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Incorporating Rooftop Farming in Urban Residential Household of Buddhanagar Neighborhood, Kathmandu

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Abstract
Kathmandu is one of the fastest growing cities and population centralization due to rural-urban migration has negatively affected the lives of its residents. Economic shift from agricultural sector to service sector has increased food circuit between the producer and consumer in urban cities which has resulted to price hike on imported vegetables linking to affordability, freshness and health risks associated. In this context, one possible remedy is to cultivate consumable plants in household building rooftops by individuals. Urban rooftop agriculture is gaining relevance because of its potential for increasing resource efficiency, contributing to city food security and enhancing associated ecosystem and social services.

The research addresses the main features of rooftop agriculture, providing an interdisciplinary assessment of different approaches for development, bringing together existing experiences as well as suggestions for planning of future sustainable community. The results indicate the perception of people based on their needs and concerns in context to the dimensions of sustainability which helps organization and policy maker for development of sustainable community.

Keywords
Urbanization, Rooftop farming, Sustainability, Social cohesion, Barriers

1. Introduction

Nepal is one of the ten least urbanized countries in the world. However, it is also one of the top ten fastest urbanizing countries. In 2014, the level of urbanization was 18.2%, with an urban population of 5,130,000 [1]. The urban area expanded up to 412% in the last three decades and most of this expansion occurred with the conversions of 31% agricultural land which resulted to decrease of cultivable land by 30,334 hectares in fiscal year 2016/17 [2] . Urbanization in Nepal is dominated by a few large and medium cities with an excessive population concentration in the Kathmandu Valley. Growing demand of food for daily consumption is met by importing products from sub-urban domestic areas or the neighboring countries India or China [3]. The roads often get blocked due to natural disasters like floods and landslides that have become more frequent due to climatic changes resulting in steep price hike [4].

J.W Hansen claims that "Agricultural systems are considered to be sustainable if they sustain themselves in all three dimensions over a long period of time, that is, if they are economically viable, environmentally safe and socially fair" [5].

Urban farming addresses social, economic and environmental gaps thereby becoming multifunctional food systems. Beyond improving urban food security urban agriculture initiatives are linked to community empowerment, social inclusion and community building processes [6].

One of the greatest unused resources or capacities of cities is flat roofs, especially in denser and inner-city areas where other growing spaces may be lacking or polluted- and city space is generally quite expensive.

Rooftop agriculture is the production of fresh vegetables, herbs, fruits, edible flowers and possibly some small animals on rooftops for local consumption. Productive green roofs combine food production with ecological sustainability, such as reduced rainwater run-off, temperature benefits such as potential reduction of heating and cooling requirements (resulting in reduced emissions), biodiversity, improved aesthetic value and air quality [7].

In the past, Kathmandu Metropolitan Council (KMC) and a local non-governmental organization (NGO) called Environment and Public Health Organization-(ENPHO) had teamed to promote RTGs, coupled with harvesting rainwater and recycling organic household waste using climate-smart production technologies. To encourage RTGs, demonstration and trainings were organized. In 2014/2015 KMC initiated an RTG program that was expected to cover a total of 14 hectares of rooftops involving 139 households. Though these were initial steps that drew attention, RTGs have not developed in every household [8]. Promotion of rooftop farming is currently limited due to the scarcity of water, limited technical knowledge on appropriate farming techniques and limited supply of seeds and saplings.

2. Problem statement

People have been practicing form of roof top farming varying from traditional pot method to advanced hydroponic system, in residential buildings of Kathmandu valley with a concept of social tool and a productive system. However, detailed study on the dynamics and impacts on various parameters of sustainability is still to be determined.

The case locality is highly dense in terms of building and population and has limited green space. Growing number and size of vegetable shops indicate the increasing household demand and market dependency for vegetable goods.

3. Objectives

Main objective

Evaluate rooftop farmers experience based on opportunities and threats in environmental, economic, and social dimension

Specific objective

- Explore perception of residents in neighborhood on incorporating rooftop farming
- Assess impacts in environmental, economic and technical dimension

4. Methodology and methods of data collection

The research is based on constructivist paradigm and focuses on subjective reality. The research is exploratory, and approach is based on case study and literature review. The logical approach starts with observation of rooftop farming practice in household level. Based on the experience of rooftop farmers, opportunities and threats are evaluated. To understand the measures of viability and acceptability of a green project, a case of community rooftop farming project in Trondheim, Norway is studied.

In the case neighborhood, the research starts with mapping the locality to know the existing physical structure. Considering the accessibility and ownership of household rooftop, residential buildings are selected. Qualitative data is gathered through individual interviews using semi-structured and unstructured questions to know residents' level of understanding and agility to adapt rooftop farming. And, based on the interest and preference of size; impact assessment is done in environmental, economic and technical dimensions. The findings from literature is used as an instrument for dimensional analysis.

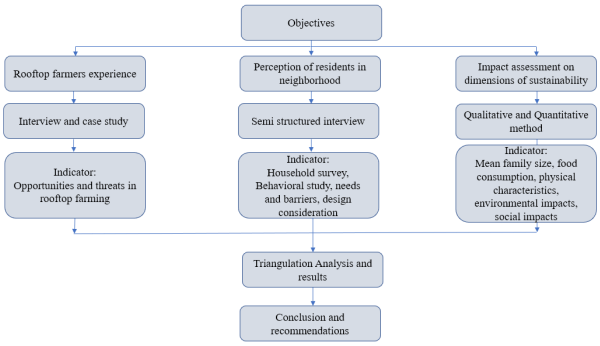

Figure 1: Research framework

5. Findings and discussion

5.1 Basic information on practitioners

Two practitioners using modular system and aeroponic system were selected and were interviewed to discover the existing situation as well as the opportunities and obstacles of rooftop farming.

Shesh Narayan Maharjan, is a trainer for rooftop farming and owns a nursery in Paknajol. The initial cost of establishing RTF was less than NRs 3000 (25USD). Use of local resources is evident; compost manure produced from household organic waste and reuse of old drums, pots and styrofoams. The basic plants grown are onions, garlic, coriander, brinjals, tomato, chillies, green vegetables, cauliflower etc. He

has now become a role model in his community as a rooftop gardener and his roof is nowadays crowded with the local enthusiasts who are inclined in rooftop gardening.

Kings college is an institution for undergraduate and graduate studies. Aeroponic system is installed by Aeroroots Pvt. Ltd to provide practical ground for agrobusiness students. With learning, the highly productive system provides fresh vegetables to canteen in the college. The high-tech system uses precise technique for optimal use of water and organic pesticide. Although the initial cost is NRs 75000 (625 USD), use of automatic system is less labor intense and has lower operational cost.

Option	Modular system	Aeroponic
Weight	Lighter system depending on the type and number of containers used. Distributed load	High variability. Concentrated load as size of tank increased cylindrically
Installation	Quick installation, containers may be moved	Installation generally requires higher investment and technical knowledge
Costs	Costs depend on the number and quality containers. Consider using recycled materials	Costs of growing containers and structural supports, as well as soluble fertilizers, generally high
Repair and maintenance	Containers can be moved easily	Maintenance requires a higher technical level
Alteration and addition	Alterations and additions can be made easily	Alterations are difficult and a new installation takes a long time
Plants variation	Root growth limited by the container capacity	Vegetables that grow in water

Figure 2: Comparison of modular and aeroponic system

5.2 Rooftop farming in Trondheim, Norway

Trondheim municipality is well developed in terms of infrastructure. The proportion of green space: urban parks and lawns to grey space: buildings and roads is 1:5 (source: google earth) in 0.16 sq km area of Dropsfabrikken neighborhood.

With limited ground space, urban agriculture is performed in rooftop space of apartment buildings. The roof-space in 'dropsfabrikken borettslag' and 'speilet borettslag' is accessible to the residents of more than 50 families in the building, and has revitalized the unused space.

The initiation of project is effort of organization in conduct of pilot testing and monitoring the impacts on social life of people. Bjørn Inge Melås, researcher in Ecologies of urban gardening, mentioned two major policies benefiting the project. Firstly, municipality based on the proposal and results of pilot testing provides fund for a year and budget is allotted annually based on progress. Secondly, for strengthening knowledge the center for urban farming in Trondheim conducts necessary training, counseling and has established seed library.

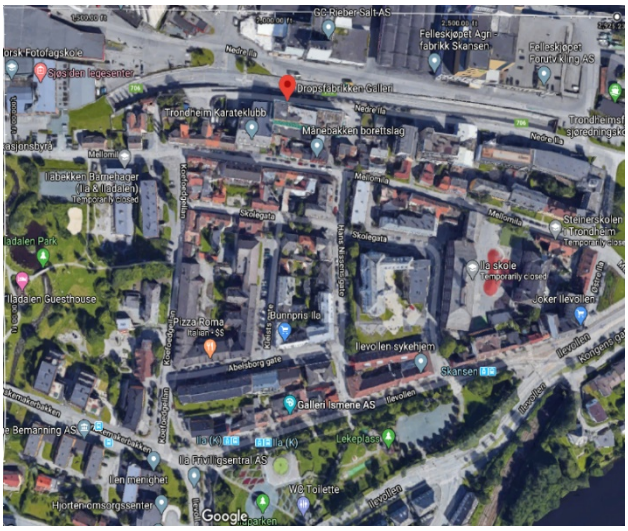

Figure 3: Dropsfabrikken neighborhood map

Sustainable practice and behavioral change in people is evident as organic waste is segregated from restafval bin in household level. Bokashi compost along with cow manure is used for plant nutrients. The rooftop space in these apartment buildings has become livelier. Physical activity linking up people, creating a green space with mutuality fostered the social value among the residents.

The major challenge for agriculture farming in Trondheim is climatic condition and load to the building which limits the choice of plants and vegetables grown. As the apartment building are tall, transportation of growing medium and installation of new pipelines for irrigation is hurdle at the start of the project.

5.3 Dimensional analysis on parameters of sustainability

Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. The concept of sustainability is composed of three pillars: economic, environmental, and social—also known informally as profits, planet, and people [9].

The basic parameters on each dimension is driven from literature, overview on opportunities and threats is stated in hierarchal order based on case study of Kathmandu.

5.3.1 Environmental dimension

The environmental dimension deals with the fragility of ecological and biophysical systems, and their different functions.

Opportunities

Recycling organic waste and reuse of materials: Household generated organic waste is used as resource by composting. For structural support to plant and growing medium plastic pots, styrofoam box, and wooden container are reused. This effort of reusing and recycling has decreased burden to landfill.

Using and recycling water resources: Use of harvested rainwater and grey water decrease diversion of water from sensitive ecosystems. And has led to a breakthrough in mentality of water scarcity as barrier for hindering urban farming.

Naturalization of household: Rooftop farming has improved greenery in living environment.

Reduction of plastic waste: Vegetable packaging plastic is normally used once and goes to landfill. Rooftop farmers claimed that use of basket to carry vegetables after harvesting, picking up parsley, and peeling at rooftop has significantly reduced plastic use in household.

Threats

Pests and rat attack: Pests feed on nutrients from plants for survival and rats feed on organic waste in compost bin. Proper Integrated pest management (IPM) practice; use of healthy seeds, weeding and maintenance, use of organic pesticide is necessary for eradication of pests and rat and for improved productivity.

Competition with solar energy: In order to increase productivity per area, containers are placed in stacks over scaffold support. It is necessary to design the space properly as it is also used for laundry drying, solar water heating system.

5.3.2 Social dimension

The ability to develop processes and structures which support the ability to maintain a healthy community. Social dimension deals with social investment, health, skills development, and caring communities.

Opportunities

Fresh and organic produce: Claims have been made in regard to imported farm goods being contaminated with excessive pesticides. Growing own vegetable ascertains about quality.

Physical and Mental Health: Green spaces in neighborhood are important assets that support recreation and leisure. Farming has encouraged physical activity as well as relaxation; promoting health, psychological and therapeutic benefits.

Education: Theoretical knowledge on nutrition and health science of children's and practical skills on farming of parents has developed mutuality learning ground.

Improved food security: Growing food by self in own space creates a sense of food security. Lockdown and undersupply of vegetable is common in Nepal, so to be self-sufficient in basic needs it seems necessary to utilize the resource.

Social cohesion: Farming is a common activity linking interest of old age people in community. It is seen that with growing age people get interest in farming. The culture of sharing of one's produce has strengthen social network in community.

Threat

Conflict with concept of urbanity: Urban sociology contrasts concept of urbanity with natural environment. Misconception of rooftop farming as false agriculture and linking it to as an activity of rural area.

5.3.3 Economic dimension

The economic dimension of sustainability concerns with the cost and benefits in regard to monetary value.

Opportunities

Skills enhancement: Farming is a comprehensive workfield requiring physical, emotional and mental labor. Food is primary need for existence of human kind, training and knowledge about farming is an asset.

Reduction of daily costs: Fluctuation as coordination between supply and demand of Nepali vegetable market is lacking. And, involvement of middlemen for retailing of goods from farmer to consumer chain has triggered price hike. As, vegetables have a short production cycle and can be harvested within 60 days of planting resulting to reduction in daily cost of purchasing goods.

Threat

Opportunity cost for time: Farming needs dedication

and hard work. The results measured in terms of productivity depends on various physical and natural conditions. Without technical learning and support, the chance of failure is high at beginning and people consider it as opportunity cost for time.

5.4 Case area: Buddhanagar, Kathmandu

Buddhanagar lies South-west of New Baneshower chowk. The locality is 800 metres from the chowk and is in between the Patan-Bagmati bridge and Baneshower. The total area of study is 0.017 sq km and comprises of 55 residential building and 25 commercial building (2 vegetable shops and 1 vegetable market).And, density of building is 4705 building per sq km.

Figure 4: Buddhanagar neighborhood mapping

5.4.1 Perception and conceptualization on RTF

The interviewed residents from case area can be divided into those who emphasize the social values of urban farming and those who promote urban farming as a food production opportunity. The choice is dependent in age variant, technology enhancement and size of the family.

Farming as an activity needs to have balance of human effort and technological intervention. Although major motive of rooftop farming is to produce food to become self-sufficient, but has to have social value. Current practitioners of kitchen gardening mentioned health benefits and social level development as key identity.

Whereas, few highlighted on higher productivity to limited space and advancement in level of technology and coping with progress as major factor for including hydroponic and aeroponic essential.

Considering the practicality and need of each household; 37 are interested, 6 are not interested and remaining are doubtful. 78% of interested considered modular gardening as their choice because it is similar to inherited farming technique with less sophistication. Rest stated the importance of progress in field of farming and practical learning ground for children as key points.

With regard to the dimensions of sustainability, major barriers which has limited residents from initiating RTF are highlighted

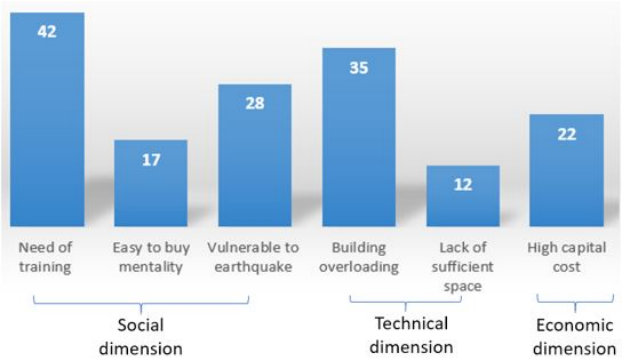

Figure 5: Highlighted barriers

Majority of them answered that they did not have technical knowledge about farming on the roof. 63.6% of people stated that they are afraid of using soil as the media on their roof because it leads to heavy load which may create the problem of seepages in the roof. And, easy to buy mentality is due to lack of leisure time for gardening and easy access to market.

5.4.2 Behavioral study: waste and water

People have mentality of segregating waste at household level initially. But, only 9 residential household have kitchen garden and compost organic waste. For the rest, lack of farm space and untimely pickup of waste from household by Kathmandu Metropolitan waste management division has driven people to mix up the organic and inorganic waste in order to avoid foul odor.

The limited supply from Kathmandu Upatyaka Khanepani has compelled people to build underground water extraction and filtration facilities in their houses as safer alternative water sources. Depletion of ground water during peak summer, resident have to buy water from private suppliers resulting to economic burden.

5.5 Impact assessment

5.5.1 Environmental dimension

Recycling organic waste and water resource

The total waste generated at Kathmandu metropolitan city is 0.3 kg per capita per day of which the organic waste is 67.77% of the total waste volume [10]. The organic waste generated by a family of four members over a time period of one months is 24kg. If the organic waste can be reutilized in household level, there will be a reduction of 1320kg of waste from the locality of 55 household per month going to landfill site.

The grey water after washing vegetables, rice and lentils is used in the farm but a separate tank connected to the basin is not established.

Incorporation of rain water harvesting system with filtration will be sufficient for rooftop farm. The rain water collected in terrace can be mobilized without requiring pumping system. Design of a proper roof covering of size 100 sq ft can harvest 14000 litres of rain-water annually (considering filtration and evaporation loss) [11]. Along with that, it provides shade during peak summer, covers during heavy rain and hailstones.

The residents interested in up taking roof top farming in their household stated the space allocation as

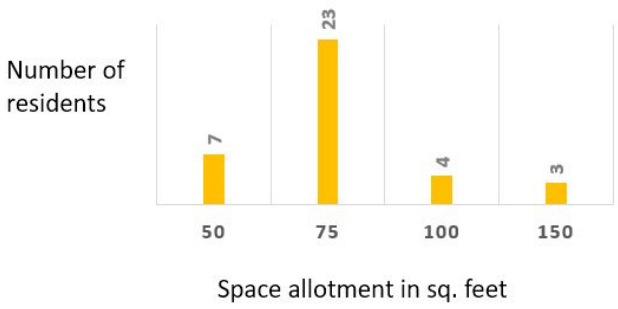

Figure 6: Space allocation

Total area in 37 interested households of neighborhood is 2925 sq feet. Median value of space is 75 sq. feet.

Pollution filtration

It is reported that 19.8 hectare of green roofs in Chicago has improved its air quality by removing 1700 kg of air pollutants (including O3, NO2, PM10, and SO2) in one year. With the selected area, it would remove 2.33 kg of air pollutants [12].

Place	Area (sq. km)	Amount of air pollutant removed	Proportion of air pollutant removal to total area
Chicago	606.1	1700	2.81
Buddhanagar	0.017	2.33	137

Figure 7: Air quality improvement

Urban heat dissipation

Total heat dissipated= (Total heat lost- total heat gain) * area of surface; for a surface of 75 sq. feet area

Types of roof surface	Total heat gained over a day (kJ/ sq. m)	Total heat lost over a day (kJ/ sq. m)	Total heat dissipated (kJ/day)
Hard surface	366.6	4.2	-2529.55
Bare soil	86.6	58	-199.6
Shrub	0	104.2	727.3

Figure 8: Heat island effect and dissipation

Plants absorb heat from sunlight which eventually reduces the heat flux of the building resulting into net positive heat dissipation [13].

5.5.2 Economic dimension

It is claimed that average of 280 square feet fulfills consumption requirement of 5 members family for a month [14]. Therefore, 75 sq. feet size farm will fulfill 33% of monthly vegetable needs for a family of four.

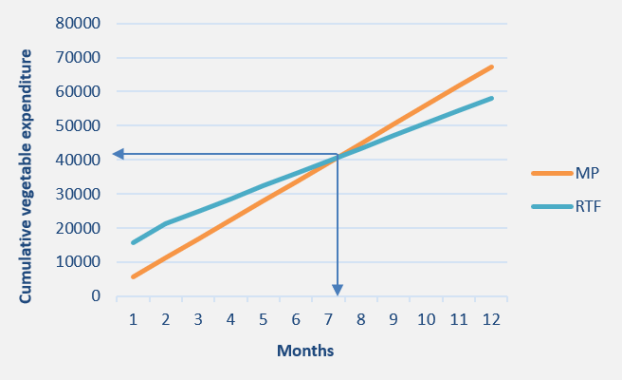

Figure 9: Break even point analysis

Initial capital for RTF as NRs. 10,000 and initial harvest period is 60 days. With in house production reducing cost of buying, the calculated 'Break even point' is 7 months and 8 days.

5.5.3 Technical dimension

Major concern for household owner for rooftop farming is the load pressure in the building and its impact. Although the building in the case area: Buddhanagar is structurally safe, psychological impact of earthquake prevails and people hesitate to put load in the roof space for the safety reason.

As per the guidelines by UN Habitat; use of soil 20%, compost 25%, leaf compost 20%, ash 15%, coconut husk fiber 20% is right composition of growing medium and technically suitable for building safety [14]. Average density of the growing medium for the composition is 710 (kg/ cu. m).

For a case of 75 sq feet roof top farm space and 20 cm depth, Mass of growing medium is 990 kg and calculated load bearing capacity is 1.39 kN/ sq. m.

As, live load capacity and dead load capacity of RCC roof is 2-3 kN/ sq. m and 5-7 kN/ sq m respectively for a residential building in Kathmandu [15].

Therefore, it is structurally safe to incorporate rooftop farm in case area.

6. Conclusion

In a typical urban household of Kathmandu, it is common to see a water tank, a solar-panel water heater, lines to dry laundry. The remaining unused space can be reinvented to reap benefit of fresh edible plants. Out of 55 residential building, 67% are interested in incorporating with an average size of 75 sq feet. It is evident that major barriers are related to social factors i.e. easy to buy mentality and lack of knowledge and can be mitigated with proper awareness and training from expert.

Conclusively, concept of being a part-time city farmer, RTF has several benefits and is listed in terms to each dimension of sustainability.

Benefit	Environment	Social	Economic
Bringing nature closer to city	Increase bio-diversity	Improve health, reduce stress and enhance psychological well-being	Create activity in the city
Reusing grey water, and harvested rainwater	Reducing surface water run off of roof to roads	Efficient use of natural resource	Reduce costs
Recycling organic waste	Save the environment by reducing needed land fills	Improve food quality and subsequently consumers health	Turn waste into asset
Reduced fertilizers, herbicides, and pesticides	Improve the environmental well-being	Improve food quality and subsequently consumers health	Decrease costs
Repurposing unoccupied rooftop space	Enhance the environment. Remove eye sores and stigma from neighborhoods.	Create opportunities for social interaction	Revive economy

Figure 10: Benefits to dimensions of sustainability

As the motive is to initiate household based rooftop farm in a community level, therefore hierarchy of beneficiaries are:

Individuals/participants, local bodies, organization and national level government.

Individuals: Domestication of vegetables with a closed chain of production and consumption in household leads to healthy life. Although it benefits the participants economically, the flow of monetary is not evident hence no conflict for economic gain.

Local bodies and policy maker: Creation of self sustaining community remains an example. Green and transparency feature is visible to neighboring community which notes as a progress in growing urbanization. The baseline of impacts from policy design helps measure the progress. Impacts on sustainability enhances the need as per present context.

Organization: Opportunity for skilled people from backgrounds like agriculture and engineering to work in community level and flourish practical skills dealing with the changing need.

7. Recommendation

7.1 Local government/ Policy makers

- Associate RTF users with organization for well suited downstream of information/ subsidies and upstream for monitoring and impact assessment
- Integrative policy-making processes involving various relevant stakeholders
- Establishment of urban integration standards (i.e., green space regulations in a locality)
- Development of model for measuring impacts should be exercised

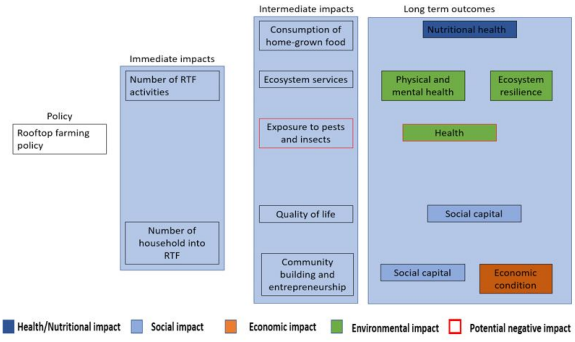

Figure 11: Impacts monitoring

7.2 Organization

The lack of proper channeling of information and inconvenience in procedure for receiving financial benefits has hindered the scaling of RTF. Therefore, organization can play the role of linking two entities. In order to make workshops effective, training using low-tech growing techniques (not requiring high level of education) should be conducted.

In regard to establishing RTF, inspection of building safety and water proofing of rooftop should be done by designer. For the farming side, retailing of quality seeds and seed sharing platform should be established at community level. And a digital system for communication with the organization and other users should be promoted.

7.3 Rooftop farming users

- Practice composting and rain water harvesting for self-sufficiency
- Promote rooftop as place for interaction to influence others

In order to bring the change from paper to practice, UNDP has come together to create an agile approach to development that stands for Mainstreaming, acceleration and policy support.

Mainstreaming: Community people are unaware about individual roles for contribution to SDGs. The results from the research helps stakeholders obtain an image based on the benefits creating awareness in community level. Unpredictable crisis/lockdown and growing inflation has made people realize its importance to create a sustainable community in terms of food resource. The basis for measurement is impacts assessed in research which gives a scale to understand the relation and measures importance with each dimension of sustainability.

Considering current status-quo, there is national level support for rooftop farming with provision of subsidy for equipment: compost bin and tax concession for the household with roof top farm and rainwater harvesting system. However, lack of flow of information from local governing body has hindered the resource utilization.

Organization consisting a team of agriculturist, engineers should take the role to channel, supervise and monitor along with local government body, stakeholders and participants for initiation and development of the project.

Acceleration: As preferred by the people interested, basic motive is to grow healthy food in limited space without impacting the building structure. Therefore, training and workshops should be conducted for facilitation and mitigation of barriers should be included in the module by organization to the participants. National level should implement course related development of resilient urban cities which eventually develops roof space as practical ground for exchange of knowledge among generation in family.

Policy support: Due to the cross-cutting and multi-dimensional nature of urban rooftop farming, policy development and action planning should involve various sectors and disciplines. Urban farmers, and the community organizations and NGOs supporting them, must be involved in the planning process. To enhance the productivity and economic viability of urban agriculture by improving access of urban farmers to training, technical advice, and financial support.

Capacity Enhancement: Focus on capacitating households (HHs) (already practicing RTF) and take measures that prevent/reduce health and environmental risks associated with urban agriculture, including sectoral coordination between health, agriculture and environmental departments, education and training.

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