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Rooftop farming: A sustainable means to food security for Gangtok city in Sikkim, India

Bijaylakhmi Goswami [1*], Biju Pariyar [2]
[1] Research and Development, Agrithink Services LLP, Guwahati, Assam, India
[2] Department of Horticulture, Krishi Bhawan. Gangtok, Sikkim, India

* Corresponding Author: **Bijaylakhmi Goswami**

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Abstract
Sikkim, India's 22nd state, is facing agriculture-related challenges due to its mountainous terrain. Climate change land degradation and other soil and pest-related issues further complicate the scenario. With only 12.8% of its total area dedicated to agriculture, the state encounters difficulties in sustained food production, exacerbated by urban migration. Sikkim, a fully organic state since 2016, heavily relies on imports to meet its food needs. So, Sikkim needs to exploit its potential for rooftop farming, particularly in urban areas like Gangtok, as a practical and innovative solution to address Sikkim's agricultural challenges and enhance local food production. Rooftop farming emerges as a practical solution that can help mitigate challenges associated with limited arable land and climate uncertainties to a certain degree. The assessment underscores the role of rooftop farming in enhancing food security, promoting organic produce, and reducing dependence on external sources. Government support and community engagement are crucial elements for realizing the transformative impact of rooftop farming. The article envisions rooftop farming not only as a practical response to immediate challenges but also as a pathway to align with global sustainability goals. The proposed model cited in the article is aimed to serve as a guiding light towards self-sufficiency and resilience, steering Sikkim's agricultural landscape to a future that is both sustainable and secure.

Keywords: Rooftop Farming, Urban Agriculture, Model Terrace Garden, Sikkim, Rooftop vegetable farming, Organic Cultivation

Introduction
Sikkim, the twenty-second state of India is a mountainous State, with rough dimensions of about 65 km width and 110 km length. The state is located in the Eastern Himalayas between 27º04'46" to 28º07' 48" North latitudes and 88^0 00'58" to 88^{0}55' 25" on the southern slope of the eastern Himalayas (Subba, 2009) [36] engulfing a geographical area of 7096 sq km. Most parts of the State are rugged and mountainous with altitudes varying between 300 meters above msl to 8595 meters peaking at Mount Kangchenzonga, the third highest mountain peak in the world. The habitable areas of Sikkim cover up to 2100m, which covers about 23.9% of the total geographical area however human settlements and Agricultural activities are confined within the altitudes from 300 to 3000m but most of the cultivated area lies below 1800m elevation. Human settlements are mainly confined to areas lying below 1800m (Subba, 2009; Dhungel, 2021; Sharma *et.al* 2009) [36, 6, 32].
There is a tremendous diversity in the climate of Sikkim which should have otherwise provided immense scope for diversification in the food production systems unfortunately though, the highly undulated topography and other biotic and abiotic productivity-related issues like pestilence, climate change, land degradation, soil health etc. pose a limitation in optimum production. There are but very few opportunities left for further expanding the agricultural area. Moreover, much of the additional land available is not suitable for agriculture. Bringing that land into agricultural production would carry heavy environmental, social and economic costs (FAO, 2017).

Table 1: District-Wise Estimate of Agriculture Area and Land Use (All Social Groups)

Sl No	District	Total Holdings		Net Area Sown (Ha)	Area Under Current Fallows (Ha)	Net Area Cultivated (Ha)	Uncultivated Area (Ha)
		No.	Area (Ha)				
1	North	4895	11952.4	10279.54	849.626	11129.17	823.237
2	East	23486	25375.25	20010.2	1351.076	21361.28	4013.972
3	South	20120	26005.63	18315.98	1693.934	20009.92	5995.709
4	West	23031	27532.03	21675	1574.316	23249.31	4282.718
State Total		71532	90865.31	70280.73	5468.952	75749.68	15115.64

***Source*:** Annual Report 2020-21 Agriculture Department Govt. of Sikkim

Table 1 shows the land use pattern of the agricultural area the net cultivated area covers only about 10.67 per cent of the total area of 7,09,600 hac in the state. Whereas, agriculture used to be practised in 85,000 hac in 1980-81 to feed a population of 3.15 lakh (Subba, 2009) [36] it has to produce food enough for 6.78 lakhs in 2021 (Sikkim Population, 2021) from an area of 75749.68 Ha reflecting a shrinking land resource.

Out of the total population, around 74.85 per cent live in the villages of rural areas whereas the urban population comprises 25.15 per cent of the total population. The urban population has increased in the last 10 years as more and more people are relinquishing agriculture occupations and migrating to urban settlements in search of better opportunities. Nowadays, People do not want to live in villages due to unremunerative production, food insecurity and poverty. They prefer to work in the non-agricultural sector such as doctors, lawyers, researchers, teachers, and educationists (Ali, 2020) [2] government departments, pharmaceutical companies Malls etc. rather than toil in the unremunerative farm enterprise. Hence, the burden of food production is entirely upon the ageing rural dwellers in Sikkim. In the meantime, a commendable impact has been made by Production Incentive Schemes in 2021 by the State Government to motivate the farmers. However, only the rural or peri-urban areas are engaged in cultivating the F&V, whereas the urban population depends entirely upon the rural sector for their fresh food supplies. Consequently, a huge challenge is posed to feed its increasing population with a sub-optimal backup of fresh foods. Recently the government of Sikkim has taken a keen interest in rooftop gardening and hydroponics which is in the cradle stage and needs wide-scale adoption by urban dwellers.

Relevance and Prospect of Rooftop Farming in Sikkim:

Sikkim was declared an organic state in 2016. Since then, the state has been producing chemical-free fresh Agri-products be it grains, fruits, vegetables, milk, meat, fish and the likewise. But as put beautifully by a researcher for Sikkim's farmers, the unknown journey of "organic" has just begun (Pradhan, *et. al* 2015) [28]. The landlocked hilly state faces alarming low production and productivity. Kirchmann (2019) [16] reveals a 35% organic yield gap across crops compared to conventional methods. Organic farming demands 50% more arable land due to lower yields than conventional fertilizer-fed farming in the initial years. Pests, diseases, rainfall, and hailstorms further reduce farm output. Sikkim's acidic soils (Sikkim, 2007) limit vital plant nutrients and harbor phytopathogens. Barros *et al.* (2023) observed a higher abundance of plant-parasitic nematodes in highly acidic soils when compared to slightly acidic. Overall, soil acidification is a major problem in modern agricultural systems and is an important factor affecting the soil microbial community and soil health (Li *et.al* 2017, 2020). Ameliorating these soils is costly, impacting fruit and vegetable productivity. Limited land is a demotivating factor for farming, worsened by intra-family land divisions affecting crop productivity and production.

WHO recommends daily fruit and vegetable intake for health, as low consumption contributes to 1.0% of DALYs and 2.8% of global deaths (WHO, 2023). Fruits and vegetables provide essential vitamins, carbohydrates, salts, and proteins, preventing diseases. Chemical-treated produce harms health, while high-energy processed foods promote obesity compared to low-energy options like fruits and vegetables. WHO recommends 400 gms of fruit and vegetable consumption to keep oneself healthy which should be split to 80 gms/serving in a total of five servings (Motkuri, 2020). Krishnaswamy *et.al* (2011) [17] have recommended 300 gm of vegetables in 3 portions of 100 gms each and 100 grams of vegetables in one portion. But usually, it is seen that the diet of people is cereal-dominated with consumption of all other food groups being less than the RDI levels (MSSRF, 2017). The accessibility and affordability of certain food items, especially fruits and vegetables, can play a significant role in shaping dietary preferences. Economic constraints and limited availability of diverse food options may contribute to the dominance of cereals in people's diets.

Table 2: Annual Requirement of Grains, Fruits and Vegetables for Population of Sikkim 2020-21

Items	WHO Recommended (gm/person /day)	Annual requirement (kg /person/year	Population of Sikkim	Annual food required for the population in MT
Fruits and Vegetables	400	146	6,77,800	98,958.8
Grains	180	65.7		44531.46

***Sources*:** Derived from Dietary Recommendation of WHO

Sikkim will need 98.95 thousand MT of F&V to feed its population (Table 2). Fig. 1 show the Area and Production of Fruits and Vegetables in India, North Eastern states and Sikkim during 2020-21. It is observed that the productivity of F&V in Sikkim is far behind the average production of the nation and the northeastern states and that as compared to the average yields of fruits and vegetables in India (17.03 MT/Ha) and Northeastern states (10.83MT/Ha) the average yield of fruits and vegetables in Sikkim is only 3.78 MT/Ha. But at the same time Fig. reflects an optimistic scenario, showcasing Sikkim's F&V production at a noteworthy 144.20 thousand MT, exceeding the annual requirement of 98.95 thousand MT. However, skepticism arises as Sikkim relies heavily on imports, especially from Siliguri's regulated

market, which supplies approximately 50 tons of vegetables daily to Sikkim (Gupta, 2023) [13]. Some F&V Imports are also there from unorganized sellers in Dhupguri, Maynaguri however the data could not be authenticated. Furthermore, reports suggest Bhutan exports potatoes to Sikkim through certain traders (Roder *et. al* 2007) [30]. Despite its 100% organic status, Sikkim appears to lean considerably on imports to meet resident needs and sustain the tourism-driven local economy. While production figures seem positive, a strategic evaluation of the state's reliance on external sources is crucial for ensuring a robust and sustainable food production model.

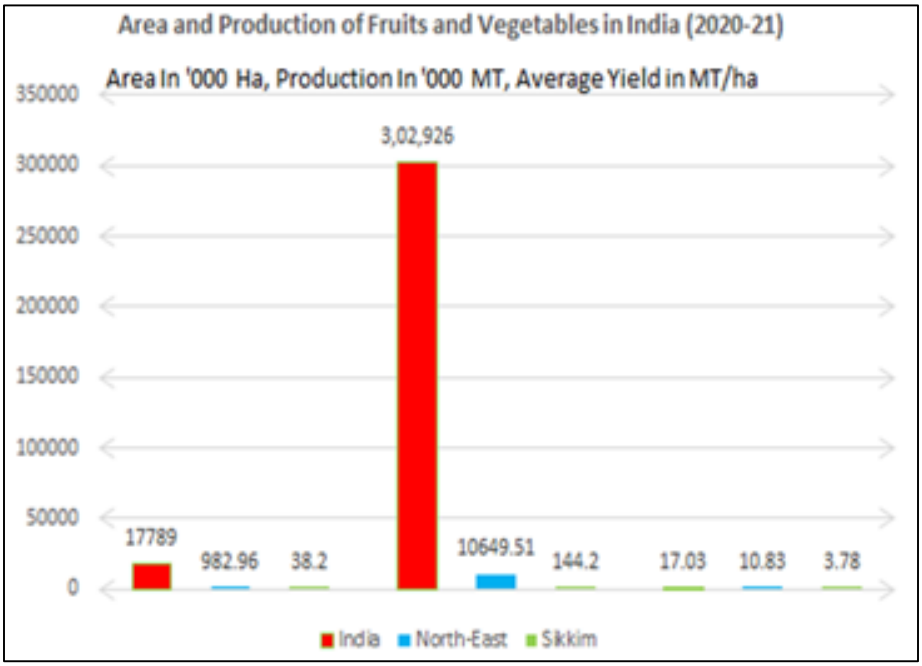

Fig 1: Source: 2020-21 Final Estimates of Area & Production of Horticulture Crops MoA & FW GoI

Food security and the increasing population

Looking from the ecological perspective, present-day urban centres consume 75% of the world's resources despite covering a mere 2% of the Earth's land area. Consequently, they function as both resource parasites and drains. Inefficient urban planning and rapid development often result in the depletion of natural resources and a reduction in green spaces, as indicated by Jha *et.al* in 2019 [15]. Additionally, there is an immediate need to bolster the capacity of smaller towns to prepare for impending challenges. This can be accomplished through the regulation of population migration and the implementation of appropriate urban planning, monitoring, and government intervention strategies, as suggested by Paul and Sharma in 2016 [27]. At this point of crisis, some respite was brought by the concept of Urban Farming.

Urban agriculture represents a pivotal response to the challenges posed by swift population expansion, urbanization, food insecurity, and climate change (Bhat and Paschapur, 2020) [5]. The concept of urban farming is emerging as a big trend towards self-food reliance worldwide. People are becoming more and more conscious about the quality of organic food which they grow in the limited spaces available to them. Urban gardens are places where food is grown locally in cities. (Slavica and Tomićević, 2017) [34]. Among other forms of urban farming, rooftop farming is gaining wider acceptance among city dwellers as they can grow fruits and vegetables easily on their rooftops for home consumption.

Rooftop Farming in India

In India, there's a growing interest in urban farming, prompting various state governments to launch programs encouraging this practice (Giri, 2018) [12]. In 2008, Pune initiated a city farming project, and Kerala, once food-dependent, boosted vegetable production through a development program (Nitnaware, 2023) [23]. Tamil Nadu introduced a "do-it-yourself" kit for urban dwellers, and Bihar has supported terrace gardening in smart cities since 2021 (Singh, 2019; Nitnaware, 2023) [34, 23]. Delhi organized a 'Smart Urban Farming Expo' in 2021, launching the 'urban farming' campaign. A 'Draft Citizen's Policy for Urban Agriculture in Delhi' was submitted in 2022 (Mint, 2023; Urban Farming, 2023). To promote green jobs in the capital, the Delhi cabinet on Wednesday approved the 'smart urban farming' initiative, through which it aims to popularize rooftop farming, both for self-consumption and as an entrepreneurship venture (Hindustan Times, 2022). Ahmedabad's metropolitan region boasts a market and home gardens.

Dr. Ramesh T. Doshi's popular Doshi method involves planting vegetables in polyethene bags or drums with biomass. He has perfected a method of growing fruits and vegetables for domestic consumption on his terrace which involves relatively low labour input, organic production methods and very high yields (Yasmeen, 2001). Mumbai Port Trust's central kitchen hosts an organic farm on its rooftop, feeding 2,000 employees daily (Mumbai Port Trust Report; Purohit and Singh, 2011, Dubbeling and Massonneau, 2012). Telangana offers a 50 per cent subsidy kit for urban farming in Hyderabad (Lopez, 2022) [20].

Similarly, developments in urban farming have interested the neighbouring countries. In 2020, Thapa and colleagues documented that the residents of Dhulikhel, a small region in Nepal, found rooftop farming to be a viable means of reducing their household expenditures. Residents there, were

utilizing urban waste such as plastic bags, polythene sheets, bottles, cans and jars for planting and household vegetable waste was generally used as compost. The findings of another study by Thapa *et.al* (2021) reported that out of the total roof area under the study of 325.8m^2 in Dhulikhel and 326.3m^2 in Kathmandu, the average area under rooftop gardening is 13.52% and 7.32% respectively. Interestingly, the study also revealed that the majority of the rooftop garden maintainers were females (52.8%) and that all of the respondents had a positive response regarding rooftop gardening. Bangladesh is also gearing up to practice rooftop farming. It is reported that the Agricultural Botany Department of Sher-E-Bangla Agricultural University imparts training in rooftop gardening in Bangladesh (Naher, 2022) [25]. Urban agriculture has made a significant impact in many cities of countries like Egypt, Australia Cuba Thailand China, the United States, the United Kingdom, Argentina, Boston, the US and Thailand (Bhat and Paschapur2020; Awasthi, 2013) [5].

Rooftop farming+an aspiration for Sikkim

The United Nations' call to the nations to achieve Sustainable Developmental Goals (SDG)is the roadmap for all nations to formulate resilient agriculture Systems and sustainable development (UN, 2023). The Green Cities initiative by the Food and Agriculture Organization (FAO) and SDG 2, SDG3 and SDG 11 are very much relevant to Sikkim. Many city residents are unaware of the importance of growing their food, and it is crucial to change their habit of relying entirely on rural food supplies. Urban administrations are facing increasing challenges in meeting the demands of city populations. (Sahasranaman, 2016) [31]. Therefore, the adoption of urban farming especially rooftop farming is necessary to utilize the minimal area on the terraces and balconies of residences and reduce the load upon the rural sector. In the meantime, Rooftop gardens are gaining relevance as they have the potential to meet the growing demand for food in cities and also enhance the ecosystem along with the conservation of biodiversity (Jha *et.al* 2019) [15]. Rooftop Gardening, backyard kitchen gardens, hydroponics, protected greenhouse cultivation and utilization of unused governmental land for short-term cultivation can increase the organic production of Sikkim. Although Rooftop farming may not possibly independently sustain a large population; which of course is not the purpose either, it can buffer the impacts of inflation, vulnerabilities of weather, roadblocks due to landslides or crises such as COVID-19 and provide a year-round supply of homegrown fresh organic food. Resources are always limited and in a developing and highly populous country like India, resources are even scarcer. Gangtok, the capital city of Sikkim is located in the East District and lies between 27º17’ 20" to 27º 21’ 47" N latitude and 88º 35’ 12" to 88º 39’ 40" E longitude. The topography of the study area is highly undulating with hills of 900m to 2400 meters above the mean sea level of the Gangtok area. Rani Khola and Rora Chu is important drainage pattern of the area. The present situation covers an area of approximately 19.25 sq. km. Mukhopadhyay *et.al* (2014) [23] have expressed concern that the state capital is experiencing rapid urbanization resulting in the loss of forest and cultivated areas. He has suggested taking appropriate measures to save Gangtok City and its surrounding environments from more catastrophic landslides in the future. Based on Gangtok Town Municipal Census, 2011, the current estimated population of Gangtok Municipal Corporation in 2023 is approximately 136,000. The overall density of the Gangtok urban region was 34 persons/ha in 2008 but the core areas, wards no 12, 13, and 5 reported a density of over 300 persons/hectare (Acharya *et.al* 2012) [1]. Out of the total population, 43,776 are engaged in work or business activity of which 86.47 % were engaged in Main Work while 13.53 % of total workers were engaged in Marginal Work. There are 35,718 households 5048 no. of residential buildings and 6758 commercial buildings under GMC (Gangtok Municipal Corporation) in Gangtok (GMC Town Planning Record 2023). Hence, to begin with, the concept of rooftop farming can be initiated intensively with wide coverage in Gangtok city. A conceptual idea about adopting rooftop farming in Gangtok City is visualized and presented here.

Potential for vegetable production from rooftops in Gangtok

The shortage of fresh organic vegetables in Sikkim has driven to conduct a study to assess the feasibility of adopting rooftop farming based on the available information given below in Table 3 which shows that the annual requirement of vegetables to feed the population of Gangtok is 14,892 metric tonnes if the individuals were to adhere to the vegetable intake recommended by the WHO and ICMR.

Table 3: Annual Requirement of Vegetables in Gangtok

Population	RDA (Vegetables (Kg)	Veg/ Person /Year (Kg)	Annual Req. MT	Truck Loads Per Year. (No).	Value @Rs 40/Kg	Res./Com Buildings
1,36,000	0.3	109.5	14,892	1489.2	74,46,00,000.00	11,806

Source of estimation: ICMR Dietary Guidelines (Krishnaswamy et.al, 2011) [17] and Gangtok Municipality Corporation

Table 3. also informs that there are 11,806 residential and commercial buildings in the GMC jurisdiction. The estimated production and savings of the involved household are worked out in the following tables. A Model Terrace Garden layout plan is drawn over a 100 sq. feet area which is designed to accommodate 24 grow bags of 12-inch diameter and an additional area of 27.5 sq. ft consisting of four beds measuring 6.876 sq. ft each (Fig 2). Three crop seasons can be utilised to cultivate homestead vegetables on rooftops viz kharif, rabi and Zaid crops. A random choice of crops and their production and values are given in Tables no. 4, 5, 6 and 7. During the kharif season, a yield of 75.25 kg of vegetables can be obtained from 24 grow bags, amounting to a value of Rs 4206 (Table 4). Similarly, 43.90 kg of vegetables worth Rs 2894.00 can be harvested from rabi vegetables (Table 5). An additional benefit of 75.25 kg of vegetables can be derived from Zaid crops saving Rs 4116.00 (table6). The estimates of production from the four beds stated above can supply production of 58.50 kg of vegetables saving Rs 3746.67 for the practicing household. (Table 7).

Table 4: Tentative Estimate of Kharif Crop Production From 36 Sq. Foot Containing 24 Grow Bags

Sl	Crop	No of Bags	Plants Per Bag	Total Plants	Yield Per Plant Gm	Estimated Yield Per Season Kg	Rate (Rs/Kg)	Total Savings
1	Amaranthus	2	5	10	400	4.0	50.00	200.00
2	Bean (Pole)	2	2	4	450	1.8	50.00	90.00
3	Bitter Gourd	2	2	4	1000	4.0	50.00	200.00
4	Bottle Gourd	1	1	1	2000	2.0	50.00	100.00
5	Cucumbers	1	1	1	6250	6.25	50.00	312.50
6	Egg Plant	2	2	4	7000	28.0	50.00	1400.00
7	Spinach	2	5	10	250	2.5	60.00	150.00
8	Green Pepper	2	2	4	500	2.0	80.00	160.00
9	Okra	2	2	4	500	2.0	50.00	100.00
10	Capsicum	2	2	4	300	1.2	120.00	144.00
11	Spiny Gourd	2	2	4	2000	8.0	60.00	480.00
12	Tomato (Slicing)	3	2	6	2000	12	60.00	720.00
13	Turmeric	1	1	1	1500	1.5	100.00	150.00
		24	29		Total	75.25		4206.50

Table 5: Tentative Estimate of Rabi Crop Production From 36 Sq. Foot Containing 24 Grow Bags

Sl	Crop	No of Bags	Plants per Bag	Total Plants	Yield per Plant (Gm)	Estimated Yield per Season (Kg)	Rate (Rs/Kg)	Total savings (Rs)
1	Beet	1	4	4	150	0.6	60.00	36.00
2	Cabbage	3	2	6	2000	12	60.00	720.00
3	Broccoli	3	2	6	2000	12	80.00	960.00
4	Cauliflower	2	8	16	150	2.4	80.00	192.00
5	Garden Pea	3	2	6	500	3	80.00	240.00
6	Pole Beans	2	2	4	500	2	60.00	120.00
7	Knol Khol	2	4	8	200	1.6	50.00	80.00
8	Lettuce	2	4	8	300	2.4	60.00	144.00
9	Mustard Green	2	3	6	300	1.8	60.00	108.00
10	Radish	2	6	12	300	3.6	40.00	144.00
11	Spinach	2	5	10	250	2.5	60.00	150.00
		24	42	86		43.9		2894.00

Table 6: Tentative Estimate of Zaid Crop Production From 36 Sq. Foot Containing 24 Grow Bags

Sl	Crop	No of Bags	Plants per Bag	Total Plants	Yield per Plant gm	Estimated Yield per Season Kg	Rate (Rs/Kg)	Total Savings
1	Amaranthus	2	5	10	400	4	50.00	200.000
2	Bean (Pole)	2	2	4	450	1.8	50.00	90.000
3	Bitter Gourd	2	2	4	1000	4	50.00	200.000
4	Bottle Gourd	1	1	1	2000	2	50.00	100.000
5	Cucumbers	1	1	1	6250	6.25	50.00	312.500
6	Egg Plant	2	2	4	7000	28	50.00	1400.000
7	Spinach	2	5	10	250	2.5	60.00	150.000
8	Green Pepper	2	2	4	500	2	80.00	160.000
9	Okra	2	2	4	500	2	50.00	100.000
10	Capsicum	2	2	4	300	1.2	120.00	144.000
11	Spiny Gourd	2	2	4	2000	8	60.00	480.000
12	Tomato (Slicing)	3	2	6	2000	12	60.00	720.000
13	Turmeric	1	1	1	1500	1.5	40.00	60.000
		24			Total	75.25		4116.5

Table 7: Estimate of Vegetable Production from Beds

Total No of Beds and Area 6.87 x 4=27.48 =2.55 Sq. mtr								
Sl	Season	Crop	Spacing Cm)	Area M2	Plants Per Bed	Yield Per Plant (Gm)	Estimated Yield Per Season Kg	Rate (Rs/Kg)	Total Savings
1	Rabi	Cabbage	30x45	1.2	8	1000	8.00	60	480.00
		Cauliflower	30x45	1.2	8	1000	8.00	60	480.00
2	Summer	Rayo Saag	30x45	2.55	19	450	8.50	60	510.00
3	Kharif	Spinach	10x15	2.55	170	200	34.00	60	2040.00
						Total	58.50		3510.00

Table 8: Annual Vegetable Production per 100 Sq ft

Production	Value (Rs)	Rate (Rs/kg)	RDA kg	Daily requirement of a family of 4	Annual requirement of family of 4 (kg)	per cent support by roof top
252.90	14727.00	58.23	0.3	0.9	328.5	76.99%

From Table no 8 it can be summarised that 252.90 kg of fresh vegetables can be harvested annually per 100 sq. ft. which can supply 76.99% of the annually recommended dietary allowance for vegetables. Further small spaces on the windows and balconies of the kitchen and bedrooms can be used for round the yearly supply of fresh aromatic condiments like coriander, spring onions, and mints etc (Table no 9).

Table 9: Year-Round Goodies

Crop	Yield/ Month	Yield / Year	Rate Rs/Kg	Amount Saved/month (Rs)	Amount Saved /Year (Rs)
Coriander leaf	0.5	6	150	75.00	900.00
Spring Onions	0.5	6	200	100.00	1200.00
Mint	0.5	6	200	100.00	1200.00
					3300.00

Table 10: Estimate of gross production and returns

Total Commercial /Residential Building (No)	Proposed Area/ Structure (A)	Total Area Sq.ft	Annual Production (Kg/100 Sq. Ft)	Gross Production MT	Gross Value @Rs 50/Kg (Rs)	Truck Loads
11806	100	11,80,600	252.9	2985.73	1492.87	298.57374

Table 10 shows that out of the potential 11,80,600 Sq. ft of residential and commercial buildings can produce 2985.73 MT fresh organic vegetables which is 20.05 per cent of the annual vegetable requirement of Gangtok. The gross value of this bulk of production will be 1492.87 lakh rupees. The conservative estimation of a 100 sq. feet minimum space requirement serves as a starting point. Much more rooftop space is available in many buildings, allowing for potential expansion and increased production. Appropriate structures can be erected to protect the plant on the rooftop from heavy downpour in rainfall prone areas. It's not just homes; spaces in offices, schools, hotels, and restaurants could be utilized for growing vegetables. There's also an opportunity to use community and government land for farming. If this is done on a large scale, the production of vegetables and even some fruits could be significantly supported by rooftop farming. Government involvement is deemed crucial. Assistance with funding and the sharing of knowledge about the optimal ways to grow crops could be provided. With adequate support, rooftop farming could be a sustainable and impactful solution for local food production.

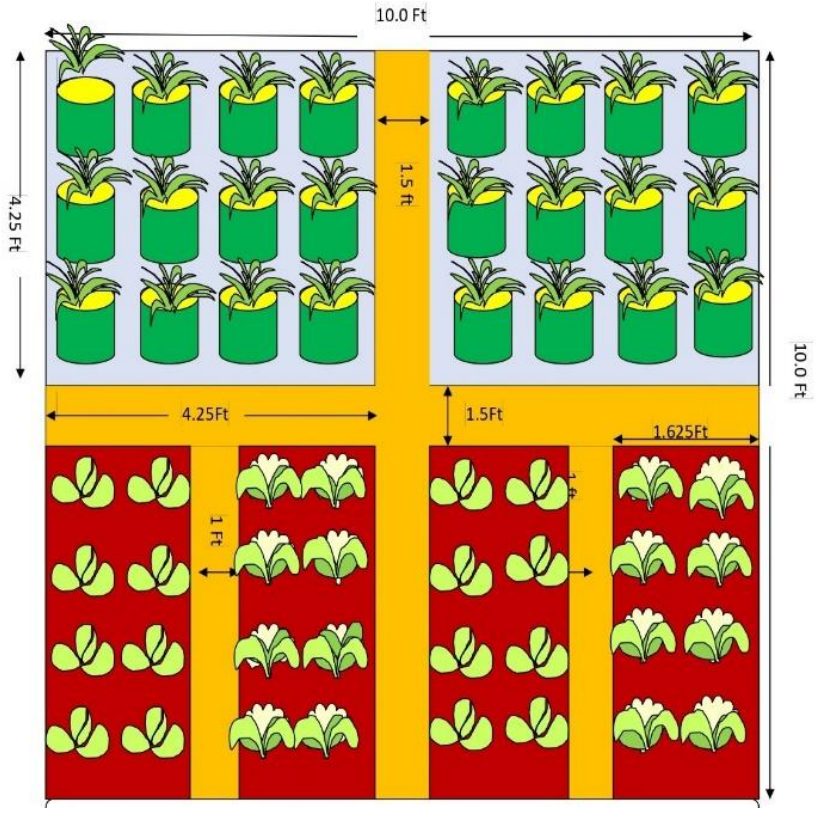

Fig 2: The layout of a model rooftop garden on a terrace of 100sq. ft.

Goals of the Rooftops for Organic Vegetable Production

1. Increase the production and consumption of fresh organic vegetables and fruits by more to the end that we become a stronger and healthier state.
2. Encourage the proper storage and preservation of the surplus from such gardens for high markets or preservation for use during lean times.
3. Enable families and institutions to save on the cost of vegetables and apply this saving to other necessary foods which must be purchased.
4. Maintain and improve the morale and spiritual well-being of the individual, family, and Nation.
5. The beautification of home gardening provides healthful physical exercise, recreation and release from stress and strain.
6. Making home and neighborhood a more beautiful place in which to live by maintaining and improving the appearance of a home and surrounding areas

Roadmap for popularizing rooftop farming

1. The government can publish messages via local media, newspapers social sites, and pamphlets, organize sensitizing meeting sessions in the various municipal wards involving the residents, further similar meetings and training sessions and workshops can be organized in schools, colleges, universities, departmental offices etc. where the message can be driven home to the mass.
2. Identification of beneficiaries through workshops, training & newspaper.
3. Visit beneficiary residences for inspection after the establishment of an urban farming garden.
4. Identification of resource persons for organizing training for Urban Farming.
5. Preparation of training material.
6. Grounding/hand-holding the programme.
7. Identified beneficiaries can be provided one day of training/orientation with an emphasis on hands-on experience.
8. If the terrace/backyard is found suitable for establishing a nutritional garden then incentive subsidies may be extended to the beneficiary.
9. If it is found suitable the installation work will be commenced by the beneficiary.

Conclusion

In conclusion, the challenges faced by Sikkim in sustaining agricultural productivity amidst a mountainous terrain and changing demographics stress the urgency of innovative solutions. Rooftop farming emerges as a promising avenue, particularly in urban centres like Gangtok. The feasibility assessment reveals its potential to address vegetable shortages, enhance food security, and contribute to sustainable development. Embracing rooftop farming in Sikkim with global sustainability goals will present a sensible response to urbanization challenges. Government support, community engagement, and widespread adoption can transform rooftops into vibrant spaces for organic cultivation, fostering a resilient and self-sufficient future for the state.

Reference

1. Acharya S, Bandyopadhyay ST, Praharaj S. Carbon Intensive Urbanization, Climate Variability and Urban Vulnerabilities in Hill Areas: A Case of Gangtok Urban Region, Sikkim. Journal of International Development and Cooperation. 2012; 18:93-112.
2. Ali E. Urbanisation in India: Causes, Growth, Trends, Patterns, Consequences & Remedial Measures, 2020. DOI: 10.13140/RG.2.2.19007.05284
3. Awasthi P. Urban Agriculture in India and Its Challenges. International Journal of Environmental Science: Development and Monitoring (IJESDM) ISSN No. 2231-1289, 2013, 4(2).
4. Baltic Journal of Health and Physical Activity. Volume 3, PP 34-43,
5. Bhat C, Paschapur A. Urban Agriculture: The Saviour of Rapid Urbanization Indian Farmer. 2020; 7(01):01-09.
6. Dhungel TP. History of Agricultural Development in Sikkim. International Journal of Research Publication. 2021; 2(10):960-970. Doi: https://doi.org/10.20546/ijcmas.2018.705.024
7. DOI:10.2487/V10131-011-0004-6
8. Dubbeling M, Massonneau E. Rooftop agriculture A climate change perspective. RUAF Foundation, Kastanjelaar Leusde n, the Netherlands, 2012.
9. FAO. The State of Food Security and Nutrition in the World 2022. Repurposing Food and Agricultural Policies to Make Healthy Diets More Affordable. Food and Agriculture Organization of The United Nations, 2022. https://www.fao.org/3/cc0639en/cc0639en.pdf
10. FAO. The future of food and agriculture – Trends and challenges. Rome, 2017.
11. GangtokTownPopulationCensus2011. https://www.census2011.co.in/data/town/801421-gangtok-sikkim.html
12. Giri P. E-paper report. Traders decry Sikkim's move to ban the sale of non-organic vegetables, and fruits. Hindustan Times, Siliguri, 2018.
13. Gupta R. Traders in Siliguri count losses, price hike in Sikkim. News Report. TNN Times of India, 2023. https://timesofindia.indiatimes.com/city/kolkata/traders-in-siliguri-count-losses-price-hike-in-sikkim/articleshow/104253926.cms?from=mdr
14. Hindustan Times. To promote kitchen gardens, Delhi govt takes up 'smart urban farming, 2022. https://www.hindustantimes.com/cities/delhi-news/to-promote-kitchen-gardens-delhi-govt-takes-up-smart-urban-farming-101656528122033.html
15. Jha RK, Bhattarai N, KC Suraj, Shrestha AK, Manahar K. Rooftop Farming: An Alternative to Conventional Farming for Urban Sustainability. Malaysian Journal of Sustainable Agriculture (MJSA), 2019. Doi:Http://Doi.Org/10.26480/Mjsa.01.2019.39.43
16. Kirchmann H. Why organic farming is not the way forward. Outlook on Agriculture. 2019; 48(1):22-27. doi:10.1177/0030727019831702https://doi.org/10.1177/0030727019831702
17. Krishnaswamy K, Bhaskaram P, Bhat RV, Glamorousness, Raghuram TC, Raghuramulu N, *et al*. Dietary Guidelines for Indians-A Manual. National Institute of Nutrition. Indian Council of Medical Research. Hyderabad – 500 007, India, 2011.
18. Li S, Liu Y, Wang J, Yang L, Zhang S, Xu C, Ding W. Soil Acidification Aggravates the Occurrence of Bacterial Wilt in South China. Front. Microbiol. 2017; 8:703. Doi: 10.3389/fmicb.2017.00703
19. Li B, Wang S, Zhang Y, Qiu D. Acid Soil Improvement Enhances Disease Tolerance in Citrus Infected by Candidatus Liberibacter asiaticus. Int J Mol Sci.

2020; 20;21(10):3614. doi: 10.3390/ijms21103614. PMID: 32443846; PMCID: PMC7279377
20. Lopez C. Telangana Govt Greenhouse Subsidy for Rooftop farming, 2020-2022.
21. Mint. 2023. https://www.livemint.com/news/india/delhi-govt-soon-to-distribute-10-000-diy-kits-to-promote-urban-farming-11650865308698.html
22. MSSRF. Farming System for Nutrition (Fsn). M S Swaminathan Research Foundation, 2017.
23. Mukhopadhyay A, Mondal A, Mukherjee S, Khatua D, Ghosh S, Mitra D, *et al*. Forest cover change prediction using hybrid methodology of geoinformatics and Markov chain model: A case study on sub-Himalayan town Gangtok, India. Journal of Earth System Science, 2014. 123. 10.1007/s12040-014-0476-2.
24. Mumbai Port Trust terrace garden-The activity of city farming was started initially to dispose of kitchen organic waste in an eco-friendly way. Appropedia, 2010.
25. Naher K. Short of Funds, A Promising Rooftop Farming Training Program Wilts the Business Standard, 2022. https://www.tbsnews.net/features/panorama/short-funds-promising-rooftop-farming-training-program-wilts-469070
26. Nitnaware H. Cultivated idea: Urban farming in India requires holistic policy support; here is why, 2023. https://www.downtoearth.org.in/news/agriculture/cultivated-idea-urban-farming-in-india-requires-holistic-policy-support-here-is-why-85450
27. Paul K, Sharma D. Post facto, trends, pattern of Urbanity in Sikkim Malaysia Journal of Society and Space. 2016; 12(13):12-27.
28. Pradhan U, Devy S, Purushothaman S. Organic paradox Sikkim will be the first Indian state to go wholly organic. But lack of markets can become counterproductive NEXT COVERAGE ❯ Organic Paradox, 2015.
29. Purohit Abhinav Singh B. Evaluation of global Physical Activity Questionnaire (GPAQ) among Healthy and Obese Health Professionals in Central India, 2011.
30. Roder W, Nidup K, Wangdi S. Marketing Bhutanese potato – Experiences, Challenges and Opportunities CIP/CFC/BPDP, Working Paper No, 2007, 4:46.
31. Sahasranaman M. Future of urban agriculture in India occasional, 2016, 10-1216. Institute for Resource Analysis and policy). http://irapindia.org/images/irap-Occasional-Paper/IRAP-Occasionalpaper-10.pdf
32. Sharma AK, Joshi V, Krishna A. Land Use Pattern mapping using Remote Sensing and GIS in Gangtok area, Sikkim Himalaya, India.), 2009.
33. Sikkim population India growing accessed from https://www.indiagrowing.com/Sikkim#:~:text=As%20per%20the%20Aadhar%20Statistics,from%20year%202011%20in%20Sikkim.
34. Singh A. Government to promote terrace gardening in Bihar: Prem Kumar /TNN, 2019. https://timesofindia.indiatimes.com/city/patna/govt-to-promote-terrace-gardening-in-bihar-minister/articleshow/69681018.cms
Slavica, C& Tomićević, J. 2017. Urban Community and Allotment Gardens: Research Trends and A Look Ahead. 63. 191-200. 10.17707/AgricultForest.63.4.20.
35. Soils of Sikkim State of environment -Sikkim 2007. http://www.sikkimforest.gov.in/soer/Soils%20of%20Sikkim.pdf
36. Subba JR. Indigenous knowledge of bio-resource management for livelihood of the people of Sikkim. Indian Journal of Traditional Knowledge. 2009; 8(1):56-64.
37. Thapa S, Anjal Nainabasti A, Acharya A, Neha Rai N, Bhandari R. Rooftop Gardening as A Need for Sustainable Urban Farming: A case of Kathmandu, Nepal Int. J. Appl. Sci. Biotechnol. 2020; 8(2):241-246. DOI: 10.3126/IJASBT.v8i2.29592.
38. Thapa S, Bhandari R, Nainabasti A. Survey on people's attitudes and constraints of rooftop gardening in Dhulikhel. Ecofeminism and Climate Change. 2020; 1 (2):89-96.
39. Thapa S, Nainabasti A, Bharati S. Assessment of the linkage of urban green roofs, nutritional supply, and diversity status in Nepal, Cogent Food & Agriculture. 2021; 7(1):1911908, DOI: 10.1080/23311932.2021.1911908
40. Trinjal. https://trinjal.com/telangana-subsidy-rooftop-farming/
41. UN 2023 https://sdgs.un.org/goals
42. Urban farming 2023. Urban farming | IASbaba
43. WHO 2002. Diet, Nutrition and the Prevention of Chronic Diseases, Report of the joint WHO/FAO expert consultation, WHO Technical Report Series No. 916 (TRS 916), World Health Organisation (WHO), Geneva. https://apps.who.int/iris/bitstream/handle/10665/42665/WHO_TRS_916.pdf;jsessionid=F433759A0A78F48F37 DB88EA5ABE66FE?sequence=1
44. WHO 2023. Fruit and vegetable intake. The Global Health Observatory. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3417
45. Yasmeen G. Urban Agriculture in India: A Survey of Expertise, Capacities and Recent Experience CFP Report 32. International Development Research Centre South Asia Regional Office New Delhi, India, 2001.