• Carbon sequestration on improved vegetation is 12250 lbs which normalise existing air quality index. • Air quality improved by 16% • Energy consumption reduced by 42643 kWh (from 80 households) annually • Enhance Communal activities from planning to monitoring of green infrastructure intervention • Increased social bonding • Health benefits • Consumption of organic vegetables from terrace farming

Figure 13: Comparison between BAU and Improved scenario

8.6 Social Perspective towards Green Infrastructure Retrofit

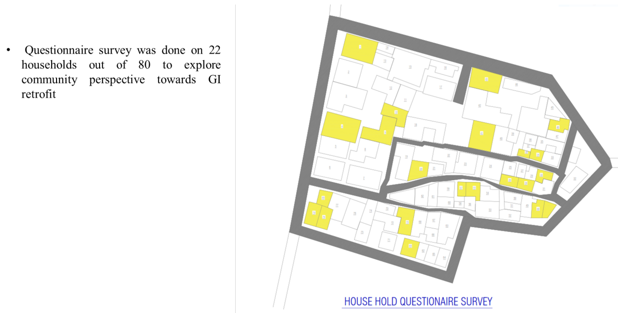


Figure 14: Household Questionnaire Survey

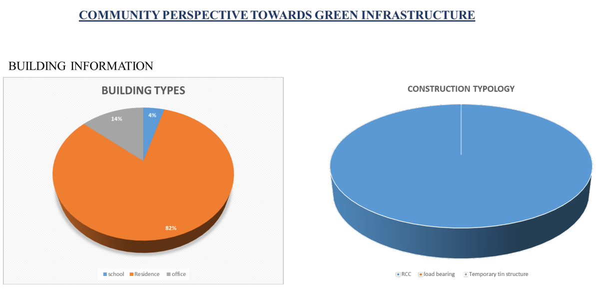


Figure 15: Building Information

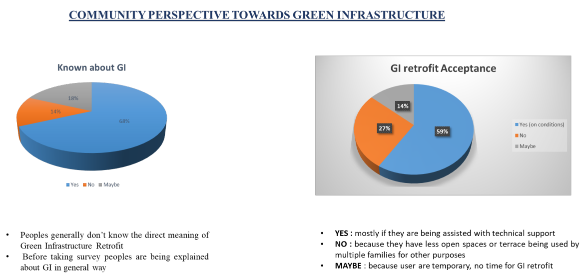


Figure 16: Perspective on GI and its retrofit

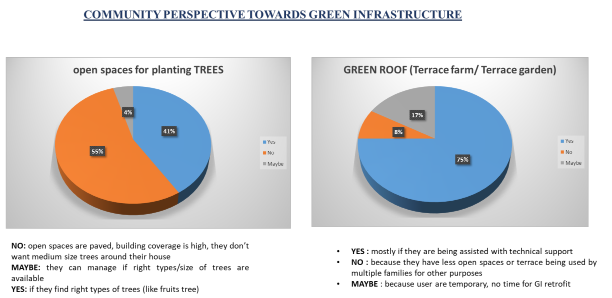


Figure 17: Perspective on planting trees on open spaces and green roof

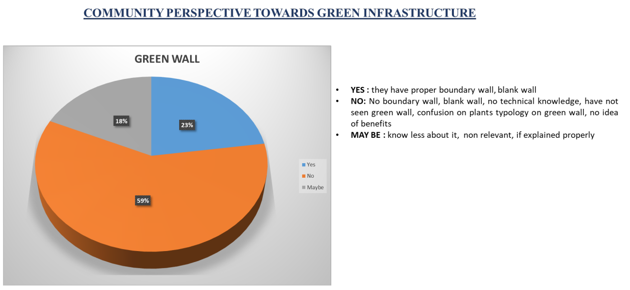
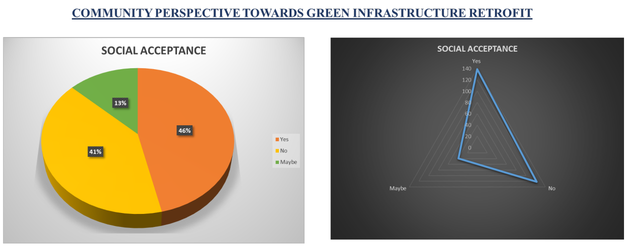


Figure 18: Perspective on Green Wall



ANALYSIS

	PRACTICES	YES	NO	MAYBE
1	planting trees	41	55	4
2	Green roof	75	8	17
3	Green wall	23	59	18
	Total	139	122	39

Figure 19: Social Acceptance

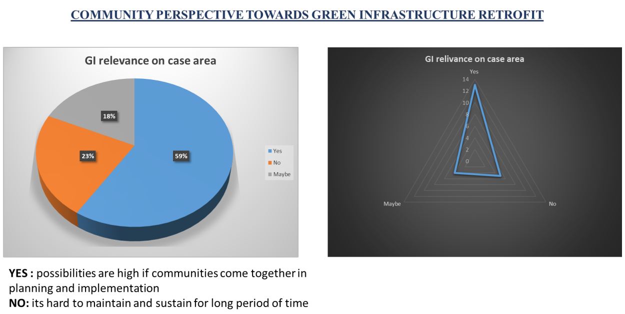


Figure 20: GI relevance on case area

8.7 Sustainability Parameters

Social impacts

Green infrastructure has a range of social benefits. These include picturesque environs that reduce stress and improve mental health, assist with medical recovery, encourage exercise and social interaction, and improve quality of life.

Environmental impacts

Green infrastructure has substantial environmental benefits for communities. These include improved air quality, reduced emissions, protection and enhancement of biodiversity values and ecosystem services, a cooler urban environment, and greater capacity for water filtration, absorption and retention. For example:

• Street trees are 20 per cent more cost-effective at shading than metal shelters

• Vertical green walls lower interior temperatures by 2 degrees

• Constructing green infrastructure is less carbon intensive than conventional infrastructure

• Planting 12 trees can offset a person's entire annual carbon dioxide emissions.

Economic impacts

• Increase property value

• Low energy consumption for indoor heating/cooling

• Terrace farming reduces expenses on vegetables buying. Organic consumption improves health which reduces expenses on medicine

• Construction, Operation and

9. Conclusion and Recommendation

G I approach should be an essential component of all new and redevelopment policies, with focus on retrofitting existing urban environment with green infrastructure as part of communities and stakeholders attempt to counter urban challenges. This concept is not widely recognized in many developing nations which is a matter of concern as GI mitigates to a vast range of challenges. The benefits attributed to GI therefore need to take into consideration how people, policy and place are influenced by the three main components of sustainable development: social, ecological and political equity.The multi functionality of GI in urban areas as contributing to creating healthy and comfortable places where people or visitors want to live, recreate and work is an established fact supported by various case studies. G I retrofitting with tactically designed and managed system of green spaces is imperative to the sustainability of any urban area such as Kathmandu valley. The concept requires great deliberation to plan, develop and manage the existing GI resources and possible retrofit the cities with same. For the purpose of retrofitting cities with GI, a proper planning, policy and promotion for GI development and retrofit to be followed. The stakeholders can be inspired case studies of G I from the rest of the world.

Thus, GI can be achieved in this city with minimal cost and creating incentives in policy. So, while selecting a retrofit policy option, the first step would be to understand the most significant barriers for implementation and overcoming them with setting of target with incentive program. Incentives should be in form of policies economic advantage such as subsidies and tax reductions in form of rebate for reducing the economic burden of infrastructure by incorporated GI programs. The active involvement of stakeholders must be at local, regional and national planning policy particularly, in developed countries. Sustainable communities are places that balance their economic assets, natural resources, and social priorities so that residents' diverse needs can be met now and, in the future. The reductions in tax revenue can be justified by the decreased demand on municipal services provided by green infrastructure. As segment of the smart growth for more sustainable living and climate change adaptation, the addition to GI, is recognized as a must for it has a number of multi-functional benefit to the community Moreover, planning and decision making for vibrant and environmentally sustainable communities requires a systems perspective that integrates green and grey infrastructure. Incorporation of Green infrastructure to the spatial structure shall transmit benefits from nature to people, augment nature's ability to transmit multiple precious ecosystem services, such as

• Improved quality of life and well-being by providing quality environment in which to live and work.

• Mitigate impact of climate change and other environmental disasters, for instance by alleviating floods, storing carbon or preventing soil erosion.

• Foster smarter, more integrated approach to development which ensures space utilization is efficient and coherent.

Thus, enhancing urbanization and development with green infrastructure for reaping benefits of globalization and striding towards future sustainability is the objective of the study.

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