Roof Top Farming a Solution to Food Security and Climate Change Adaptation for Cities

Gunjan Gupta and Pradeep Mehta

Abstract Two distinct phenomena shape our planet: more than half of the world's human population is urbanised (World Watch Institute 2007); and global warming induced climate change is a grave threat. Modern cities, in ecological terms, have become parasitic energy and resource 'sinks,' consuming 75% of the world's resources on only 2% of the global land area (TFPC 1999). In this way cities 'short-circuit' the natural ecological cycle, harming both the nutrient source and sink. As the rate of urbanisation increases over time, food production sites should be increasingly located near main consumption centres. Roof top farming is one such solution to meet growing demand of safe and healthy food, improving air quality, heat influx, reduced corridors for local flora and fauna. Urban agriculture is gaining relevance all over the world due to its ability to provide direct benefits (food) but also some indirect ecosystem services at a macro level (conservation of biodiversity). This paper presents a survey of roof top farming in South Delhi, India and their importance from ecosystem services, food security and climate change perspective. The paper shows the way forward to popularise roof top farming in cities through outreach programmes, capacity development and policy interventions.

Keywords Climate change · Food security · Urban agriculture · Ecosystem · Urban biodiversity

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1 Introduction

Two distinct phenomena shape our planet: more than half of the world's human population is urbanised (World Watch Institute 2007); and global warming induced climate change is a grave threat. The former's relation with environment has been the focus of academic discourse from an ecological footprint perspective and an enhanced understanding of global warming has increased linkages between the two phenomena (De Sherbinin et al. 2007). Increased contemporary focus on carbon footprints differs from earlier conceptions of ecological footprints. In attempts to lower their rating as carbon emitters, many cities in the world have tried to shift carbon emitting activities outside their municipal boundaries, thus reinforcing a long term tendency of the expulsion of environmental risks from the core to the periphery. Ecological footprints, on the other hand, suggest a different orientation in which cities, as dynamic spaces of production as well as consumption, have to bear responsibility for the consequences of the sum total of their activities (Franchetti 2013; Cartwright et al. 2012; Da Schio and Brekke 2013).

The growing city-based or dependent production and consumption of crucial resources and also the sheer numbers of poor people dwelling in urban centres in developing countries highlight how important it is for cities to prepare for climatic impacts and lower their anthropogenic contribution towards greenhouse gas emissions (Satterthwaite 2008, 2011; Bicknell et al. 2009). India's urban centres are already confronted by environmental concerns, such as increasing energy consumption, large scale pollution, a scaled up built environment at the cost of green spaces, unmanaged waste generation, unsustainable use of natural resources like water, pressure of increased population density (Mukhopadhyay and Revi 2009).

India has submitted the Second National Communication (NATCOM) to the UNFCCC in 2012. The first National Communication was submitted in 2004. As per the Second national Communication submitted by India to the UNFCCC, these climate change projections are likely to impact health, agriculture, water resources, natural ecosystems and biodiversity. India's strategy for addressing Climate Change is reflected in many of its social and economic development programmes. National Environment Policy, 2006 outlines essential elements of India's response to Climate Change. The National Action Plan on climate change (NAPCC) is coordinated by the Ministry of Environment and Forests. It is being implemented through the nodal Ministries in specific sectors/areas. Under NAPCC India has several other missions covering other sectors that can help mitigate the effects of climate change. These missions will be institutionalised by respective ministries ad will be organised through inter-sectoral groups which include in addition to related ministries, ministry of finance and planning commission, expert from industry, academia and civil societies.

In order to respond to the challenges of climate change effectively, the government has created advisory council on climate change. The council has a broad base of key stakeholder representative including the government, Industry and civil societies. This council also provides guidance on the matters of domestic agenda and review of the implementation of National Action Plan on Climate Change including Research and development Agenda. NAPCC will continue to evolve, based on new scientific and technical knowledge as they emerge in response to evolution of multilateral climate change regime including arrangements for international cooperation's (NAPCC, Government of India).

The agriculture sector in India is already threatened by existing factors such as land use changes, scarcity of water resources, increasing air pollution and loss of biodiversity. In a tropical country such as India, even minimal warming will lead to loss in crop yields (Parry et al. 2007). Further studies conducted by the Indian Agricultural Research Institute (IARI) indicate the possibility of loss of 4–5 million tons in wheat production with every rise of 1 °C temperature throughout the growing period even after considering carbon fertilisation. Losses for other crops are still uncertain but are expected to be smaller, especially for kharif crops (Aggarwal 2008). Research also suggests that erratic monsoons will have serious effects on rain-fed agriculture with projected decreases in the productivity of crops including rice, maize and sorghum (especially in the Western Ghats, Coastal region and North eastern regions), apples (in the Himalayan region) (Kumar et al. 2011). Studies indicate that increased droughts and floods are likely to increase production variability and lead to considerable effects on microbes, pathogens, and insects needed for the upkeep of healthy agricultural systems. The UNFCCC (2007) have indicated that increasing sea and river water temperatures are likely to affect fish breeding, migration, and harvests. Increasing glacier melt in Himalayas could affect availability of irrigation especially in the Indo-Gangetic plains, which, in turn, would have consequences on food production (Darshini, Rajiv et al.).

Rooftop agriculture is one way in which urban areas could attempt to be more balanced and sustainable in their resource consumption. It is possible to produce a variety of fruit, grain, and vegetable crops on rooftops, either in containers or as field crops (TFPC 1999).

Considering the above, a need to study rooftop gardens of Delhi was realised. The present work focuses on the theme of roof top kitchen garden as a measure of sustainable smart city and adaptation to climate change. A study was carried out for assessment and quantification of the potential of rooftop vegetable production in southern part of Delhi. Besides the contribution to food security of the city, the study discusses upon the potential benefits to urban biodiversity, creation of green corridors, and ecosystem services provided by the roof top kitchen garden.

2 Methodology

The study involves Library research which Involves identifying and locating sources that provide factual information or personal/expert opinion on a research question; necessary component of every other research method at some point. A standard outcome of research is a literature review.

Through literature reviews historical records were analysed mainly to back up the ideas and arguments, presented in the research. After doing the library research for the collection of secondary data, Field research was done to collect primary data. It involved personal interviews with key informants and surveys which are also known as PRA (Participatory Rural Appraisal) tools citizen science approach was used to collect data as well as create awareness among the respondents.

Type	Method	Technique
Library research	(1) Analysis of historical records (2) Analysis of documents	Content analysis, articles, journals, Magazines
Field research	(1) Personal interview (2) Survey	Semi structured interview Semi structured interview Questionnaire

2.1 Rapid Rural Appraisal (RRA)/Participatory Rural Appraisal (PRA) Tools: RRA/PRA Tools Were Used as Part of the Study

PRA is an approach (and family of methodologies) for shared learning between local people and outsiders to enable development practitioners, government officials, and local people to plan together appropriate interventions.

Participatory Rural Appraisal—a misnomer:

- Participatory—more or less
- Rural—but also urban uses
- Appraisal—but also used in identification, implementation, evaluation, and ESW

2.2 PRA: Key Principles

- Participation: local people serve partners in data collection and analysis
- Flexibility: not a standardized methodology, depends on purpose, resources, skills, time
- Teamwork: outsiders and insiders, men and women, mix of disciplines, optimal cost and time efficient, but ample opportunity for Ignorance: analysis and planning
- Systematic: for validity and reliability, partly stratified sampling, cross-checking

2.3 PRA: Key Techniques

- Interviews/Discussions: individual's households focus groups, community meetings
- Mapping: community maps personal maps institutional maps
- Ranking: problem ranking preference ranking wealth ranking
- Trend Analysis: historical diagramming seasonal calendars daily activity charts

2.4 Semi-structured Interviewing/Conversational Interviewing

The central technique on which any PRA is based is Semi-Structured Interviewing (SSI), or Conversational Interviewing as it is sometimes called. SSI does not involve a formal questionnaire, but instead makes use of a flexible interview guide to help ensure that the interviews stay focused on the relevant issues, while remaining conversational enough to allow participants to introduce and discuss issues that they deem relevant.

Citizen Science Approach: Inclusion of citizens in scientific research is called *citizen science*. Citizen Science promises to bring a fresh perspective to strengthen the environment conservation efforts. Citizen science has the potential to bring youth and science together at the field level and empower them with knowledge, understanding and conviction to build conservation movements at the local level. Data and other information generated through citizen science projects have been shown to be reliable and accurate. There is evidence that data from citizen science research projects are increasingly accepted in the academic literature (UNEP 2014).

This approach was utilized in this study by involving the RTG's owners in collection of the data i.e., production, biodiversity assessment, etc.

2.5 Limitations of the Study

There is a lack of literature on Roof Top Gardens nationally as well as internationally. During the study 4 key informants were identified. These key informants belonged to the organisations that help people set up Roof Top gardens in Delhi. They were hesitant to give information about their clients due to which the sample size remained small of 12.

2.6 The Study Area

To conduct the study South part of Delhi was selected. Delhi is located in northern India. Delhi has an area of 1483 km^2. Its maximum length is 51.90 km and greatest width this 48.48 km Delhi shares bordering with the States of Uttar Pradesh and Haryana. Delhi is situated on the right bank of the river Yamuna at the periphery of the Gangetic plains. The ridges of the Aravelli range extend right into Delhi, towards the western side of the city, and this has given an undulating character to some parts of Delhi.

Twelve roof top gardens were selected as part of the study and four other key stakeholders (organisations working on RTG's) were contacted to generate the desired data.

3 Result and Discussion

3.1 Role of RTG's in Biodiversity Conservation and Food Security

A survey was conducted covering twelve rooftop gardens in South, Delhi to document the diversity of pollinators like bees, honey bees, butterflies. The diversity of birds was also documented that have been observed on roof top farms. The results are summarised as under:

Identification of bees and butterflies were done through mobile applications developed by Eathwatch Institute. The results illustrated in show that twelve butterflies were spotted on RTG's. Small branded swift is the most common butterfly as all the twelve respondents confirmed its presence on their RTG. Common grass yellow butterfly has been spotted among eight RTG's. Stripped Tiger has been spotted on nine RTG's. Where as Small orange tip was observed on eight RTG's. Common Jezebel being the least common have been spotted on three RTG's. Other butterflies like lime butterfly, common Mormon, Daniad Egg fly, dark grass blue, painted lady have also been spotted. This clearly shows that RTG's are good habitat for butterflies (Fig. 1).

The results also show that vegetated roof attracts more birds than a barren roof because birds find shade and food on RTG's. Blue rock pigeon (*Columba livia*) and common Myna (*Acridotheres tristis*) are the most common. Whereas birds like blue sunbird (*Cyanomitra alinae*), green sunbird (*Nectariniidae*), white dove (*Zenaida asiatica*), Bulbul (*Pycnonotidae*), Yellow footed green pigeon (*Treron phoenicoptera*), yellow-green.

Vireo (*Vireo flavoviridis*) are also spotted. It is interesting to know that the endangered House sparrows have started showing up. Bird baths kept on the roof are also the reason why birds come and sit on the roof. Birds also find easy perch in roof tops which is missing in big farms. Some other birds observed on the roof are

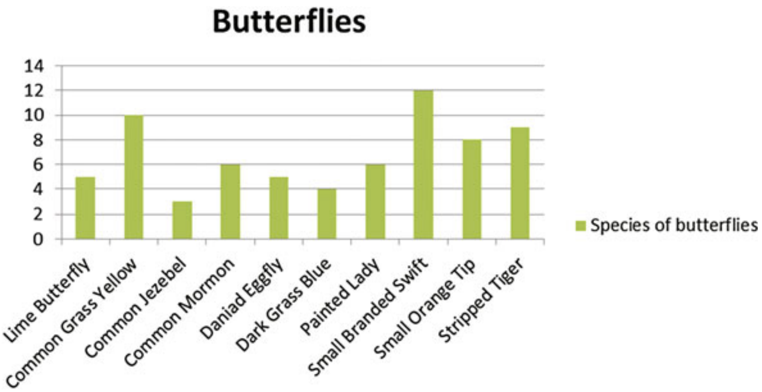

Fig. 1 Butterfly diversity in different RTG'S

brahminy-myna (*Sturnia pagoda rum*), Alexandrine Parakeet (*Psittacula eupatria*), Asian Koel (*Eudynamys scolopaceus*), Asian Pied Starling (*Gracupica contra*), Black drongo (*Dicrurus macrocercus*), Black kite (*Milvus migrans*), and Brown headed barbet (*Megalaima zeylanica*) (Fig. 2).

Two types of bees i.e., *Apis dorsata* and *Apis florea*, were observed on the roof tops. Addition to this, it was observed that bee boxes of *Apis mellifera* was kept for better production of food vegetables and fruits in one of the rooftop. All owners agreed on the presence of a variety of bugs. Lady bugs being the most common. Other bugs include the Adult brown sting bud, black orange bug, brown bug.

In order assess fruit and vegetable diversity in the RTGs, the participants were asked about the variety of fruits and vegetables they grow on their roofs. It was observed that Lady Finger, Beans, Tomatoes, Brinjal were the most common vegetables grown. Reason being that they give a good yield in terms of quantity and continuously for longer duration. It was observed that people experiment less by growing only common vegetables for example vegetables like broccoli, cabbage and sugarcane are not grown by many. Coriander and mint are also grown seasonally by most of the households.

3.2 Assessment of Ecosystem Services Provided by RTG's

As RTG's are mainly maintained for vegetable cultivation, but they provide provisioning ecosystem services. Out of total 12 RTG's owners 4 RTG owners briefed that RTG's regulates the temperature not only on roof top but also the room temperature below RTG's. The respondents also briefed that RTG's also regulates carbon by helping in carbon sequestration and providing fresh air. The respondents briefed that the air near RTG's is much fresh than the surrounding air in the locality or on ground. Diversity in RTG's and support to bird population helps in providing

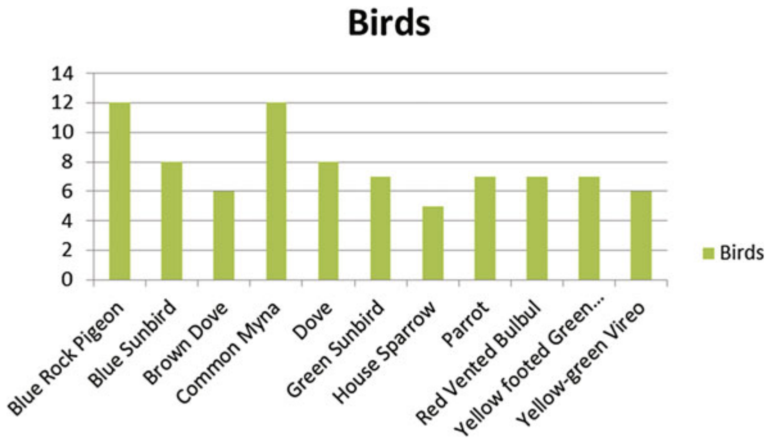

Fig. 2 Diversity of birds on RTG'S

another regulating service that is disease and pest control. Due to the diversity of plants in the RTG's, some plants acts as repellents to insects thus protecting the crop. At the same time, bird population helps in minimising pest control by feeding on larvae of insects and adult insects. The RTG's supports pollination service which was observed during monitoring of RTG's and also reported by the RTG's owners. Different pollinators like *A. dorsata, A. florea* and species of butterflies were observed in the RTG's monitored.

All the RTG's owners expressed that the RTG's provide aesthetic and cultural services. They briefed that the growing of vegetables and plants in the garden gives them a different happiness. Working in the garden keeps them busy and entertained. Most of the owner's also grow sacred plants like basil which provides spiritual benefits to the family members. RTG owners also expressed that they have observed reduction of noise after vegetating their roof.

The study shows that on an average size of roof with one to three plants of each vegetable can give 6 kg of vegetable. Generally, if two tomatoes plant can give 700 g of tomatoes then four to six plants can give us more than 1.5–2 kg. For a family of four people 2 kg of Tomatoes will be sufficient for a week. Similarly vegetables like brinjal, bitter gourd, capsicum, corn, zucchini can give ample quantity of yield. Lady finger must be grown only when there is space for ten to fifteen plants, even though lady finger grows rapidly, but the total amount of yield from a plant will not be suitable for consumption. At a time, one lady finger plant will on an average give four lady fingers. And hence it is advised to plant lady finger in larger number. Companion planting can save space and provide better quality of produce. For example Basil and tomatoes planted together will help make the tomatoes taste better. The basic rule of companion planting is to never grow plants that belong to the same family, together. Different plants occupy different space around them in a diverse way. Some rise vertically and then spread out laterally, some reach out for a little support, some grow deep into the ground, while others sprawl themselves across lazily over the ground. An area of 200 m^2 is sufficient for growing all the seasonal vegetables (Figs. 3, 4 and Table 1).

4 Discussion

This study shows that urban green spaces like RTG's support biodiversity and play a crucial role in biodiversity conservation. They not only support insect and bird diversity but also crop diversity. They are much safer for bees and butterflies as there is minimal spray of insecticide and pesticide when people grow vegetables for their own consumption. Climate change may be a further threat to pollination services (Memmott et al. 2007; Schweiger et al. 2010; Hegland et al. 2009). In order to adapt to climate change RTG's can be one of the solutions for conservation of pollinators.

RTG's also support the population of birds which get easy food, perch and water on RTG's. They not only supports bird population but also acts as pest control as the harmful insects and caterpillars are eaten by the birds. Because most extensive green roofs are inaccessible to the public, they can provide undisturbed habitat for microorganisms, insects, and birds. Similar results have been found in Similar studies have been reported in Germany, Switzerland, and England (Brenneisen 2006). This shows that RTG's have more diversity compared to commercial farms as they are mainly grown for sustenance while the commercial farms are mainly mono cropping or have least diversity. Therefore, RTG's play an important role in maintenance of crop diversity which the rural commercial farms don't. It was also revealed from the study that cultivation in RTG's is more organic and thus supports more biodiversity and is more pest resistant. The greater the biodiversity, the more immune plants are to pests and disease (Gomiero et al. 2011).

Research at Trent University has found on a typical day with a temperature of 18.4 °C a normal roof surface temperature was 32 °C while that of a green roof was 15 °C. Roof gardens keep roofs cool in summer and also help insulate in winter. They require little maintenance and reduce energy bills significantly (Fig. 5).

RTG's reduces the Intensity of solar flux. The Tokyo government estimates that if half their roofs were green it would save a million dollars every day in air conditioning energy use. The majority of the roofs in the world are dark-coloured and as a result have a low albedo and absorb excessive amounts of heat. Earlier there used to be infrastructure that used to maintain the temperature inside the house. But today our architecture is not sustainable. Green roofs can aid reducing urban heat islands effect and help in climate change adaptation. RTG's provide added insulation in the colder months and prevent excessive heat absorption in the summer. By regulating temperature variability; green roofs also reduce energy consumption. The aim is to keep buildings cool and curb carbon footprint.

Fig. 3 Baby corn plant (*Zea mays* L.)

More than 30% of all carbon dioxide emissions in many developed nations is heating or cooling buildings. A study was performed by the University of Cardiff which shows that plant surfaces by transpiration process, do not rise more than 4–5 °C above the ambient. This then translates into a cooling of the environment between 3.6 and 11.3 °C (6.5 and 20.3 °F), depending on the area on earth (gob-eshona). Similar results were reported by the respondents during this study. (Global Warming Videos by Futurist Dr Patrick Dixon).

Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves because of the nature of the substrate and vegetation. At the airport in Frankfurt, Germany, a 10-cm-deep green roof reduced noise levels by

Fig. 4 Marigold (Tagetes) and red spinach *Amaranthus cruentus* are potted in one *pot* to promote companion planting. Other *pots* has been planted with Mint (Mentha)

Table 1 Quantification of the produce

Vegetable	Plants	Area/pots	Produce (g)
Lady finger	10	5	250
Bitter gourd	3	1	225
Brinjal	2	1	450
Capsicum	4	2	225
Chilli	3	1	60
French beans	3	1	125
Garlic	1	1	40
Onion	3	1	1000
Potatoes	1	1	500
Corn	2	1	1500
Tomatoes	2	1	700
Apple gourd	2	1	250
Zucchini	1	1	600
Cucumber	1	1	150
Black eyed peas	1	1	50
Flat green beans	1	1	50
Cluster beans	1	1	50
Total		22	6225

Fig. 5 A garden bed on the roof

5 dB (Oberndorfer et al. 2007). Other research shows that 12 cm of green roof substrate alone can diminish noise by 40 dB (Peck and Monica 2001).

With the presence of more green area the carbon cycle can function more appropriately. One of the primary benefits is reduction of carbon footprint. More green space means less air pollution. A city with green roofs will have a clean and healthy environment. This will help the city in terms of sustainability and climate change adaptation. Green roofs are, in fact, the best technology to improve sustainability. Increasing urbanisation is leading to large-scale deforestation. One might think it better to check urbanisation than invest in setting up green roofs. But checking urbanisation is a massive step. One can focus on doing little bit to make cities healthier. Cities are already devoid of vegetation. Increasing vegetation in these urban spaces is a good idea which is not in conflict with stopping deforestation or other pro-environment activities in the larger sense. RTG's can regulate the micro as well as macro climate if encouraged on larger scale. "Cities are where change is happening the fastest and we must seize the opportunities we have been presented with to make that change significant and permanent." Miller (2007). Climate change poses serious threats to urban infrastructure, quality of life, and entire urban systems. Not only poor countries, but also rich ones will increasingly be affected by anomalous climate events and trends (World Bank 2010). In 2003, more than 70,000 people died in Europe from a severe heat wave (World Bank 2010). These kinds of extreme events will increase in coming years. The deaths were also considered as an indication as the victims were disproportionately elderly. This acute vulnerability of the elderly, children, and infirm is even more pronounced in the cities of developing countries. The effects of climate change are especially unfair as those most unable to adapt, and those who contributed least to the problem, will be harmed the most (Cities and Climate Change: An Urgent

Agenda, December 2010, vol 10, part III). The International Energy Agency (IEA) estimates that urban areas currently account for over 67% of energy-related global greenhouse gases, which is expected to rise to 74% by 2030. It is estimated that 89% of the increase in CO_2 from energy use will be from developing countries (IEA 2008).

Agricultural production, trade, income, food quality, clean water, sanitation, governance and political stability are all factors influencing one's food security status. Jacques Diouf, FAO Director-General [FAO: The State of Food Insecurity 2006] says that a major question for India concerns the agriculture sector's contribution to national food security. India is the world's second most populous country, and it has the largest number of farmers and rural population. About one-quarter of the world's total food insecure people live in India (India Policy Brief, OECD, and November 2014). At a fast pace and it will not be long before a greater part of developing Country's populations will be living in large cities. Therefore, urban food security and its related problems should also be placed high on the agenda in the years to come.

Urban agriculture contributes to food security, nutrition and livelihoods by providing food for self-consumption, giving us healthy food and allowing for saving on food expenditures. Rooftop agriculture is one way in which urban areas could attempt to be more balanced and sustainable in their resource consumption. It is possible to produce a variety of fruit, grain, and vegetable crops on rooftops, either in containers or as field crops (TFPC 1999).

Many cities worldwide continue to source a large percentage of their food from within city boundaries, though as the global food system is growing, that percentage is declining. Urban agriculture is strongest in developing countries, but even in the Netherlands, 33% of total agricultural production is within urban lands (Brown 2002). Also from an environmental perspective, it is important to point out that food grown in urban areas is more likely to be organic than that produced by the conventional industrial food system. This is due to a number of factors, including the fairly small scale of urban agriculture, the large labour pool, and cost reductions due to lowered transport costs. In addition, urban farms, since they are worked more intensely, can produce up to 15 times more per acre than their rural counterparts (Ableman 2000). Literatures indicate climate components like temperature, precipitation, CO2 concentration and extreme climate events have an effect on food security components. The most direct effect and well researched component of climate change on food security is food availability by reducing net crop production. It is also found that climate change has an impact on food accessibility and utilization but not well studied due to its complexity. Projections indicate that this problem will be more severe in the future than today unless climate change mitigation and adaptation strategies are done (J Earth Sci Clim Change).

5 Conclusion

Roof top farms help in achieving six important sustainable development goals (SDG's). They aid in provisioning of ecosystem services, enrich urban biodiversity and reduce food insecurity. Roof Top gardening is an alternative agricultural approach to farming system that is more responsive to natural cycles and biological interaction. The reason for focusing on urban agriculture is that that RTG's have potential for application in cities and must be seen as a permanent element of urban system because ecological imbalances created due to abuse and overuse of environmental services in the city has left a very thin line between natural and man-made disasters.

The present study shows that there is immense scope of RTG's in urban context as they enhances food security and availability of healthy food. The food produced in RTG's is much safer than the food we get in the market as there is less or no pesticide, insecticide and fertilisers are added. Today the pollinator species are facing extinction worldwide. Farmers are forced to keep bee boxes on their farms for increasing their production. This decline in pollinators is due to overuse of chemicals on agriculture fields. Therefor urban areas provide more conducive environment for pollinators. RTG's help in supporting and conservation of urban biodiversity by providing safer environment and habitat to insects, bees, butterflies and birds. Therefore, they have a key role in biodiversity conservation of urban species. The study also proves that RTG's also help in maintaining room temperature and in saving energy. They have a very important role in climate change mitigation and adaptation. The study showed that there are minimal families who are adopting RTG's which shows that there is huge potential for the promotion of RTG's in urban areas in general and Delhi in particular. The study also showed that there is lack of skilled labour which can develop RTG's, therefore, there is scope of green skilling as part of which employed youths can be trained in developing and maintaining RTG's. This will not only give employment to the youths but will also help in bringing roof tops under green cover.

There is only a small proportion of people who are practicing roof top gardening for growing fruits and vegetables, others only have decorative plants. This is because they are unaware of the fact that one can grow vegetables in containers on roofs. As they are introduced to the potential benefits of RTG's they feel motivated to develop their roofs into a vegetable garden. Rooftop owners have stated that they do feel the difference in quality of home grown food compared to the food available in the market. They have also seen improvement in the available biodiversity on the roof.

RTG's provide different ecosystem services like provisioning, regulating, supporting and aesthetic/cultural due to which they should be adopted by the urban population for their future sustainability. Green roofs come with many perks, such as less air pollution, cooler homes and easy access to green space. We have on our hands vast tracts of rooftop space which mostly lie unused. We must dedicate more serious thought to utilising this wasted space more productively. Buildings absorb a lot of heat, and growing vegetation on the roof can keep it cool. This, in turn, will reduce the use of air-conditioners and fans and can minimize energy uses. Thus green roofs are catching on in Indian cities like Delhi and Bengaluru. While many might adopt a green roof for beautification, it serves a larger purpose. Rooftop cultivation has immense scope for and their services should be made available throughout the country through the offices of the state agriculture department, Horticulture Mission and Vegetable and Fruit Procuring Council. Policies should be made to make RTG's mandatory in urban cities for food security, increase in green cover and biodiversity conservation. If this happens, urban rooftop farming will revolutionize the food deficit state. Transforming our roofs is a practical and comparatively easy way to mitigate climate change. It is also the most effective if not the only way to adapt to a warming climate. Due to their long-term viability and a host of other positive externalities, green roofs are a better option. By restoring vegetation to our cities, we not only reduce carbon and adapt to climate change but we can also reconnect with nature, increase food security and provide habitat for wildlife especially insects.

In cities not everyone has access to roof or spacious balcony, therefore, the limitation of the concept of Roof top gardens. There is a lack of research on roof top gardens in urban areas and hence the research faced certain shortcomings.

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