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Development of Food Green Cities for Urban Sustainability



ABOUT THE BOOK

With rapidly growing urban populations, shrinking green spaces, and increasing climate vulnerabilities, the idea of **Food Green Cities** has emerged as a critical option for rethinking how cities manage land, food systems, waste, and ecosystems. This book presents an integrated exploration of these themes through research and case studies primarily from Nepal, with broader relevance to the Global South.

The chapters included in the book collectively highlight the growing importance of urban agriculture, urban forestry, green infrastructure and community-led environmental initiatives in shaping sustainable cities. From rooftop gardening practices in Kathmandu Valley to composting methods for household waste management, several contributions demonstrate practical, locally adapted solutions that improve food security, enhance ecological balance, and strengthen community resilience. These chapters not only present current sustainable practices but also identify opportunities and gaps for scaling up successful models across urban and peri-urban areas.

What sets this book apart is its interdisciplinary range of articles connecting ethnobotany, waste management, urban design, forestry and community development into a coherent narrative. By bridging scientific research with practical applications, the book provides a roadmap for designing cities that prioritize ecological health, food security, climate change and social well-being. It underscores that urban sustainability depends not only on technological advancements but also on inclusive planning, community engagement and evidence-based decision making. Food Green Cities also contribute to achieve UN Sustainable Development Goals on Zero Hunger (SDG-2) and Sustainable Cities (SDG-11).

This book containing 16 chapters will be a valuable reference material for urban planners, policymakers, researchers, sustainability practitioners, environmental consultants, development agencies, and academicians working in the fields of urban development, urban food systems and climate-resilient cities. The book holds particular significance for the Global South, where urban challenges are complex yet opportunities for sustainable transformations are immense.



Centre for Science and Technology of the Non-Aligned and
Other Developing Countries (NAM S&T Centre)

**Development of
Food Green Cities
for Urban Sustainability**

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EDITORS

**Ambika P. Adhikari
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Sunil Babu Shrestha**



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SWARNIM WAGLÉ, PHD

Member of Federal Parliament, Nepal

डा. स्वर्णिम वाग्ले

सदस्य, संघीय संसद, नेपाल

Foreword

It is my pleasure to write a few words of appreciation for the book “Development of Food Green Cities for Urban Sustainability”. With rapid urban expansion over the past two decades, the Nepali and South Asian cities have faced challenges related to pollution, open space, greenery, and food supply. This publication addresses these important issues in the chapters written by experts.

The book chapters analyze urban agriculture, forestry, solid waste management, roof-top gardens, public open spaces, and micro-economic activities for city residents. The authors also propose various theories and recommendations to improve urban activities in these areas. I find this book to be a useful reference for urban planners, policymakers, community leaders, and national leaders who wish to understand these topics in depth and influence policies to improve the quality of life.

As an economist, who is also an entrant into national politics in Nepal, I appreciate the many issues and challenges our urban population faces. Cities lack adequate infrastructure, are acutely short on public open spaces and parks, have limited greenery, and modest community activities. Further, the recent COVID pandemic showed that urban food supply could be disrupted any time, robbing the residents of the availability of affordable, healthy, and fresh food supply.

Promotion of urban agriculture can begin to make a dent on these challenges. Also, Nepali cities found out how the acute shortage of urban open spaces creates an unsafe and unhealthy situation for urban residents when Nepal experienced a major earthquake in 2015. The impacts of ongoing global warming are also creating serious problems in urban life such as extreme heat, flooding, water shortage, and increase in vector borne diseases. Programs to promote and expand urban forestry,

agriculture, and parks and open spaces will help mitigate some impacts of climate change as the authors show.

I laud the editors and authors of this book for researching on, and publishing, emerging topics of policy salience tied with the collective aspirations of the people in Nepal, South Asia, and other developing countries.

Swarnim Wagle, *PhD*

Member of Federal Parliament,
Nepal

15th August, 2025

Preface

Cities in modern times have become the center stage of humanity's progress, prosperity, and resilience, as World Bank reports more than half of the world's population (57.7%) residing in the urban areas in 2024. At the same time, urgent challenges of explosion of population growth, climate change, environmental degradation, diminishing areas of arable land resulting food insecurity are becoming complex global issues along with the heightening promise of innovation and opportunity in multi-sectoral development around the world. As urbanization accelerates particularly in low- and middle-income countries, the question before us is whether cities can feed their ever-growing population, with sufficient supply chains of food, either grown locally in sustainable manner or through imports with a sustainable balance of trade.

This book, *Development of Food Green Cities for Urban Sustainability*, was conceived as a partial response to that critical question from the context of supplemental food production in urban and peri-urban areas that are not typically allocated for agriculture. It builds on the momentum of the International Workshop on Food Green Cities held in April 2022, jointly organized by the Nepal Academy of Science and Technology (NAST) and the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre). The Workshop emphasized that sustainable urban futures depend on knowledge exchange, inclusive planning, and the integration of ecological wisdom into everyday practices. This volume carries forward those recommendations, translating them into a set of structured insights and practical strategies.

The chapters that follow are authored by expert scholars and practitioners who bring diverse perspectives of knowledge from Nepal, Asia, North America, and beyond. They collectively explore how the urban landscape often seen as a site of consumption and waste can be reimagined as a hub of food security, ecological resilience, and community well-being. Topics range from urban forestry, rooftop agriculture, composting, and waste utilization, to the preservation of open spaces, rainwater harvesting, and innovative green infrastructure. Each contribution demonstrates that Food Green Cities are not a utopian vision but a replicable, actionable pathway towards climate-smart and socially inclusive urban development.

What emerges from this interdisciplinary effort is a clear message: the health of cities and the health of people are inseparable. Urban forestry cools overheated neighborhoods and purifies the air; composting reduces landfill burdens while nourishing rooftop gardens; public open spaces foster biodiversity and strengthen mental well-being; and rainwater harvesting mitigates both droughts and floods. Together, these strategies create feedback loops that enable cities to be more self-reliant, equitable, and resilient in the face of uncertainty.

This book is particularly timely for cities of the Global South, where rapid urbanization often collides with resource scarcity. Yet, the lessons here are equally relevant to the Global North, where climate stresses, rising inequalities, and food supply vulnerabilities are intensifying. By drawing from both advanced practices and grassroots innovations, the volume bridges global divides and underscores the universality of green urban strategies.

We hope that the insights offered here will inspire policymakers, urban planners, academics, and community leaders to rethink the future of cities not just as centers of commerce and concrete, but as regenerative spaces that feed people, sustain ecosystems, and nurture human potential. The challenges we face are daunting, but the solutions are within reach. If pursued with foresight, collaboration, and determination, the development of Food Green Cities can become one of the most hopeful transformations of our time for complementing the food supply chains for feeding urban population, while they become self-serving for alleviating aforementioned challenges of population growth, climate change, environmental degradation and diminishing areas of arable land.

We earnestly hope that this volume will be a reference book for academic researchers, faculty and students alike, policymakers, development practitioners, and even the leaders in corporate sectors who would be engaged in various aspects of development of green cities, especially in the Global South.

As the book comprises chapters contributed by experts from diverse fields, invited without a rigid predefined structure for the volume, within relevant thematic areas, and largely shaped by a topic-focused Workshop held in Kathmandu, it is not intended to be a comprehensive treatise on the subject. Rather, it seeks to address key issues relevant to the development of “Food Green Cities”. Any gaps in coverage should, therefore, be regarded as inherent limitations of the book’s scope and approach. In addition, the geographic distribution of contributions may reflect stronger representation from South Asia, particularly Nepal, due to existing academic networks, which is acknowledged as a limitation of the volume.

Ambika P. Adhikari
Keshav Bhattarai
Drona Prakash Rasali
Sunil Babu Shrestha

Introduction

The development of Food Green Cities represents a vital strategy for advancing urban sustainability. By integrating urban agriculture, green infrastructure and sustainable food systems into urban planning, these initiatives promote local food security, reduce carbon footprints and enhance urban resilience. Food Green Cities not only reconnect people with nature but also transform urban spaces into productive, livable and climate-smart environment.

The concept of Food Green Cities emphasizes the integration of food production within urban environment to create self-sustaining and resilient communities. It focuses on transforming rooftops, vacant plots and community spaces into productive green zones that contribute to local food systems. By promoting urban farming, vertical gardens and green infrastructure, Food Green Cities help reduce food miles (how far the food has travelled before reaching the consumer), manage waste efficiently and improve urban air quality. These initiatives also enhance biodiversity and mitigate the impacts of climate change through increased vegetation cover.

Ultimately, Food Green Cities foster social inclusion and community engagement while strengthening urban sustainability. They redefine cities as spaces that not only consume but also produce - nurturing both people and the planet. Promoting Food Green Cities also help in general improvement in health of city dwellers.

Considering the importance of the subject, the *Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre)*, New Delhi, India [an Inter-governmental Organization] has published this book titled "*Development of Food Green Cities for Urban Sustainability*". The edited volume comprises 16 comprehensive chapters, contributed by researchers, academicians and practitioners from various developing countries. Collectively, these chapters provide a multidimensional perspective on the evolving concept of *Food Green Cities*, addressing themes such as *urban agriculture, rooftop gardening, waste management, composting, climate change adaptation, sustainable food systems, urban forestry, digital innovations and ethno-botanical applications* for better urban health and resilience. The volume begins with an introductory chapter that offers an overview and a brief summary of all chapters included in the book. Additionally, a Prologue has been written by the Editors, providing context and highlighting the significance of the theme in advancing urban sustainability and food security and Nepal's efforts towards creating Food Green Cities.

This book aims to advance understanding and practice in developing sustainable, self-reliant and climate-resilient urban ecosystems. It is a valuable reference for policymakers, urban planners, researchers and practitioners working towards achieving the goals of urban sustainability and food security in the developing world.

We express our sincere gratitude to our editorial team: Dr. Sunil Babu Shrestha, Academician, Nepal Academy of Science and Technology (NAST), Nepal; Dr. Ambika P. Adhikari, Distinguished Adjunct Fellow, Institute for Integrated Development Studies (IIDS), Nepal; Dr. Keshav Bhattarai, Professor, University of Central Missouri, USA and Dr. Drona P. Rasali, Adjunct Professor, University of British Columbia, Canada, for sparing their valuable time for technical editing of the papers published in this book.

I also express my deep gratitude to Dr. Swarnim Wagle, Member of Federal Parliament, Nepal, for graciously contributing the “Foreword” to this publication.

I will take this moment to express my sincere thanks to Mr. Madhusudan Bandyopadhyay, Senior Adviser, NAM S&T Centre, for his kind advice and guidance in various stages of planning and execution of this book project. Further, I am also thankful to Ms. Jasmeet Kaur Baweja, Senior Programme Officer, NAM S&T Centre for her significant contributions in coordinating this book project.

I also acknowledge the support received from the entire team of the NAM S&T Centre, particularly Mr. Pankaj Buttan, Data Processing Manager; Mr. Rahul Kumra, Assistant Administrative Officer; Mr. Sunil Kumar, Accounts Manager and Mr. Jayakumar, Public Relations Manager for their support in bringing out this publication.

I am also thankful to Mr. Jagdish Singh, Editorial Assistant, Allied Publishers Pvt. Ltd. for his significant efforts in bringing out this valuable publication.

Amitava Bandopadhyay, Ph.D.
Director General
NAM S&T Centre, New Delhi

Prologue

Background for the Publication of the Book

Following the COVID-19 pandemic, food security and self-reliance for urban residents have become increasingly important considerations for planners and policymakers. Urban farming has emerged as a strategic policy instrument for local governments worldwide, to enhance food security while promoting environmental quality and public health through effective phytosanitation practices. To support stakeholders, particularly in Non-Aligned Movement member countries, a variety of policies and practices are presented in this book.

The impetus for this publication originated from a Virtual Workshop held in April 2022, jointly organized by the Nepal Academy of Science and Technology (NAST) and the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre). The International Workshop, titled “Development of Food Green Cities for Urban Sustainability,” served as a platform for generating ideas and fostering discussions that directly inspired the creation of book.

The Workshop aimed to explore the concept of the “Food Green City” and covered a broad range of topics, including urban farming, energy-efficient technologies, food security, socio-economic development, traditional and modern technologies, entrepreneurship, and employment generation. Participants engaged in discussions on themes such as urban agriculture, solid waste management, global climate change, and urban planning strategies, framed by the principle that “small farmers can cool the planet,” as articulated at the landmark 1992 Rio de Janeiro Earth Summit. Conference participants also addressed the pressing challenges of food self-sufficiency that have intensified in the aftermath of the Covid-19 pandemic. Experts from nine countries presented their research and findings, contributing to a rich exchange of knowledge, which eventually crystalized as the topics for this book.

Food Green City Principles

The concept of the “Food Green City” was developed in 2004 as part of a doctoral research dissertation of Shrestha, S.B. at Osaka Sangyo University, Japan. It refers to a planned approach for achieving sustainable urban development that integrates agriculture into urban planning, maintains edible and supportive landscapes, ensures food security and self-reliance, and generates supplemental income for the urban residents.

According to Shrestha, S.B. (2011), the following principles summarize the objectives of the “Food Green City”:

- Abundant food green spaces
- Mixed land use (adjacent residential and commercial uses)
- Optimal utilization of spatial resources
- Attain sustainable neighborhood through Public-Private Partnership
- Walkable environments and promote public transportation
- Adoption of energy-efficient and environmentally friendly technologies
- Community participation and local resource utilization
- Minimization of waste production and use of organic waste as compost
- Promotion of food security and self-sufficiency for restructuring the cities

Nepal’s Efforts Towards Creating Food Green Cities

Nepal has progressively embraced the Food Green City concept through various policies, strategies, and institutional initiatives. Some significant documents, strategies, and initiatives are listed below.

- **National Urban Development Strategy (NUDS), 2017** found that urban agriculture was largely excluded from land-use planning and recommended integrating farming into urban management to promote the production of vegetables, fruits, and cereals to enhance food security.
- **Fourteenth National Plan, 2016–2017 (2073 B.S.)** called for the promotion of Food Green Cities with an emphasis on conserving agricultural land, ensuring urban greenery, and strengthening food security. It proposed developing two Food Green Cities by the end of the plan period.
- **Government Policy and Budget, 2021/22** included specific provisions for developing Food Green Cities, such as expanding urban tree planting, promoting kitchen gardening, balcony farming, and planter cultivation, and encouraging fruit tree planting by private, cooperative, and community organizations on public land, rights-of-way, and riverbanks.
- As a part of **NAST Initiatives**, The Nepal Academy of Science and Technology (NAST) has entered into Memoranda of Understanding (MoUs) with 15 municipalities to advance the Food Green City program. These partnerships focus on knowledge and technology exchange for the production, processing, storage, and marketing of nutritious and medicinal plants. They also emphasize educating students and residents on modern soilless systems such as hydroponics and aquaponics.
- **Nepal’s National Report to UN Habitat III, 2016 (MoUD)** highlighted the need for an urban spatial framework that promotes efficient land use, compactness, mixed uses, and higher densities through infill and planned extensions.
- **Sixteenth National Plan, 2024 of National Planning Commission (NPC)** recommended a spatial planning system for sustainable and resilient urban

infrastructure, emphasizing urban agriculture, riverbank beautification, and the protection of open spaces for farming use.

- **National Urban Policy, 2024 of Ministry of Urban Development (MoUD)** aims to strengthen urban–rural linkages, protect agricultural land, improve storage and infrastructure for agricultural products, and formally define the Food Green City concept.
- **Bagmati Province Second Periodic Plan, 2024 of Bagmati Province Planning and Policy Commission (BPPC)** promotes urban agriculture by utilizing wastelands and formally launching Food Green City programs.

Book Publisher, Editors, and Authors

The NAM S&T Centre, New Delhi, initiated the publication of **Development of Food Green Cities for Urban Sustainability**. At its request, Dr. Sunil Babu Shrestha, Academician at NAST, took the lead as Corresponding Editor. He is joined by three Co-editors:

- Dr. Ambika P. Adhikari, Distinguished Adjunct Fellow, Institute for Integrated Development Studies (IIDS), Nepal
- Dr. Keshav Bhattarai, Professor, University of Central Missouri, USA
- Dr. Drona P. Rasali, Adjunct Professor, University of British Columbia, Canada

The editors have called upon researchers, academics, and practitioners from Nepal and Mauritius, as well as members of the Nepali diaspora in the USA, Canada, Japan, and Australia, to contribute chapters to this book. The authors represent a diverse array of expertise, including scientists, academics, policymakers, administrators, field workers, and activists in the fields of urban planning, agriculture, food sciences, biology, health sciences, rural development, economics, and poverty alleviation. This book serves as a valuable resource for academics, planners, policymakers, and students seeking to discuss and develop effective policies aimed at achieving self-reliance, efficiency, and sustainability in the rapidly expanding urban areas of South Asia and other developing regions

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Development of Food Green Cities for Urban Sustainability: Introduction to the Book

Keshav Bhattarai¹, Ambika P. Adhikari²,
Drona P. Rasali³ and Sunil Babu Shrestha⁴

1. INTRODUCTION

Since 2007, the global urban population has outnumbered the rural population, and by 2050, nearly 70% of people worldwide are expected to live in cities (United Nations, 2018). This unprecedented pace of urbanization in the twenty-first century underscores the pressing need to build cities that are sustainable, resilient, and equitable. The COVID-19 pandemic further exposed the fragility of urban food systems, as reliance on long-distance supply chains left millions vulnerable. The importance of greenery and sustainable practices had already been recognized during the 1992 Rio de Janeiro Earth Summit, which stressed that even small farmers could play a role in cooling the planet. Today, in the face of ongoing urban crises, urban farming and greenery are increasingly vital. They not only strengthen food security during disruptions but also mitigate urban heat, reduce pollution through phytosanitation, create local employment opportunities, and provide recreational and therapeutic value for city residents. The chapters that follow, though diverse in focus, collectively illustrate how urban farming, forestry, waste recycling, and ethnobotanical practices can reimagine cities as Food Green Cities. While many examples in the book are drawn from Nepal, the underlying principles are broadly applicable to urban areas worldwide.

2. CHAPTER SUMMARIES

Visitor Perception and Engagement in Urban Park: A Case Study of Puspatal Park in Hetauda Sub-Metropolitan City of Nepal by Sunil Babu Shrestha, Rojee Pradhananga, Saurav Shrestha, Bijan Shrestha, and Marina Vaidya Shrestha shows how an urban park can improve public health, social interaction, and environmental quality. Using a structured survey of 597 visitors in late 2021, the authors map how the visitors use the park and what improvements they seek. Most visitors are young, many arrive on

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foot, and their common activities include walking, socializing, yoga, and jogging. The park supports physical and mental health, including for people with chronic health conditions. Ecological benefits of the park include cooling of the area, biodiversity, and providing opportunities for phyto-sanitation. The authors recommend inclusive design, community participation, and eco-friendly infrastructure and to embed parks within the broader urban planning process. One key insight is that well-managed parks can become anchors of sustainable, resilient neighborhoods.

Urban Agriculture in Nepal: A Case Study of Urban Rooftop Gardening Practices in Kathmandu Valley by Astha Tuladhar explains how Rooftop Gardens (RTGs) are profiled as practical tools for food security, health, climate resilience, and waste recycling in the Kathmandu Valley. A telephone survey of 80 active gardeners documents daily practices, motivations, and constraints. Women in the 40–50 age group are prominent practitioners of RTG. Motivations include healthier produce, realizing cost savings, and gaining a hobby for the households. Challenges include waterproofing costs for roofs, pests, weather extremes, and water scarcity. Most households use containers to grow diverse vegetables, fruits, herbs, and spices, with many planning to expand and train others. Policy suggestions include integrating RTGs into urban plans, supporting peer networks, and recognizing commercial potential.

Organic Waste to Promote Food Green City in Kathmandu Valley of Nepal by Indira Parajuli, and Sunil Babu Shrestha quantifies how composting the organic portion of municipal solid waste can be used for rooftop farming and urban agriculture. The Kathmandu Valley generates a large amount of organic waste that can be converted into compost to meet or exceed the compost demand of urban agriculture. Findings suggest that several tons of compost per day from waste can be available for urban agriculture. Further, the cities and towns of the Kathmandu Valley provide a substantial amount of rooftop and balcony structures, as most buildings have flat roofs constructed in reinforced concrete, which is generally waterproof. Benefits of recycling organic waste to compost include reduced methane emissions, carbon sequestration, heat mitigation, and storm water retention. This approach creates informal jobs, empowers women and other household members, and lowers dependency on food imports. The authors propose the integration of waste-to-food strategies into policy to scale up efforts and help create Food Green Cities.

Composting for Kitchen Garden: An Alternative Way of Managing Household-Level Solid Waste in the Kathmandu Valley by Bishnu Raj Upreti and Yamuna Ghale examines household composting as a resilient, low-cost solution that turns waste into compost, especially during crises such as earthquakes, border blockades, and pandemics. Qualitative evidence from interviews, focus groups, and observations shows growing adoption, supported by subsidies, municipal policies, Non-Governmental Organizations (NGO) advocacy, and peer learning. Composting reduces landfill burden and methane emissions while improving soil health. Women emerge as key actors who link composting with daily food security and empowerment. The case

demonstrates how crises can sometimes catalyze sustainable practices with long-term benefits.

Urban Agriculture in an Era of Anthropogenic Climate Change and Rapid Urbanization by Chandra Lal Pandey, Goma Sigdel, Prakriti Niraula, and Sunil Babu Shrestha documents rooftop and container farming across communities in the Kathmandu Valley. Motivations include food security, health, stress relief, and the pursuit of hobbies. The practice of urban agriculture supplies a large share of household vegetables, and it recycles waste through composting. Challenges include erratic rainfall, pests, and water scarcity. Adaptive practices such as organic pest control and mulching are spreading. The authors call for zoning of urban lands, climate-smart techniques, and community engagement to expand urban agriculture.

Urban Sustainability Assessment in the Kathmandu Valley for Sustainable Urban Agriculture Practices Based on a Theoretical Optimization Study by Arun Kafle, and Sita Ram Ghimire evaluates profitability, employment, and emissions across rooftop, backyard, and vacant-lot farming. The measures of Net Margin, Full-Time Employment Equivalent, and CO₂ emissions guide comparisons under different farm mechanization levels, farming areas, crop values, and market conditions. Mechanization of agriculture in larger land areas raises profitability while non-mechanized systems maximize employment; small-scale direct-distribution systems minimize emissions. Land cost can be the main bottleneck in urban agriculture. Direct farm-to-consumer sales are pivotal for economic and environmental outcomes. The authors recommend integrating urban agriculture into planning, protecting land access, and supporting new technologies such as hydroponics and aquaponics.

Investigating the Current State of Rooftop Gardening in Lalitpur Metropolitan City and Bhaktapur Municipality: Opportunities and Challenges by Bijaya Maharjan, Sunil Babu Shrestha, Alina Maharjan, and Marina Vaidya Shrestha presents a mixed-methods survey of 56 rooftop gardeners in Lalitpur and Bhaktapur, profiling adoption, benefits, and barriers. They find that for urban agriculture; vegetables dominate in agriculture production. Individuals aged between 31 and 60 are most active, and households are largely homeowners with moderate incomes. Motivations include cost savings, safe food, and waste recycling. Barriers for scaling up urban farming include limited finances, technical gaps, and weak plant disease services. The chapter concludes that rooftop gardening strengthens food security, reduces urban heat islands, improves air quality, and builds community. Scaling up requires training, municipal support, and incentives.

Apil KC and Keshab Sharma's work, *Challenges and Opportunities of Climate Adaptation Planning in Growing Cities: Case from Nepal's Cities*, highlights that the rise of the green city concept reflects global recognition of the need to balance rapid urban growth with ecological sustainability. This idea emerged in response to unplanned urban expansion, which has caused rising pollution, shrinking open spaces, and increasing food insecurity (Bhattarai & Conway, 2021). The green city

paradigm responds to these issues by integrating environmental stewardship, food security, and resilience into urban planning. Urban sustainability now relies heavily on Food Green Cities, where rooftop gardening, urban farming, and peri-urban agriculture mitigate food insecurity, reduce urban heat, and recycle nutrients, as demonstrated in places like Lalitpur and Bhaktapur in Nepal (World Bank, 2022). Climate change adaptation is central to this framework, with nature-based solutions such as wetland restoration, urban forestry, and rainwater harvesting addressing rising risks while enhancing biodiversity and reducing emissions (Abbass *et al.*, 2022; Sherpa, 2024). Solid waste management through sanitary landfills, resource recovery, and waste-to-energy systems further illustrate how resilience can be built by turning waste into opportunity. Complementary practices—sustainable agriculture, rainwater harvesting, and preservation of open spaces and green infrastructure—not only ensure food and water security but also provide ecosystem services such as stormwater regulation and carbon sequestration. In sum, the transition toward green cities represents a proactive response to climate change, food insecurity, and environmental degradation, offering scalable lessons from Nepal that highlight how participatory governance and ecosystem-based adaptation can transform vulnerabilities into opportunities for resilience and align local development with global sustainability goals (Sherpa, 2024; World Bank, 2022).

Multi-sectoral Opportunities in the Development of Food Green Cities for Urban Sustainability by Kamal Kowlessur presents a cross-sector strategy that links health, environment, social cohesion, economy, education, energy, and tourism. The SPECIES principles—Social sustainability, Policies, Empowerment, Climate resilience, Innovation, Economic food sustainability, and Sustainable quality management—guide a city-wide approach. Examples include composting and circular waste systems, community and rooftop gardens, vertical farms, and renewable rooftop energy that supports food production. The chapter argues for policy frameworks that prioritize sustainability, inclusive and technology-enabled participation.

Urban Forestry in Selected Nepali and US Cities: Assessment, Analysis, and Recommendations by Ambika P. Adhikari, and Keshav Bhattarai presents a comparative analysis of urban forestry practices in Nepal and the United States. This chapter demonstrates how urban forests reduce pollution, cool cities, store carbon, manage storm water, and support food availability through fruit trees and vegetable plants. Remote-sensing datasets and GIS workflows map of canopy conditions and trends are presented as evidence of urban forest cover. U.S. cities rely on formalized master plans and canopy targets; Nepal's cities draw on cultural practices but need systematic planning and monitoring. The chapter argues that species choices must match functional needs and space constraints. Socioeconomic benefits of urban forestry include property value gains and job creation. The chapter calls for integrating tree canopy targets and public participation into urban plans.

Sustainable Food Systems in Urban and Peri-urban Areas in the Global South, with Special Reference to Heifer International's Experience by Mahendra Nath Lohani,

Drona Prakash Rasali, and Dilip Prasad Bhandari presents urban and peri-urban agriculture to improve diets, income, and environmental quality across Asia, Latin America, and Africa. Community-based models, women-led cooperatives, and micro-livestock programs feature prominently. Nature-based solutions such as Sponge Cities and chemical-free organopónicos offer scalable models. Locally led development with facilitative support from Non Governmental Organizations (NGO) is a key success factor. The chapter argues that the planning of food systems in urban and peri-urban areas should shift from supplemental to a central urban strategy.

The Changing Nature of Public Open Spaces in the Kathmandu Valley: What Does It Mean for Social Sustainability of New Growth Areas by Rajjan Chitrakar presents a historical and spatial comparison showing dramatic loss and neglect of public open spaces when urban sprawl occurs in the Kathmandu Valley. Traditional settlements reserved generous communal squares and courtyards, whereas modern neighborhoods allocate very little land for open space. Weak bylaws and poor maintenance erode social life and cohesion. The chapter proposes policy reforms that restore open spaces as the city's lungs and as places for community interactions, recreation, and even food production.

The Impact of Digital Platform on Food Green City Sustainability by Deegendra Khadka, Pawan Kumar Neupane, and Kanti Shrestha argues that digital platforms connect farmers, consumers, researchers, and policymakers to accelerate the practices of rooftop gardening, hydroponics, vertical farming, and waste-to-fertilizer conversion. A Farming Network enables knowledge exchange, fair pricing, and the removal of intermediaries for selling. Digital tools also promote circular economy practices and reduce pollution. The lesson is clear: connectivity is as vital as physical infrastructure for building Food Green Cities.

Urban Forestry as a Tool for Disaster Risk Reduction in Rapidly Urbanizing Areas: Study of Dudhauri and Siraha Municipalities by Smriti Kayastha and Abishek Karn analyzes land-use change in those jurisdictions from 2010 to 2023. It shows rapid expansion of built-up areas, loss of forests, resulting in rising exposure to floods, erosion, and heat. Urban forestry—through buffers, green corridors, and agroforestry—mitigates floods, stabilizes soils, cools cities, and supports recreation and food production. Community surveys reveal serious public concern about flood risk and strong support for green solutions. Policy proposals include minimum green-space mandates in zoning bylaws, community participation, and cross-sector collaboration facilitated by the local governments.

Harnessing Ethnobotany and Ethnopharmacology for Better Urban Health and Sustainability: Supporting Food Green City about Niranjan Koirala and Melina Poudel presents how the traditional knowledge about plants can be utilized to support urban food, medicine, and ecosystem services. Many modern drugs originate from ethnobotanical practices, and urban gardens can integrate medicinal species alongside food crops. Community and allotment gardens foster social cohesion, promote biodiversity, and support climate resilience. Safeguarding indigenous knowledge and

fair benefit-sharing are essential while devising policies and programs for urban agriculture. The chapter positions ethnobotany and ethnopharmacology as pillars of healthy, resilient, and inclusive green cities.

3. CONCLUSION

Across these chapters, a coherent pathway emerges to integrate urban agriculture, forestry, waste-to-resource systems, digital networks, and traditional knowledge to build Food Green Cities. These approaches can help secure food during shocks, mitigate urban heat islands, clean air and water, and create dignified jobs. They also reduce greenhouse gas emissions by shortening supply chains and expanding urban green cover. Policy must anchor this transition through land-use protection, incentives for rooftop and community farming, targets for increasing tree canopy, circular economy mandates, and inclusive digital access. Local leadership, women's participation, and community networks ensure the adoption and long-term stewardship of urban farming and city greening efforts. The evidence from Nepal and the Global South shows global transferability, from Cuba's organopónicos to community gardens in Europe and North America. Urban futures will be sustainable when food, greenery, health, and knowledge are designed as one system (United Nations, 2018; Altieri *et al.*, 1998).

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Visitor Perception and Engagement in Urban Park: A Case Study of Puspupal Park in Hetauda Sub-metropolitan City of Nepal

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ABSTRACT: Public parks in cities are important to enhance urban life by providing places for recreation, relaxation, and socializing. This chapter explores the perception of different population groups in the usage of public parks concerning health, economy, environment, and infrastructure. A case study on the perceptions of visitors and their level of engagement in Puspupal Park, Hetauda Sub-metropolitan City of Nepal is presented. The research will also describe the socio-economic group's trends of the use of public parks, their perception about the public space, issues relating to the park, level of park use regarding health benefits, and perception about the environmental aspect of the park.

The methodology used was based on a questionnaire survey where 597 respondents were interviewed and responses were analysed using SPSS software version 20. The findings explore the socio-demographic characteristics of park visitors, access to the park, frequency of visits, length of stay in the park, and purposes for visiting the park. The study focused on the activities of visitors in the Puspupal Park of Hetauda, Makawanpur district, including walking, leisure, and socializing. It identifies the role of the park in enhancing physical activity and mental well-being, thus playing a crucial role in the management of health conditions, such as chronic diseases.

The findings from the study help to understand public perceptions and engagement in parks and inform future improvements and management strategies for similar spaces. Other key suggestions include enhancing infrastructure, transportation, and connectivity, environmentally sustainable practices, such as waste management and events that engage the community. The policy

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implications from these studies call for parks to be an integrated part of urban planning through active partnerships with healthcare institutions for health promotion programs.

Keywords: *Green Space Engagement, Socio-Economic Groups, Urban Parks, Urban Planning, Visitors' Perception.*

1. INTRODUCTION

Urban public parks play a vital role in enhancing the quality of life in cities. They offer spaces for recreation, relaxation, social interaction, and environmental benefits, such as improved air quality and biodiversity. As green spaces within urban areas, they are specifically designed and maintained for public use, like public open spaces, which are accessible for freely chosen and spontaneous activities (Lynch, 1960). These parks function as the “lungs” of a city, providing natural, relaxing sites within urban landscapes. Despite variations in size, design, amenities, and activities, their overarching goal is to deliver wide range of benefits to both residents and visitors. Urban green areas offer ecological, environmental, and cultural advantages, including enhancing human well-being and conserving biodiversity. However, many parks are maintained as well-kept lawns, which reduces their ecological services. Transitioning to diversified meadow management improves biodiversity and offers broader ecological benefits (Paudel & States, 2023).



Figure 1: Different Activities Inside Puspapal Park

Rapid urbanization has led to environmental degradation, particularly in large cities, adversely affecting residents' quality of life (Kuddus *et al.*, 2020). The city of Hetauda in Nepal, is no exception. In recent years, it has experienced significant development, with new constructions and commercial activities concentrated in central and riverside areas. Despite these changes, Puspapal Park remains a tranquil area, providing a healthy environment and a public space for family gatherings, leisure activities and entertainment purposes.

The park also houses the city's largest Puspapal memorial library, operational with support of the municipality. Urban expansion and unpredictable geographic features in some areas have reduced wind speeds across the city, leading to an increase in urban heat islands. Heat islands arise primarily from dark or asphaltic surfaces (e.g.

roads or buildings) that absorb solar radiation and retain heat (Alves and Lopes, 2017; Pacheco-Torgal *et al.*, 2015). The effect intensifies when local air is saturated with pollutant gases. The health and well-being benefits of urban green spaces are well accepted. Prolonged exposure to green spaces helps people escape the chaos of urban “gray spaces”, promoting relaxation (Gong *et al.*, 2024). Urban green spaces contribute to sustainability, mental and physical health, and overall well-being. For individuals with disabilities, these benefits are particularly significant, though access disparities persist, highlighting the need for inclusive urban planning (Selanon and Chuangchai, 2023).

1.1 Relevant Literature

Urban parks or green spaces have received increasing research attention globally. Dinter *et al.* (2022) explored the relationship between park characteristics and personal traits along with the sense of place, usage of the park, and satisfaction with life in medium-sized cities in the Netherlands, including Hertogenbosch and Eindhoven. Through an online questionnaire survey and the analysis of the survey data using structural equation modelling, the study revealed that facilities and the absence of disturbances positively influenced the sense of place, ultimately improving inhabitants’ life satisfaction. Stedman (2011) examined the concept of “sense of place” emphasizing the meanings and attachments individuals associate with specific locations. By assessing the sense of place in lakes, they found that while landscape features successfully predicted place satisfaction, they did not necessarily predict place attachment. In Portuguese cities, Madureira *et al.* (2018) identified playgrounds and sports facilities as the most favoured features of public green spaces. The study highlighted the need for localized assessments of citizen preferences as such preferences may vary based on regional contexts.

Gong *et al.* (2024) investigated the psychological benefits of nature connectivity in urban green and gray spaces through a lab experiment. Grey space typically refers to parts of the urban environment that aren’t considered green or natural areas. These include places like industrial zones, commercial complexes, roads, parking lots, and other built-up, non-residential areas that lack vegetation and are primarily used for infrastructure, business, or transportation purposes. This study, involving 68 undergraduate students, found that individuals with high nature connectivity significantly benefited from high-biodiversity green spaces, whereas those with low nature connectivity adapted better to gray spaces. These findings emphasize the importance of urban green spaces in promoting mental health, with biodiversity and nature connectivity playing a pivotal role. Selanon and Chuangchai (2023) emphasized the substantial health, sustainability, and well-being benefits of urban green spaces for individual with disabilities. Despite these benefits, the study noted significant accessibility disparities and the neglect of this group in urban planning. It argued that prioritizing the needs of individuals with disabilities in designing green spaces could foster more inclusive and sustainable communities.

In contrast to well-kept lawns, managing urban green spaces as meadows offers enhanced biodiversity, improved storm water management, and greater aesthetic value. Paudel and States (2023) examined the ecological services and potential drawbacks of lawns and meadows. The study highlighted the trade-offs and synergies between ecosystem services and proposed research objectives to better balance ecological, environmental, and cultural functions in urban environments.

In Nepal, research on urban parks is an emerging field. Thapa and Poudel (2018) used a GIS-based approach to analyze urban green space coverage in Butwal Sub-Metropolitan City. Their findings emphasized the role of green spaces during emergencies and their contribution to improving citizens' quality of life. Landsat 8 OLI imagery was used to assess green space coverage, which was calculated at 86.37 km². The study established a baseline for urban planners and stakeholders to enhance the effective management of green spaces

Shrivastav and Sigdel (2019) evaluated the relationship between happiness and urban green spaces in Janakpur, Nepal. Through paired sample testing, the study found that 43.3% of participants reported greater happiness inside parks compared to outside. Factors such as gender, park activities, and employment status significantly influenced participants' happiness, indicating a positive correlation between park availability and inhabitants' well-being. Manandhar and Tiwari (2022) assessed the current state of urban parks in Nepal and the involvement of local communities in their management and use. Their study identified potential for utilizing vacant spaces as parks and suggested strategies to encourage community participation in urban green space development.

1.2 Objectives and Contribution

While the positive correlation between the availability of parks and physical and mental well-being has been widely acknowledged (Liu *et al.*, 2017), the extent and nature of this relationship often vary based on contextual factors, including socio-economic indicators, cultural values, visitor lifestyles, and environmental perceptions. In the context of developing countries like Nepal, where urbanization is accelerating, the role of open green spaces and urban parks in promoting public health remains underexplored. This study seeks to address this gap by focusing on Puspatal Park in Hetauda Sub-Metropolitan City, Nepal, as a case study to investigate the multifaceted role of urban public parks. Specifically, the research aims to evaluate the diverse perceptions, engagement patterns, and usability of the park among various demographic groups. It explores how aspects such as health, economy, environment, and infrastructure influence park usage and examines their interrelationship within the Nepalese urban context.

The primary objectives of the study include:

- Understanding socio-economic trends in park usage.
- Evaluating public perception of the public spaces in Hetauda and their concerns for the park.

- Assessing the benefits of the park in health, environmental, and sustainability aspects.

This study contributes to understanding the role of urban parks in developing countries, addressing the research gap in rapidly urbanizing regions like Nepal. By focusing on Puspalaal Park, it offers localized insights to guide urban planning, policymaking, and park management. It enriches the knowledge of how people perceive urban parks and their role in promoting sustainable and healthy urban environments in developing contexts. This knowledge can guide the integration of urban parks into frameworks for public health, environmental sustainability, and community well-being, advocating for inclusive planning that meets the diverse needs of all groups, including marginalized communities

2. METHODOLOGY

2.1 Study Area

Puspalaal Park is situated in Hetauda Sub-metropolitan City, Nepal, at coordinates of 27°25.672’N to 85°2.327’E, with an elevation of 350 meters above sea level. It stands out as a vital green space amidst the urban sprawl, providing ecological and social benefits to the local community. The exact location of the park and a Google Earth view of the area is shown in Figures 2 and 3, respectively.

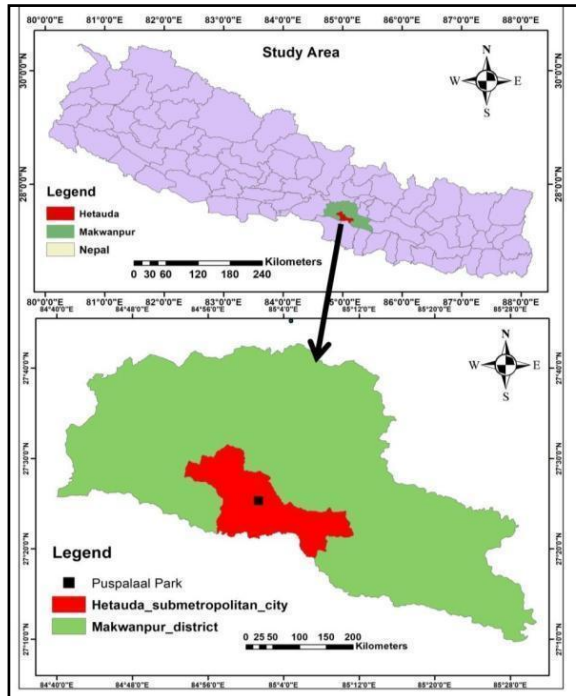


Figure 2: Location of Puspalaal Park, Hetauda

2.2 Park Characteristics

Puspalaal Park features a flower garden, library, some statues, well-maintained pedestrian walkways, and a pond used for manual boating (without electric motors), which is one of the park's prominent attractions. The pond also serves as a venue for fish feeding, offering recreational opportunities for visitors. A street with a solar-powered light is present within the park, enhancing its sustainability efforts. Additionally, the park has a provision for Wi-Fi facility, though it is currently non-operational due to lack of funding. This public park is governed and managed by Hetauda Sub-metropolitan City. The municipality has entrusted the operation and management of the park to Om Shanti Brahma Kumari, a non-profit spiritual organization.

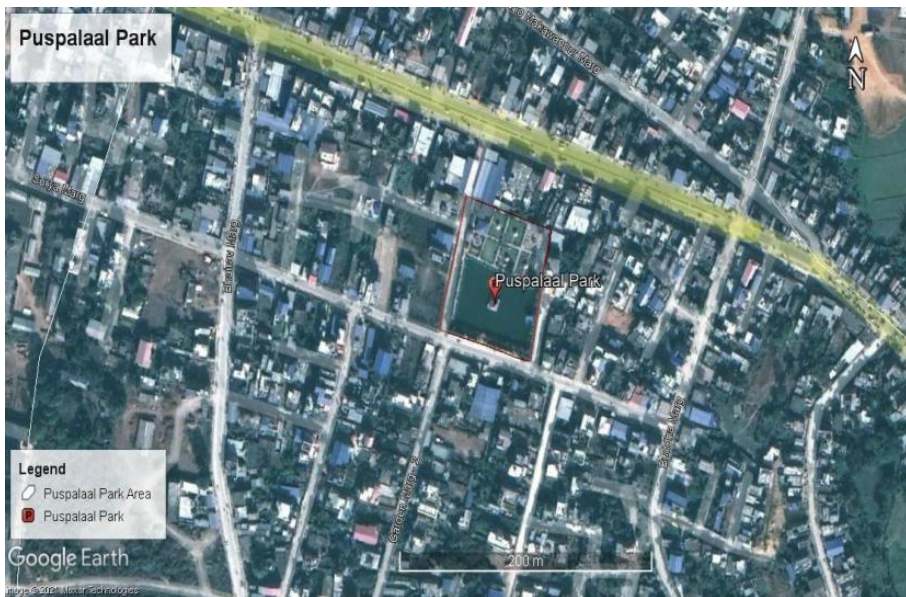


Figure 3: Google Earth view of Puspalaal Park Area

2.3 Data Collection and Sample Characterization

The questionnaire survey was the primary tool used to analyse public perceptions regarding the usability of the park. A set of questions was prepared following relevant literature, such as Viebrantz and Fernandes-Jesus (2021), and considering the features and services offered by the case study park. Multiple-choice questions were designed with a relative ranking of alternatives, supplemented by an “others” option for greater flexibility. The survey explored various aspects, including the motive for visiting, patterns of use and access, the park's characteristics, and its overall importance. Additional questions, focused on the level of health, environmental conditions, and infrastructure within Puspalaal Park. The survey also included specific questions about the mode of transport use to access the park, the

time taken to reach it, and the frequency of visits. These questions aimed to assess the usability of the park by the individual users. A structured questionnaire was tailored to participants' residential location and the questionnaire was prepared in English language. An average of 80 people participated in the survey daily, with higher participation observed on Saturday. In total, 597 respondents of various age groups and genders completed the survey between November 26 and December 3, 2021.

Convenience sampling, as outlined by Neuman (2000), was used to select participants, often consisting of individuals readily available or the first encountered in the park. To ensure representativeness, data collection was carried out at differed times of the day. A sampling criterion of visiting the park for at least one year was set to ensure that the respondents had sufficient familiarity with the park.

2.4 Data Analysis

The responses collected from participants were first documented and then analysed using the Statistical Package for Social Sciences (SPSS 20). Initially a demographic summary was generated, which included variables such as age, marital status, and gender. Descriptive statistics were subsequently conducted to compare key factors such as the frequency of park visits, the duration of time spent in the park, average commute times, primary motives for visiting, and perceptions of the parks' characteristics. These characteristics included aspects like conservation efforts, physical features and surroundings, adaptability for sports, and other related factors.

Questions regarding the importance of the park were also documented. In accordance with Züll (2016), a content analysis was carried out to the open-ended questions. Participants' satisfaction was assessed through survey questions addressing both the quality and quantity of the park features. The primary focus of the study was to evaluate the reported levels of satisfaction expressed by participants and to identify the key factors and motives behind dissatisfaction with the park. The main factors and motives which led to the dissatisfaction in the park. Finally, the association between the health and well-being of visitors and their usage of Puspapal Park was examined through qualitative analysis.

3. RESULT AND DISCUSSIONS

3.1 Socio-Demographic Summary

The socio-demographic variables include Age, Gender, Marital Status, Occupation, Religion, and Level of Education of visitors. Table 1 summarizes the distribution of various socio-demographic groups among the surveyed visitors. The gender and age distributions are shown in Figure 4. Among the surveyed visitors, 59% were female, while 41% were male. When comparing age groups, the majority of visitors (50.3%) were of age 15–30 years. Visitors aged 31–45 years accounted for 38.6%, those aged 46–59 years constituted 10.6%, and the smallest group, aged over 60 years, comprised just 0.5%.

Visitors to Puspapal Park exhibit diverse educational backgrounds. Figures 5 and 6 shows educational, religious and occupational distributions of the visitors. Among the surveyed visitors, 12.6% had completed higher secondary education (+2), while a significant majority (57.6%) had passed the Secondary Education Examination (SEE). Only 4.2% of visitors hold a graduate degree or higher. Additionally, 16.1% of visitors are illiterate, and 9.5% are literate but lack formal education. This indicates that most visitors had at least a secondary school education or a basic level literacy. The religious composition of Puspapal Park visitors also reveals interesting trends. The majority (55.3%) identified as Buddhists, followed by 40.0% who were Hindus. Muslims accounted for 4.0% and Christians made up 0.7%. This indicates that the park is predominantly visited by Buddhists and Hindus.

Table 1: Socio Demographic Characteristics Summary

<i>Socio-Demographic Characterization</i>	<i>Summary</i>
Gender	
Female	59.3%
Male	40.7%
Age	
Mean Age	32
15–30 yrs	50.3%
31–45 yrs	38.6%
46–59 yrs	10.6%
Over 60 yrs	0.5%
Education Level	
Illiterate	16.1%
Literate	9.5%
SEE	57.6%
+2	12.6%
Graduate or higher degree	4.2%
Religion	
Hindu	40.0%
Buddhist	55.3%
Muslim	4.0%
Christian	0.7%
Main Occupation	
Agriculture	37.5%
Business	28.13%
Other	21.88%
Govt. Service	6.25%
Private Service	6.25%

The majority of visitors to Puspapal Park in Hetauda are employed in the commercial (28.13%) and agricultural (37.5%) sectors, according to occupational statistics, demonstrating the park's high attraction to those with ties to the local economy. The

park’s inclusivity is demonstrated by the sizeable percentage (21.88%) that comes under “Other category,” which includes a variety of demographics like seniors, homemakers, and students. The lesser percentage of visitors from the public and private sectors (6.25%) suggests that these groups may have different leisure choices or little free time. Overall, the information emphasizes the park’s function as a community-focused area that primarily serves rural and enterprising communities.

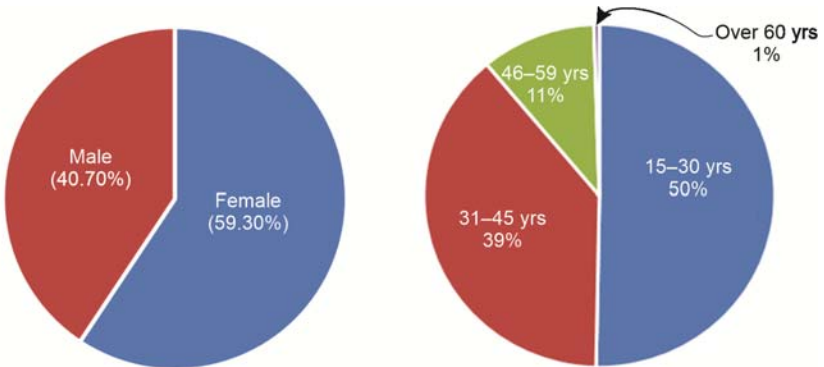


Figure 4: Gender and Age Distribution of Visitors

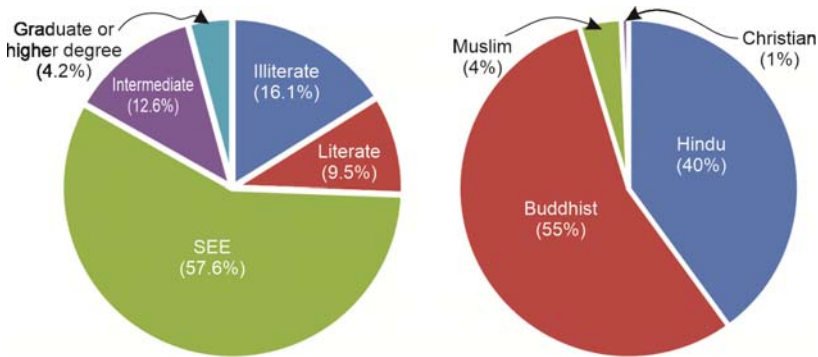


Figure 5: Education and Religion of Park Visitors

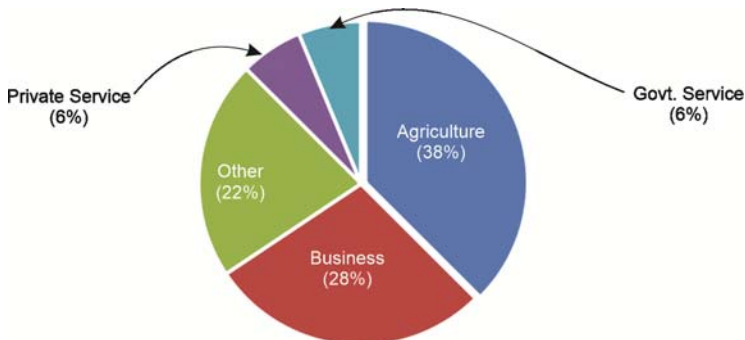


Figure 6: Occupational Status of Visitors

3.2 Descriptive Analysis

This section summarizes the information related to the use, access, and motives of park visits.

3.2.1 Park Access

Based on the descriptive statistics, 40% of participants typically accessed the park on foot (walk), followed by 31.3% who used bus, and 19.3% who travelled by auto rickshaw. The time taken to reach the park was also assessed through a questionnaire survey.

3.2.2 Time to Reach the Park

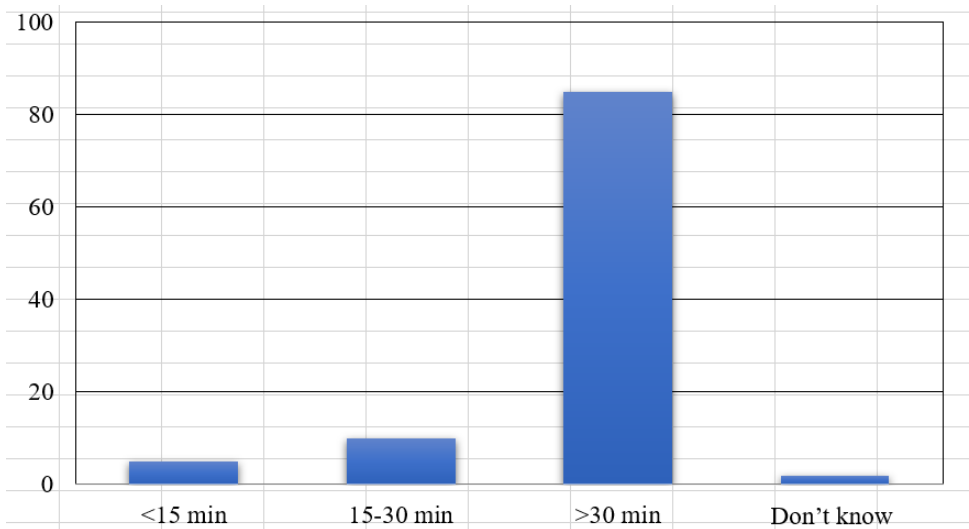


Figure 7: Time to Reach the Park

The questionnaire categorized travel time into three ranges: less than 15 minutes, 15 to 30 minutes, and greater than 30 minutes. As shown in Figure 7, only a fraction of participants (4.4%) reported taking less than 15 minutes, while 8.9% reported taking 15–30 minutes. The majority of the visitors (approximately 85%) reported taking more than 30 minutes to reach the park. Additionally, 1.7% of participants indicated they did not know the exact time required to reach the park.

3.2.3 Frequency of Park Usage

Figure 8 illustrates the frequency of park visits. Most respondents (approximately 58%) reported visiting the park “sometimes,” that is, at intervals greater than a month. This was followed by visits twice a week and once a month, which had similar percentages of visitors. Daily visits to the parks were the least common.

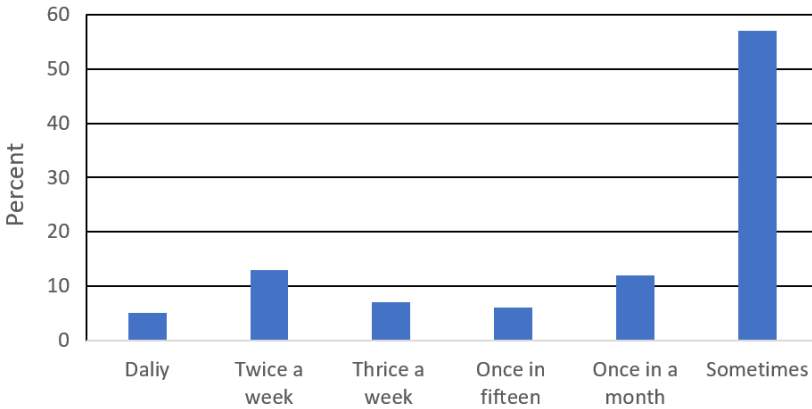


Figure 8: Frequency of Visiting the Park

3.2.4 Time Spent in Park

As shown in Figure 9, most visitors reported spending “more than 1 hour” in the park, followed by 30–60 min. This indicates that visitors tend to spend a significant amount of time in the park. Additionally, most visitors resided in the area where the park is located, although 4.2% of respondents lived in the park’s vicinity.

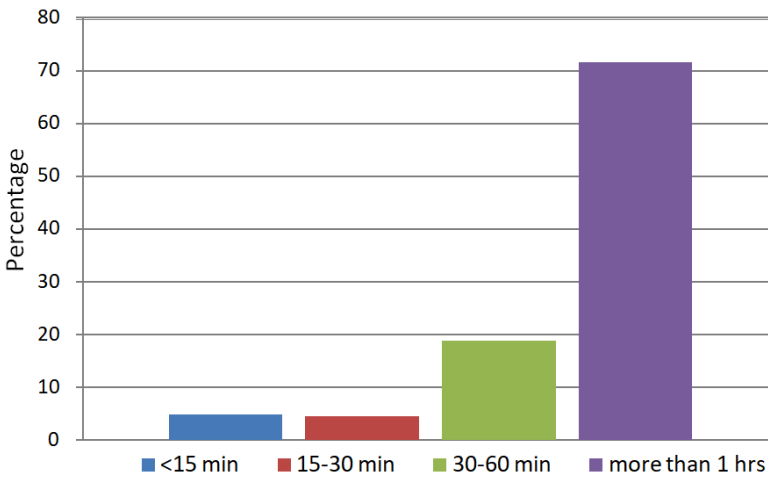


Figure 9: Time Spent in Park

3.2.5 Accommodation of Visitors

Information on the accommodation or house ownership of park visitors provides insight into their lifestyle or economic status. As shown in Figure 10, 39.9% of visitor lived in rental flats, closely followed by 37.4% who owned individual houses. Additionally, 22.4% of visitor lived in housing colonies while only 0.3% resided in apartment.

3.2.6 Purpose of Park Usage

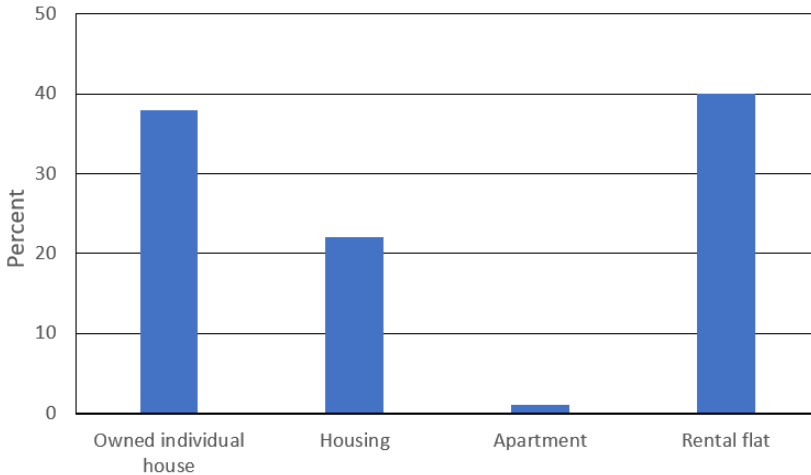


Figure 10: Accommodation of Visitors

The reasons for visiting the park varied among respondents. The most common purpose, as shown in Figure 10, was walking, accounting for over 60% of visitors. This was followed by general time passing and socializing with friends without any specific purpose. Other activities included yoga, jogging, and exercise. When asked for their preferred activities in the park, a majority (39%) mentioned observing greenery, followed by walking around and socializing as shown in Figure 11.

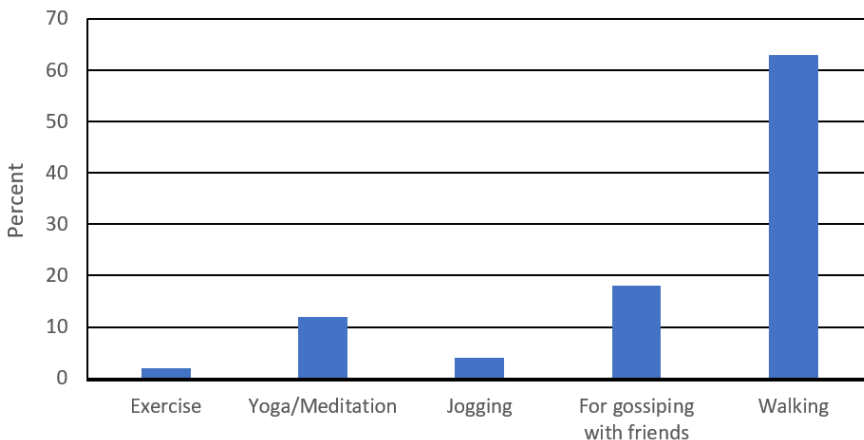


Figure 11: Purpose of Visiting the Park

3.2.7 Health Aspect

Park usage may be influenced by chronic health conditions that necessitate exercise in green spaces. The survey assessed the prevalence of chronic diseases among

visitors, as shown in Figures 13 and 14. Of the 597 visitors surveyed, 58 reported having a chronic disease. Among these, 59% had hypertension, 21% had diabetes, and the remainder had respiratory problems.

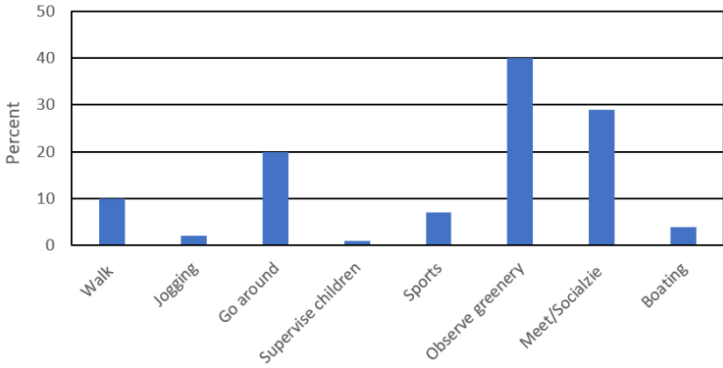


Figure 12: Preferred Activities to Do in the Park

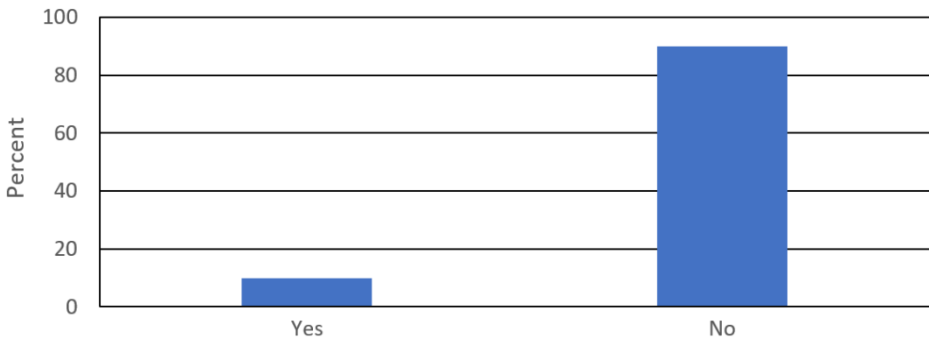


Figure 13: Presence of Chronic Disease among Visitors

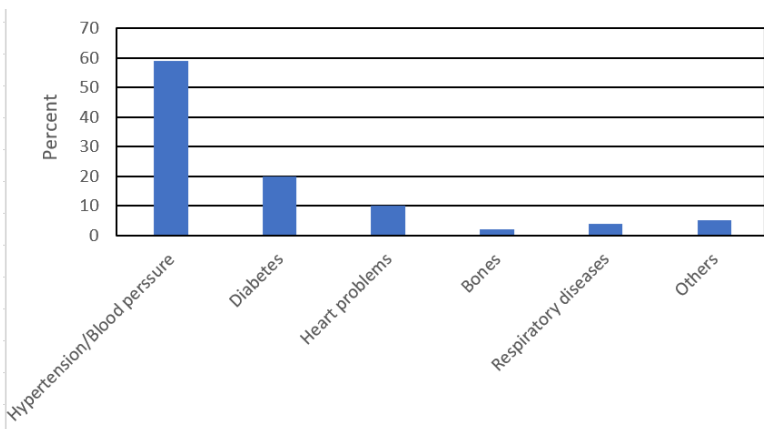


Figure 14: Description of Chronic Disease among Visitors

3.3 Discussion on the Results

This research evaluated the visitors' perception of characteristics, accessibility, usage, and importance of Puspupal Park in their daily life. Further, it has looked into the extent the park supports personal health and encourages an active lifestyle. The findings contribute to an understanding of the potential for urban parks to promote public health, social interaction, and environmental well-being. The study revealed that Puspupal Park attracts a socio-demographically varied influx of visitors, with a dominant representation of the younger age group. This gives evidence of the park's vital role in the recreational and health fulfilment of the city's inhabitants. The most frequent pattern of use is walking, socializing, and doing yoga and jogging exercises, which shows how important this open area is for physical activity and mental health.

One of the main findings is that the park may be used as a health management resource, especially for patients with chronic diseases like hypertension and diabetes. This study has emphasized the role that an urban park like Puspupal Park can play in motivating people toward healthier lifestyles, especially in urban settings where green areas are lacking. It also enumerates various infrastructural deficiencies that include pathways for walking, seating places, and playgrounds.

The research further stresses the need to improve accessibility and connectivity to parks. It suggests measures such as creating special transportation routes and improving the condition of pedestrian pathways to engage more visitors. In addition to this, increasing the greenery with indigenous plants, multipurpose plants such as fruit trees and herbal plants in the park (Shrestha, 2021) can enhance a better environment for the visitors, attract the birds, and provide knowledge about plants and birds to the visitors. The study also made a realization that community involvement in park management can implant a sense of ownership and ensure that the park is maintained for a long period.

This study has demonstrated that an urban park such as Puspupal may significantly improve the quality of life in developing cities by making strategic infrastructure improvements and increasing accessibility. These parks are important places for recreation, health enhancement, and environmental sustainability, adding to the general well-being of the residents.

4. CONCLUSION

Public parks play an important role in improving people's lives in cities, as evidenced by visitors' perceptions of Puspupal Park in Hetauda, Nepal, which is widely regarded as a vital public space for social gatherings and health-promoting activities. The primary reasons for visiting the parks are walking, exploration, leisure activities, and socializing with friends and family. This has exposed the park's importance in promoting physical activity, fostering social interactions, and supporting mental well-being. Most of the visitors use the parks for activities such as yoga, jogging, and exercise, highlighting its potential to promote healthier lifestyles and utilize the

Puspalal Memorial Library inside the park. The park's important role as a valuable place for health promotion is understood by the presence of visitors with chronic diseases. This study has also presented a widespread understanding of visitors' perceptions that contributes to the development of such urban public parks in the future with more visitor-centric design.

5. RECOMMENDATIONS

In order to maximize the park's potential and improve the visitors' involvement in the park, the following recommendations are proposed:

- **Facilities:** The facilities such as the comfortable walking paths, adding more seating places, making sure there are clean restrooms and having spots for exercise, fun activities, and yoga need to be added to make the park better for everyone.
- **Accessibility:** Park needs to improve accessibility by enhancing transportation options and connectivity from different parts of the city. It is better to consider eco-friendly initiatives such as dedicated bus routes, cycling lanes, and pedestrian-friendly pathways to encourage more accessibility with sustainability.
- **Events:** To attract a wider range of visitors, community events, workshops, mass yoga campaign and cultural activities within the park should be organized engaging community and stakeholders for maximize the potential of the park.
- **Environmental Sustainability:** Eco-friendly practices of waste management such as composting, recycling centers and proper waste collection system and promoting multipurpose green spaces should be adopted within the park. The pavement inside such parks can be constructed with concrete blocks with waste demolished concrete debris (Shah *et al.*, 2019) or rubber tires which further promotes environmental sustainability as suggested by Shah *et al.*, (2019). It's also important to make opportunity for the visitors of the park to understand and get information why it's crucial to protect the parks, natural resources and green spaces.

6. POLICY IMPLICATIONS

The following policy implications are suggested:

- **Integration of Parks in Urban Planning:** It is suggested to integrate the parks in urban planning considering development and enhancement as part of urban policy and strategy for promoting for sustainable and healthy urban living.
- **Inclusive Design:** Planning and facilities in parks should be inclusive for diverse population groups, including people with disabilities, senior citizens, and families with young children. Universal design principles should follow inclusive park design standards and criteria and should be applied to address the needs of all visitors.
- **Health Promotion:** The role of parks in physical activities, mental well-being, and community health overall is highly emphasized in partnership with healthcare

institutions and professionals. This will help in developing programs and initiatives in health promotion that use parks as spaces for improving public health.

- **Community Involvement:** In managing the park facilities and during decision-making processes and managing the parks, involvement of the communities should be contained. Relevant stakeholders and local residents need to be motivated to play a role for planning, implementing and operation of parks to foster sense of ownership and responsibility in their minds regarding those facilities.

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Urban Agriculture in Nepal: A Case Study of Urban Rooftop Gardening Practices in Kathmandu Valley

Astha Tuladhar¹

ABSTRACT: In Kathmandu, projects promoting roof-top gardens (RTGs) were implemented two decades ago. They attracted many residents to RTGs in their limited roof space. Later its popularity spread to other rapidly urbanizing areas as well. By gardening on rooftops, urban residents are able to upgrade their life-style in multiple ways benefiting the community and the local environment. Other related potential benefits of RTGs like gardening skill development, horticultural education, employment generation, diet improvement, household waste management, biotope regeneration etc. are frequently advertised through the media. Tapping such potentials and exploring new ones can become possible if studies focused on the practical aspects of rooftop gardening. For the present study, 80 roof-top gardeners from Kathmandu were selected for a survey based on their active participation on social networking service (SNS) groups dedicated to rooftop gardening in Kathmandu. They participated in a telephone-survey conducted in 2021–2022. The information and opinions collected from the survey respondents were used to formulate data providing useful insights for accelerating the rooftop garden campaign in Nepal as well as other developing nations.

Keywords: Food Security, Sustainable City, Rooftop Gardens (RTGs), Urban Agriculture,

1. INTRODUCTION

It is projected that by 2050, 68% of the world's population will live in urban areas which is an increase from 54% in 2016. Nepal's urban centers increased from 58 in 2013 to 293 in 2017 as a result of government's restructuring decisions to merge rural administrative units to municipalities, under the federal republic set up of the country. Kathmandu's population growth at 3.5% per year, indicates one of the fastest-growing metropolitan areas in South Asia (Shrestha, 2021, Timsina, *et al.*, 2020). Rural-to-urban migration, drastic increase in land prices, and shrinking remaining cultivable land area are common issues faced by Kathmandu residents. This has stimulated many migrant women to start the business of retailing vegetables,

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and they play an important role in contributing to urban health and economy by easing access to a wide range of fresh vegetables to urbanites (Tuladhar & Bushell, 2018).

Nepal was among the ten countries most affected by extreme weather events over the 2000–2019 period according to the Global Climate Risk Index (Eckstein *et al.*, 2021). Creation of sustainable cities and communities is one of the Sustainable Development Goals (SDGs) established by the United Nations General Assembly in 2015. To make our cities sustainable, there is an urgent need to develop strategies to withstand the effects of climate change and its effect on food security. The inter-related problems resulting from rapid urbanization can be addressed to certain extent, by utilizing urban rooftop space for producing varieties of food efficiently with least carbon emission. As an efficient and easy method of small-scale urban agriculture, rooftop gardening has been an easier option for homeowners in Kathmandu. The concept of Food Green City (Shrestha, 2011) which advocates integrating urban agriculture (RTG, kitchen gardening, community farming etc.) to urban land use planning for sustainability and additional productivity is valid in this context. International organizations like RUAF (Regional Resource Centre on Urban Agriculture and Food Security) established in 1999 has been promoting gardening on rooftops in major cities around the world. In Kathmandu, UN-HABITAT developed a rooftop garden manual in 2013 in collaboration with Kathmandu Metropolitan City and local NGO (non-governmental organization) Environment and Public Health Organization (ENPHO).

Kathmandu city has 32 wards and spreads across an area of 49.45 km². World population review reported that Kathmandu's population reached 1,521,000 in 2022, an increase of 3.33% from 2021. Built-up areas, covered by buildings, are expected to increase further to 352 km² by 2050 (total 570 km²) in Kathmandu valley, effectively doubling the equivalent 2018 figure (Mesta *et al.*, 2022) which can mean a drastic loss of farmlands and urban greenery. Free open spaces have become so scarce in Kathmandu that even river bank encroachment poses a new problem (Tamrakar & Parajuli, 2019). Its residents, dependent on food supplies imported from neighboring cities or countries, are frequently affected by road damage caused by bad weather conditions and international blockades that happen sometimes. Rooftop gardening makes harvesting fresh vegetables, fruits, spices and herbs possible at the comfort of one's own home. It has a direct positive effect on the gardener, the environment and the community, therefore, promoting RTGs as a campaign has continued, and Social Networking Site (SNS) groups have proven to inspire new rooftop gardeners and provided platform to share information among the existing rooftop gardeners. Rooftop gardens and other green infrastructure can bring new challenges to urban life-style, cityscape and vice-versa.

The purpose of this research is to study the practical side of rooftop garden growth and maintenance among the inhabitants of Kathmandu and paint an outline of rooftop gardening conditions in Kathmandu's context. Towards this objective, a survey was conducted during the corona virus pandemic lock-down period when many people benefited from having a rooftop garden and shared their achievements,

problems and solutions on social networking sites (SNS) which motivated others to start rooftop gardens. Rooftop gardening has emerged more recently as a source of income generation, employment, recreation, diet supplement, household waste management and biotope regeneration. Exploration of factors influencing rooftop gardeners and growing food in Kathmandu's rooftops could help build a roadmap to a modern lifestyle for city dwellers incorporating sustainable food growing skills, leading to the goal of building sustainable cities. Surveying the existing rooftop gardeners can firstly, identify common challenges faced by city gardeners which is vital for the success of RTG campaign, and secondly, find ways of incorporating rooftop gardens that best suits the context of Kathmandu preserving its unique characteristics, biodiversity and local identity.

2. MATERIALS AND METHODS

From several SNS groups dedicated to Kathmandu's rooftop gardening, a total of 80 active members who were themselves rooftop gardeners were selected. A questionnaire that was prepared and finalized for this survey is presented in Appendix 1. The questionnaire was divided into 4 sections to collect target information about:

1. Personal information of survey takers (with their consent),
2. Difficulties and benefits and of starting a rooftop garden,
3. Management of rooftop gardens and,
4. Factors important for improving rooftop gardening.

Appointments for the telephone survey were booked in advance. Each participant was also provided with the questionnaire file in their email before conducting the telephone survey so that they can prepare their responses. The questions posed to them in the interview lasted for about 15–20 minutes. The initial plan of conducting this survey in person was cancelled to lower the risk of COVID-19 pandemic. Accordingly, a telephone survey was conducted in Kathmandu between 2021–2022. The telephone survey was conducted instead of paper survey to avoid public health risk during the Covid-19 pandemic and also because some gardeners were unable to receive emails. Collection of survey data was assisted by a local university student in Kathmandu.

3. RESULTS AND DISCUSSION

The results of this survey are presented below along with data and figures:

3.1 Personal Information of Survey Takers

As seen in figure 1, the age range of participants was 20s–80s. Gardeners aged in their 40s were the highest in number, followed by 50s. Figure 2 shows that female rooftop gardeners were more than double the male gardeners. Figure 3 shows that most rooftop gardeners were married and figure 4 shows the main profession of rooftop gardeners. We found that 37.5% were housewives and 25% were job-holders; 18.75%

were running their own business and 12.5% were retired job-holders. Figure 5, shows the time taken for tending rooftop gardens. Most rooftop gardeners spent 15–20 minutes every day; those spending 2 hours per day were few. From figure 5 and 6, we know that most rooftop gardeners tended their gardens on daily, mostly devoting 15–20 minutes. Others who did not tend their rooftop gardens daily, worked on their gardens at least 2–4 days per week. Figure 7 shows gardeners who tended roof gardens on their own, were considerably high in proportion. Couples gained help from each other to tend their rooftop gardens. Other members of the same family who lent a hand were mostly female. Generally, rooftop gardens were maintained by the gardener himself/herself, while only in a few families, all family members were involved and tended a particular area of the roof. In very few cases, a professional roof-top gardener was hired for garden maintenance. Figure 8, shows people who have a rooftop garden since the past 2–5 years was the highest in number, whereas the people who have had a rooftop garden for more than 20 years was the least.

3.2 Constraints and Benefits and of Starting a Rooftop Garden

Figure 9 shows the reasons why residents want to start rooftop gardens. Most rooftop gardeners want to grow vegetables and edibles because they want to avoid consuming chemical pesticide or insecticides. 37% of the survey takers were inspired by others achievement to start their own rooftop garden. Other popular reasons were 1) to start as a hobby 2) learning about plants, 3) gaining a new skill as a gardener and 4) saving on grocery cost. Figure 10 shows the total roof area used for gardening purpose. Most rooftop gardeners used 30% of the total roof area. Less than 10 participants answered that they used 70% of the roof area. Figure 11 shows the privately invested amount, indicating that rooftop gardeners spent a minimum of 5–70 thousand Nepalese Rupees. Figure 12 shows that most rooftop gardeners did not receive any financial support, however, some gardeners received materials or financial support to start their rooftop gardens from local non-government organizations or the Kathmandu Metropolitan City (KMC).

Some common constraints mentioned by rooftop gardeners were as follows:

- (a) **Cost:** The initial high cost of water-proofing the roof floor is the main reason why most gardeners opt for containers made of plastic, clay or recycled polystyrene foam.
- (b) **Pest and disease control:** The most commonly mentioned pests were aphids and snails and powdery mildew. Home-made pesticides like spray made of neem oil, turmeric, dried marigold, soapy water, tea or coffee spray, ash and setting up pest traps were mentioned.
- (c) **Bad weather conditions:** Direct sunlight, heat, strong wind, rain and hail etc. were some of the bad weather conditions experienced. Making plastic shades using bamboo was a common practice to protect the plants from them, but it added to costs and extra skill needed.

Some common benefits mentioned by rooftop gardeners were as follows:

- (a) Using spare time at home for productive activity.
- (b) Harvesting and consuming home grown fresh vegetables.
- (c) Opportunity for recycling rain water and kitchen waste-water to water plants on roof gardens.
- (d) Creating a green ambience at home.
- (e) Gaining social connection by posting about harvest, problems on social media.
- (f) Gaining mental peace and physical exercise through gardening.
- (g) Learning gardening skills and gaining knowledge about plants and nutrition in diet.
- (h) Adding edible greenery in a previously vacant space.

Table 2 shows common 12 factors mentioned by rooftop gardeners in Kathmandu as challenges or benefits of RTGs.

3.3 Management of Rooftop Garden

- (a) **Seeds and saplings:** Most rooftop gardeners purchased seeds and saplings from local agro-vet shops, or local nurseries. Recently, rooftop gardeners exchanged seeds and saplings with people they met via social media groups or forums for free or a price. Using the internet and social media seem to benefit the rooftop gardeners in Kathmandu, however, this is limited to internet availability and internet literate people.
- (b) **Plants grown on rooftops:** The following were plant groups commonly grown on rooftops of Kathmandu as derived from table 1: 1. Seasonal vegetables mainly leaf-spinach, mustard leaf, fruit-tuber-seed vegetables; 2. Fruits mainly citrus like lemon, kumquat, orange, pomelo, guava, pear, plum; 3. Herbs like lemon grass, aloe, curry leaf, rosemary; 4. Spices used daily such as garlic, chili, coriander etc.
- (c) **Infrastructure:** Figure 13 shows that most rooftop gardens existed on private home/buildings and only few gardeners were renting their roof space. It is not yet common for the tenants to use the roof space for growing vegetables for personal consumption unless it was used for commercial purposes like running a restaurant.
- (d) **Plant varieties grown yearly:** Figure 14 shows the common variety of edible plants planted on rooftop gardens. Most rooftop gardeners were able to grow 11–20 varieties of vegetables annually, followed by those who grew 6–10 varieties and the least number of gardeners grew 1–5 varieties. The quantity of production was not mentioned.
- (e) **Plans of expansion:** Figure 15 shows 69% of the rooftop gardeners wanted to extend their rooftop gardens in other areas of their roof space, however, 27.5% did not want to extend. Only 2 gardeners answered as “maybe”. Since most RTGs are tended by the gardener alone, expanding the garden may not be the right choice for people who denied this choice.

- (f) **Rent the roof for income:** Figure 16 shows that 52.5% of the respondents did not want to rent their roof space whereas 20% of the respondents wanted to rent out their roof space so others can start a roof garden, if separate access to roof can be provided.
- (g) **Career as RTG expert or trainer:** 75% of the respondents wanted to expand their career as RTG expert or trainer, however, 25% of the participants did not wish to become a trainer even when paid, perhaps because majority of the respondents were housewives (Figure 2, 3).

3.4 Factors Important for Improving Rooftop Gardening

Figure 17 shows the responses for 8 important factors to improve the condition of rooftop gardening.

- (a) *Training for rooftop gardener:* 62.5% of the respondents thought it was very important.
- (b) *Technical knowledge for rooftop gardening:* 64% of the respondents thought it was somewhat important and 12.5% thought it was very important.
- (c) *Access to funding, subsidies and grants:* 44% of the respondents thought it was somewhat important and 30% of the respondents thought it was very important.
- (d) *More time to maintain RTGs:* 45% of the respondents thought it was less important and 30% of the respondents thought it was somewhat important.
- (e) *Access to more variety and better quality seeds:* 49% of the respondents thought it was somewhat important and 49% responded that it was very important.
- (f) *Access to appropriate gardening tools and equipment:* 59% of the respondents thought it was less important, only 9% of the respondents thought it was very important.
- (g) *Favorable weather condition:* 77% of the respondents were not sure.
- (h) *RTG expert they can call on:* 41% of the respondents were not sure. 14% of the respondents thought it was somewhat important and 9% of the respondents thought it was very important.

4. CONCLUSION

This study was conducted during the pandemic period when people were confined in their homes and had to work from home. Most respondents have continued sharing photos about their rooftop gardens on SNS, asking or giving suggestions. The combination of rooftop gardening and internet literacy was key for them to maintain their social connection, enhancing their emotional well-being as well.

Response from the survey-takers in this study, has helped us picture the challenges faced by rooftop gardeners in Kathmandu. It must be noted that, most respondents were home owners who had free access to their roof space. Residents who rent rooms located on the lower floors of these homes usually have no access to roof space for gardening purposes (Tuladhar, 2019). Also, it must be noted that in Kathmandu,

there are diverse other uses of rooftop space, other than growing edible and ornamental plants. Many people use rooftop space for placing compost bins to recycle organic kitchen waste, harvest rainwater, place water supply poly-tanks, solar water heaters or even solar panels to generate electricity (Tuladhar, 2022). It is also space for drying laundry, spices or preserved foods; a space to sunbathe, oil massage children, enjoy meals during festivals, fly kites, place flags etc. according to the ethnic background of homeowners. Considering the busy urban life-style, Kathmandu's rooftops is also acknowledged for its therapeutic purposes. Being a convenient, educational and recreational activity, rooftop gardening can generate multiple benefits to human society and environment. In the following paragraphs, some recommended actions have been described to further develop rooftop gardening in Kathmandu's context.

First, the commercial potential of rooftop gardening can be expanded by developing products and services targeting city gardeners, so it is urgent to attract the attention of investors in this sector. Examples of commercial products can be containers for container farming purpose. Since we found that most were container gardeners and did not waterproof their roofs in fear of damaging their property, further studies can be conducted focusing on developing containers specifically for rooftop gardening. According to Nagase & Lundholm, 2021, lack of attention to container gardens might be largely because rooftop gardens are unregulated by local governments, in contrast to other types of green-infrastructure, therefore, in general, they are not treated as seriously. Regulating and standardizing the container's size and shape can be diversified according to available space and vegetable to be grown. As the home size and space availability varies, trellis stands, step racks, hanging baskets, ropes etc. need to fit the building infrastructure. Further studies are necessary to learn how to maximize the productivity of available roof space. It is suggested to start keeping a record of homeowner's original innovation and creativity for using available resources. Secondly, easy annual growth cycle chart of vegetables, spices, herbs and fruits can help gardeners follow a regular pattern and know what to grow and when. Standardized methods for production of specific edibles used for daily consumption in Nepalese kitchens must be developed. This way, in future paths to develop RTGs for commercial food production may open.

Thirdly, more similar surveys can provide insights to develop materials and courses attracting whole families and communities to gardening. This way at household level, people can save or enjoy extra income, at community level, city planners, builders, architects, designers and product designers alike can benefit by generating projects and employment opportunities regarding rooftop gardening and sustainability. Further studies can help local governments to review existing policies regarding developing building codes in a way that provides more space for rooftop gardening and modifying urban life-style.

In fact, utilizing roof spaces as rentable space in Kathmandu is not a new concept. There are terrace garden cafes and restaurants are operating already. RTGs, in the case of rapidly urbanizing Asian cities, offer excellent possibilities to enhance human health, and environmental conservation, and promote eco-friendly lifestyles

therefore, practical standard methods need to be developed further to make it more than a hobby.

ACKNOWLEDGEMENTS

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APPENDIX 1

Questionnaire Survey Used for This Research

Personal Information

- Name: _____ Age: _____
- Hometown: _____ Education Level: _____ Profession: _____
- Marital status: _____ Family members-total: _____
- Length of time as rooftop gardener: _____ months _____ years
- Rooftop garden training/workshops experience: yes or no
- Which floor is your roof-garden : _____ th floor
- Number of days you work in your rooftop garden: _____
- Number of hours per day you spend looking after plants on your roof : _____
- Family members who help you with your rooftop garden: _____

Starting a Rooftop Garden, Benefits and Difficulties

1. Which of the following applies to you, please circle and add your own reason/s for starting your rooftop garden.
 - (a) I have a rooftop garden because gardening is my hobby.
 - (b) I started rooftop gardening to grown my own vegetables to save grocery cost.
 - (c) I started rooftop gardening because I feel it is safer and has no chemical insecticides.
 - (d) I started rooftop gardening to learn gardening as a new skill.
 - (e) I started rooftop gardening because I was inspired by my neighbors/ friends.
 - (f) Other reason/s: _____
2. What is the total area of your roof? About square meters.
3. How much roof area is used for growing?

10% 20% 30% 40% 50% 60% 70% more than 50%

4. Approximately how much money did you spend to start your rooftop garden?
- (a) Buying water pipe
 - (b) Water proofing the floor of the roof
 - (c) Construction of greenhouse using plastic or glass
 - (d) Others

Total cost: Nepali rupees

(a)

(b)

5. Did you apply or receive any financial support (from any organization or government) to start or improve your rooftop garden? Yes/No
6. Did you face any of the following difficulties while working on the rooftop garden?
- (a) You had no idea choosing what vegetables to grow:
 - (b) Yes/No, If yes, how did you solve it?
 - (c) Were you affected by bad weather like strong winds/heavy rain/hailstorm/snow affecting your garden and it became difficult to protect your plants:
Yes/No, if yes, how did you solve it?
 - (d) Water shortage and difficulty in watering your rooftop garden.
Yes/No, If yes, how did you solve it?
 - (e) Disease affected the plants in the rooftop garden.
Yes/No, If yes, how did you solve it?
 - (f) Pest insects damaged your vegetables. Yes/No
If yes, how did you solve it.
 - (g) Water proofing was too costly so you are limited to container gardening.
Yes/No, If yes, how did you solve it.
 - (h) Problem with other people because of your rooftop garden.
 - (i) Any other problems you faced:
7. Benefits from your rooftop garden. Circle from the following and add new ones.
- (a) I could use my free time efficiently.
 - (b) I was able to harvest fresh vegetables at home.
 - (c) I could recycle my kitchen waste is now possible.

- (d) I could improve my social connection through my posts on SNS about my rooftop garden.
- (e) I could gain more knowledge about gardening.
- (f) I have become more aware about food production supply chain.
- (g) I got a chance to learn about growing food.
- (h) Any other benefits from your rooftop garden.

Rooftop Garden and Management

8. Where do you buy the seeds and saplings to plant?
9. Do you know how to propagate them yourself? Yes/No
10. Name the vegetables, fruits, flowers, herbs and spices you grow on monthly basis.
Jan.–Feb. Feb.–Mar Mar.–April April–May May–June June–July
July–Aug. Aug.–Sep Sep.–Oct. Oct.–Nov. Nov.–Dec. Dec.–Jan.
11. Did you have any problems with rooftop infrastructure (eg. cracks, roof leaks, etc.) Yes/No
12. What measures have you taken to solve these problems and whom did you seek help?
13. Right now do you work in rooftop garden of your own house or rental property?
14. Have you hired anyone to tend your rooftop garden?
15. If anyone asks you to work in their rooftop garden would you like to work?
16. Would you like to earn extra money as a rooftop garden expert and train other people?
17. How many varieties of edible plants do you grow?
18. Do you want to expand your rooftop garden to have enough produce to sell?
19. Do you want to rent the roof of other houses to practice rooftop garden as a source of income?

Rate the following

Which of the following factors are important for improving your rooftop garden? Rate each one using this scale [1 = Not important; 2 = Less important; 3 = Not sure; 4 = Somewhat important; 5 = Very important]

- (a) Training in rooftop gardening 1 2 3 4 5
- (b) Technical knowledge for rooftop gardening 1 2 3 4 5
- (c) Access to funding, subsidies and or grants ... 1 2 3 4 5
- (d) More time to maintain my rooftop garden ... 1 2 3 4 5
- (e) Access to better quality and variety seeds, 1 2 3 4 5
- (f) Access to appropriate gardening tools & equipment 1 2 3 4 5

(g) Stable weather conditions 1 2 3 4 5

(h) Rooftop gardening experts whom I can call on 1 2 3 4 5

Please add your additional comments and opinions: Thank you for your answering this questionnaire.

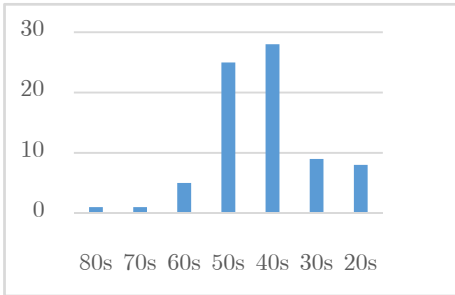


Figure 1: Age Group of Rooftop Gardeners

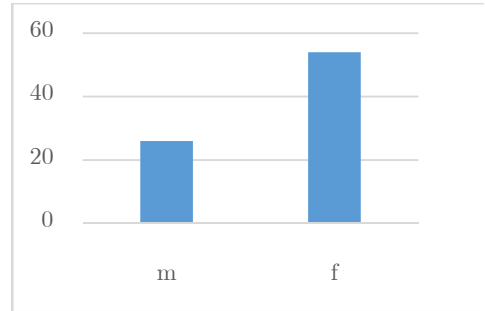


Figure 2: Gender Difference

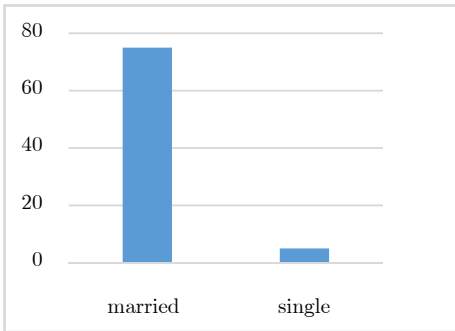


Figure 3: Marital Status

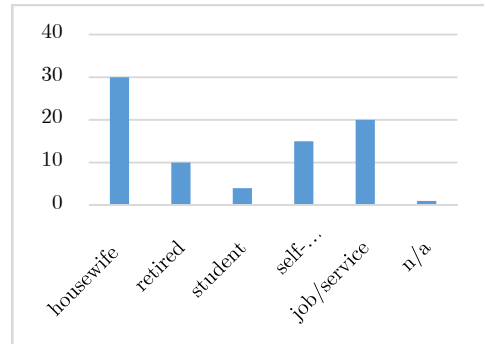


Figure 4: Main Profession of Roof Top Gardeners

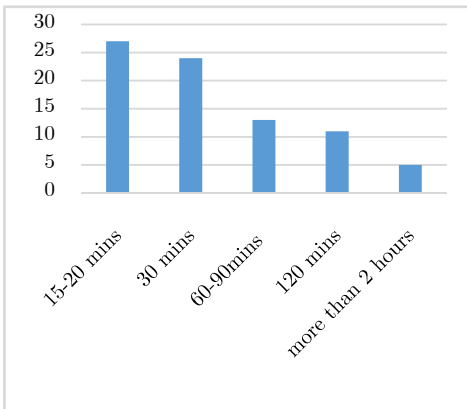


Figure 5: Time Devoted for RTGs

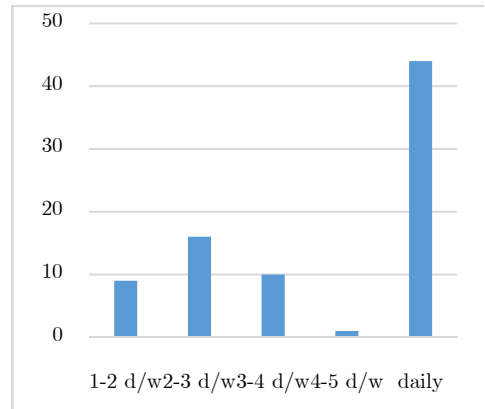


Figure 6: Work on RTGs Days Per Week

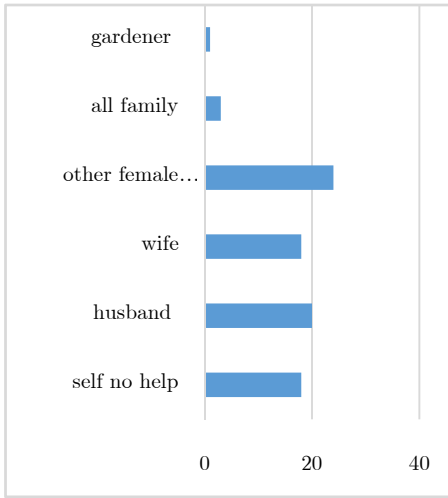


Figure 7: Help Tending RTGs within Family

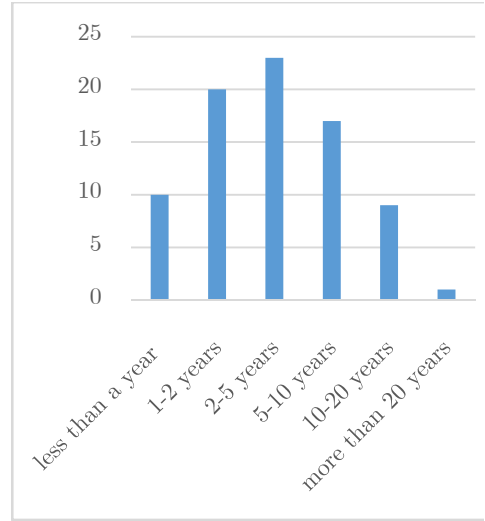


Figure 8: Years as Rooftop Gardener

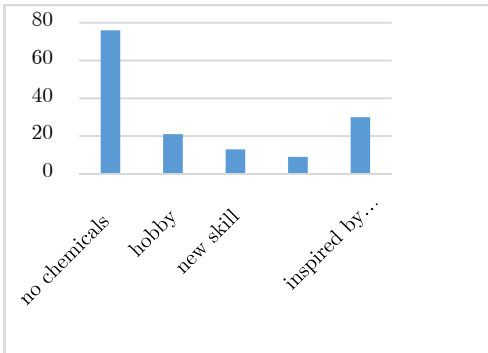


Figure 9: Reasons for Starting RTGs

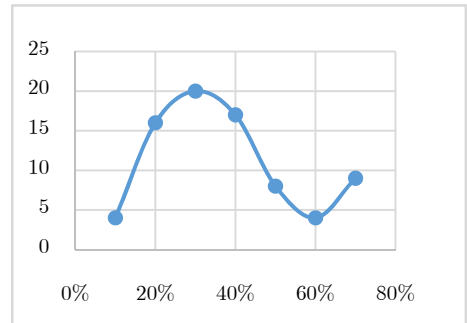


Figure 10: Roof Area Used for RTGs

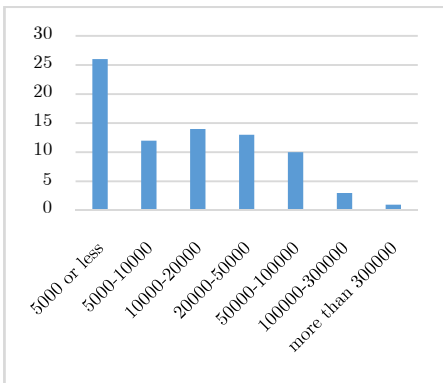


Figure 11: Amount Spent on RTGs

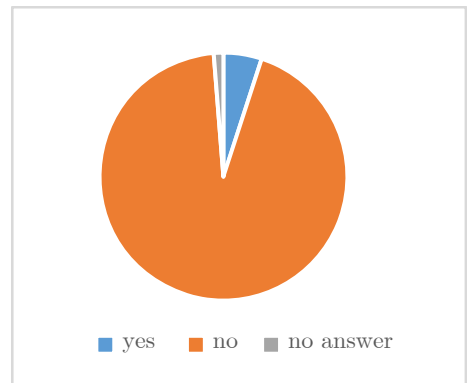


Figure 12: Financial Subsidy for RTGs

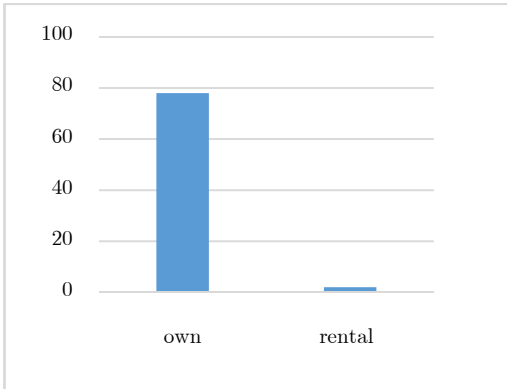


Figure 13: RTGs Own or Rental Property

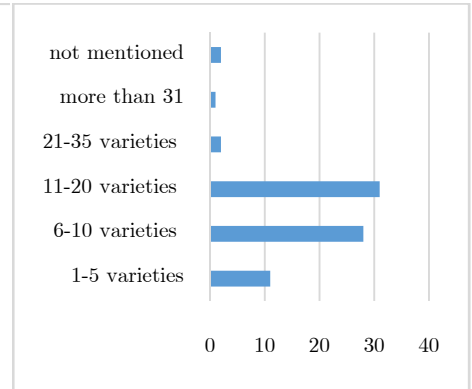


Figure 14: Varieties of Plants Grown on Rooftops

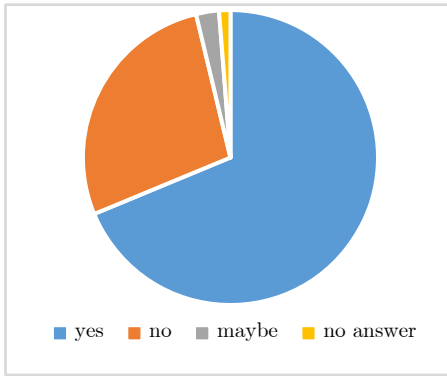


Figure 15: Intention to Extend RTGs

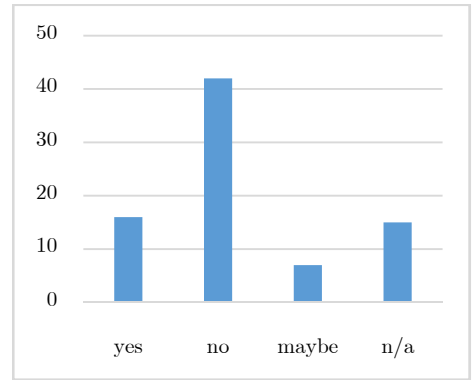


Figure 16: Intention to Rent Roof Space for RTGs

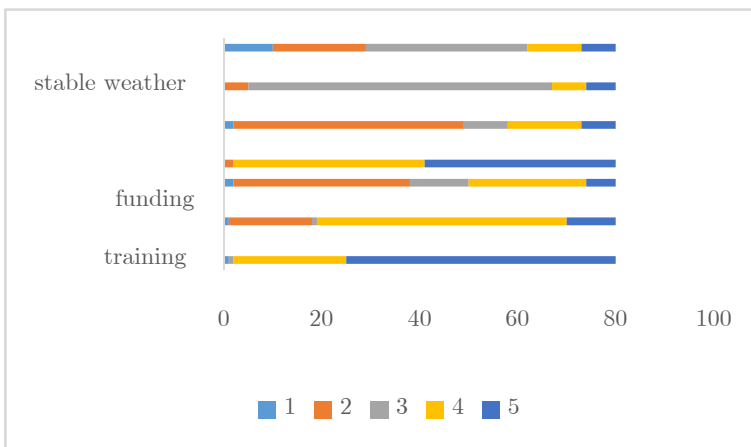


Figure 17: Factors for Improving RTGs



Figure 18: A: Buyers and sellers at the morning vegetable market on the street before shops open for business; B: Banner for rooftop garden training targeting women's group; C: A woman tending her container garden on her rooftop; D: A migrant woman vending vegetables for income generation. Photo credit for B&C goes to Shekh Narayan Maharjan.

Table 1: Edible Plants Commonly Grown on Rooftops in Kathmandu

<i>Vegetables</i>	<i>Fruits</i>	<i>Herbs</i>	<i>Spices</i>
Spinach,	Lemon	Lemon grass	Garlic
Mustard green,	Kumquat	<i>Aloe vera</i>	Ginger
Butter Beans,	Pomelo	Curry leaves	Coriander
Faba beans,	Guava	Peppermint	Chilly
Egg plants,	Pear	Chamomile	Chives
Cauliflower,	Plum		
Onion	Dragon fruits		
Tomatoes	Papaya		

Table 2: Challenges and Benefits for Maintain RTGs

<i>Difficulties Faced by Gardeners</i>	<i>Beneficial Methods Implemented by Gardeners</i>
1. Cost of waterproofing the floor	2. Water-proofing provides additional space
3. Standard container rooftop gardening not available	4. Commercial products targeting rooftop gardeners can be marketed
5. Pest and disease control using non-chemical methods	6. Knowledge sharing on SNS platforms is educational and problem solving
7. Protection from adverse weather conditions	8. Construction of shelter and shades that are temporary and easy to set up using plastic, bamboo
9. Water scarcity/shortage	10. Rain water harvesting from roofs, recycling kitchen waste water.
11. Difficulty in choosing which vegetables to plant and availability of seeds and saplings	12. RTG platforms on social media is beneficial for internet literate gardeners who purchase, exchange or donate seeds and saplings of plants.

Organic Waste to Promote Food Green City in Kathmandu Valley of Nepal

Indira Parajuli¹ and Sunil Babu Shrestha²

ABSTRACT: This chapter discusses the significance of organic waste in promoting urban agriculture in Nepal. The world is rapidly urbanizing. More than 75% of the world's food demands are now accounted for by cities. The mechanisms that supply food to cities are under tremendous strain as a result of rapid urbanization and expansion. Furthermore, many cities around the world are dealing with problems including a rapid loss of agricultural lands including green space. In such a situation, for the sustainability of cities, the urban food system must be innovative and sustainable. Nepal, being an agricultural country, is well-positioned to integrate urban agriculture with land use planning, aligning with the principles of the Food Green City concept. After state restructuring, the country now consists of 293 municipalities constituting about 66.17% of the total population according to the 2021 census. The majority of cities (municipalities) place a high priority on solid waste management. Municipalities are investing a large share of their revenue to solve this problem even though more than 60% of the country's garbage is organic. This organic fraction of solid waste can be composted and used for urban agriculture. Composting is thought to be a sustainable method. If the organic waste is converted into compost, it can help to solve the management of organic waste. Moreover, the productive use in promoting urban agriculture including rooftop farming or gardens for producing food sustainably in the cities. Using the secondary data and literature review, this chapter aims to discuss ways to promote rooftop farming using the organic fraction of solid waste in the Kathmandu Valley of Nepal.

Keywords: Compost, Food Green City, Rooftop Farming, Sustainable Urban Food System, Solid Waste Management, Urban Agriculture.

1. INTRODUCTION

Cities are significant contributors to global food demand, accounting for about three-quarters of the total. They also generate approximately 70% of greenhouse gas emissions worldwide. Moreover, cities consume more than 75% of the world's energy resources. These trends are expected to continue rising in the coming years (IEA, 2024). These cities must provide creative food solutions and long-term

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sustainability. As of now, 55% of people on the planet live in cities, and by 2050, that number is expected to rise to 66% (United Nations, 2017). Rapid urbanization and urban expansion are placing pressure on the food supply systems of cities. In addition, there are worries about growing heat island effects² and the quick disappearance of green space in many cities across the world. This is due to the replacement of green spaces by buildings, roads, and other infrastructure. This reduces the amount of vegetation that can help cool urban areas through shading and evapotranspiration. To address the challenge of ever-increasing food demand, balcony or rooftop gardening and other forms of urban agriculture are being promoted as an alternative. The Nepalese Government has focused on the concept of a Food Green City, which involves the integration of urban agriculture, including rooftop farming, with urban planning as mentioned in the Fourteenth National Plan document, the National Planning Commission of the Government of Nepal prepared Directives and Working Procedures for Food Green City (NPC, 2016).

In urban areas, rooftop agriculture has gained popularity as a means of expanding localized urban agriculture, especially concerning green roof production systems (Ouellette *et al.*, 2013). Many cities around the world currently grow more than 20% of their vegetables (Tomalty *et al.*, 2010). According to Gaglione *et al.* (2010), rooftop vegetable production should be viewed as an addition to the urban food movement rather than as a substitute for large-scale vegetable cultivation in rural areas. This is because it offers a new supply of fresh, local produce. Urban agriculture is frequently employed in developing countries, even though many cities in wealthy countries want to get at least some of their food locally (MacRae *et al.*, 2010).

Rooftop gardening has several benefits. In addition to supplying fresh produce, rooftop gardening helps reduce the urban heat by reducing the temperature of rooftops and the surrounding air. Thus, rooftop farming can assist reduce the impact of the urban heat island effect and contribute to the general cooling of the surrounding area (Ries, 2014; Hui, 2011). Rooftop gardening also helps lessen noise pollution and carbon emissions (Dubbeling, 2014). Moreover, plants collect and absorb rainwater, so overflowing has less of an effect on infrastructure (Ries, 2014). Vegetable-covered rooftops are a great place to relax, and this kind of gardening can easily create jobs (SGUFS, 2014). Rooftop gardening also promotes biodiversity by giving residence to a range of insects and birds (Higher Ground Farm, 2019).

Solid Waste Management (SWM) is a major environmental concern in many developing countries like Nepal. Urban population growth and economic development contribute to increased waste generation. Kathmandu Valley, with its dense population, faces a particularly high quantity of waste. The quantity of solid waste has been steadily rising due to urban expansion, changing consumption patterns, and industrial growth. This escalating waste volume poses a significant challenge for effective SWM.

²It refers to the phenomenon where urban or metropolitan areas experience significantly higher temperatures compared to their rural surroundings.

It is widely recognized that waste management in urban areas is a major challenge. Urban households produce a significant amount of waste daily that can be an important source of plant food in urban areas. Kitchen waste encompasses a diverse array of materials such as stale bread, eggshells, coffee grounds, damaged food, non-liquid cooked food scraps, bones, and discarded vegetable and fruit parts (peels and leftovers). When exposed to oxygen, microorganisms like fungi, actinomycetes, and bacteria facilitate the breakdown of kitchen waste into humus, a nutrient-rich material ideal for cultivating vegetables on rooftops, thus enhancing local food production (Wilson, 2009).

Composting stands out as a regulated, aerobic process that harnesses natural decomposition to convert organic matter into stable compost, a valuable soil amendment. During composting, microorganisms metabolize the organic materials by consuming oxygen for respiration, requiring water for digestion, and utilizing carbon and nitrogen for growth and reproduction. This biological process mirrors nature's recycling mechanism. Alternatively, vermin-composting, or worm composting, offers a practical indoor or outdoor solution using worms, food scraps, bedding, and a container. When managed properly, worm bins do not emit odors or attract pests, yielding nutrient-rich compost beneficial for soil health.

While studies on SWM in Nepalese municipalities have explored composting organic waste, there remains a significant gap in effectively utilizing the resulting organic manure from solid waste. Addressing this gap could greatly improve waste management practices in cities. Furthermore, urban households stand to benefit by utilizing organic manure to cultivate fresh green vegetables and fruits locally. This approach not only reduces reliance on external markets but also ensures access to fresher and healthier organic produce. Hence, this chapter delves into the potential of fostering urban agriculture in Kathmandu Valley through leveraging urban waste resources.

1.1 Rooftop Farming: As a Component of Food Green City

Rooftop vegetable production is the practice of growing different kinds of vegetables on the roofs of buildings located in major cities (Sustainability Television, 2019). Urban rooftop horticulture frequently employs hydroponics, aeroponics, organic farming, container gardens, and green roofs (Asad and Roy, 2014). Well-designed greenhouses with hydroponic systems work especially well (Sustainability Television, 2019). Urban dwellers can obtain a substantial amount of veggies via rooftop vegetable gardening while also potentially helping the environment (Liu *et al.*, 2016). Furthermore, in highly populated metropolitan regions, rooftop vegetable cultivation has social and environmental benefits (Hui, 2011).

In urban places, growing vegetables on rooftops can help achieve social, economic, and environmental sustainability. By boosting local food production, supplying the nutritional needs of those with limited access to wholesome food, lowering air pollution, increasing storm water retention capacity, boosting public health, elevating

the aesthetic value of the urban environment, and encouraging community involvement, it can improve urban food systems (Localize, 2007). The concept of Food Green City has been defined by the Government of Nepal's National Planning Commission (NPC) as a way to achieve sustainable urban development with a focus on smart and eco-city (NPC, 2016).

1.2 Rooftop Vegetable Production in the World

Vegetable gardening on rooftops has garnered significant attention recently as a means to promote agricultural sustainability within metropolitan environments. This practice offers several advantages, including enhanced resource efficiency and improved food security for urban dwellers. Rooftop agriculture is gaining prominence due to its ability to provide additional spaces for vegetable cultivation to cater to urban markets, thus becoming a pivotal component in the resurgence of urban agriculture (Ouellette *et al.*, 2013).

One of the primary benefits of rooftop vegetable production is its capacity to supplement fresh, locally grown foods to feed urban populations. Rather than replacing large-scale vegetable cultivation in rural areas, rooftop gardens should be viewed as a complementary strategy within the broader urban food movement (Gaglione *et al.*, 2010; Tomalty *et al.*, 2010). By integrating rooftop agriculture into urban planning and sustainability initiatives, cities can bolster their food resilience and reduce dependency on distant food supply chains.

Overall, rooftop vegetable gardening not only supports local food production but also contributes to environmental sustainability by utilizing underutilized urban spaces, enhancing biodiversity, and reducing the carbon footprint associated with transporting food over long distances. This approach aligns with broader efforts to create more resilient and sustainable cities in the face of growing urbanization and environmental challenges.

Currently, more than 20% of the vegetables needed by several cities are produced inside their borders (MacRae *et al.*, 2010). Urban agriculture is widely employed in underdeveloped countries, however, many cities in wealthy countries want to get at least some of their food produced locally (MacRae *et al.*, 2010). Urban agricultural activities significantly contribute to local food supplies in Bologna (Italy), Chicago (USA), Cleveland (USA), Hong Kong (China), Montreal (Canada), New York (USA), Portland (USA), Seattle (USA), Shanghai (China), Taipei (Taiwan), Tokyo (Japan), Toronto (Canada), and Vancouver (Canada), to mention a few places (MacRae *et al.*, 2010).

Bologna, Italy, has rooftop gardens that have the potential to produce over 12,500 tons of vegetables annually, meeting 77% of household vegetable demands and capturing an estimated 624 tons of CO₂ if all available flat roof space is exploited for urban agriculture (Science for Environment Policy, 2015).

For urban agriculture to succeed, more vegetable crops must be grown inside city limits. However, vacant lots and other properties that have historically been utilized

for agriculture are susceptible to development inside metropolitan centers. Because there is a shortage of space in cities, urban agriculture finds it difficult to supply the present demand for locally produced goods. It is possible to effectively replace the green space lost to construction development using green roofs. Consequently, rooftop agriculture has become a desirable means of expanding localized urban agriculture, particularly concerning green roof production systems (Ouellette *et al.*, 2013).

Increasingly now, a lot of people are interested in rooftop gardening, particularly in urban areas. This is because rooftop gardens are well-known for their many benefits, which include serving as a source of wholesome food, circulating fresh air, sequestering carbon, providing aesthetic value, and reducing heat in buildings (M. Safayet *et al.*, 2017).

Furthermore, intensive vegetable production, organic products, and resource-efficient agriculture have all been acknowledged as benefits of rooftop agriculture (Thapa *et al.*, 2020). As a result, a lot of people have already chosen rooftop farming as their hobby. Businessmen, entrepreneurs, and retired personnel from the public and commercial sectors now enjoy rooftop agriculture as a hobby. Their efforts are contributing to the greening of cities despite the scarcity of arable land. Some even go so far as to rent out their rooftops. Organic fruits and vegetables devoid of chemicals are always preferred by consumers, creating a rising trend. They have ready access to fresh, organic food because of rooftop gardens.

In addition, these people help to create a healthy atmosphere in cities by putting plants on rooftops (The Daily Star, 2019). Roughly twenty-five crops are grown in rooftop gardens in Bangladesh. In Dhaka, rooftop farming is anticipated to produce 25% of gourds, 47.8% of Indian spinach, 45.3% of chillis, and 61% of brinjal. Additionally, Chattogram City grows 48% of its produce brinjal, 35.7% of Indian spinach, 35.6% of gourds, 31% of ladyfingers, 23% of tomato, 23% of red amaranth, 18% of beans, cabbage, and 7% of cauliflower (Uddin *et al.*, 2016).

The Agricultural Extension Division offers training and logistical support to anyone interested in rooftop gardening and horticultural growth. The “Green Roof Movement,” which emphasizes the technical and financial aspects of rooftop gardening, is spearheaded in Bangladesh by the Roof Garden Association (RGA) (Uddin *et al.*, 2016).

1.3 Rooftop Farming in Kathmandu Metropolitan City (KMC)

Rooftop gardening can be potentially a key strategy for addressing issues with food security and advancing sustainable agriculture in cities. Rooftop farms make up 5 to 13% of the territory in Kathmandu Metropolitan City (KMC), and most of the people who work there are women who tend to the gardens (Thapa *et al.*, 2020).

Thapa *et al.* (2020) estimate that rooftop farming in the case of KMC will yield the following saving benefits: \$3456.86 is allocated to food production, \$11–19 to enhance air quality, \$20609 to retain storm water, and \$6–7 to sequester carbon. Rooftop farming is still maintained with traditional planting supplies like pots,

plastic bags, and Styrofoam containers. Those who are interested in rooftop farming must receive proper training because there can be many constraints to be considered when it comes to the establishment of rooftop farming. They will be able to maintain and manage their farms more skillfully thanks to this training. To solve issues with food security and advance sustainable agriculture, rooftop gardening is becoming increasingly important in metropolitan areas.

2. MATERIALS AND METHODS

This chapter is based on the analysis of previously published data. Numerous publications on waste management and methods for making compost or organic manure (OM) from organic fractions of solid waste were reviewed. We followed the ideas of food-green cities (Shrestha, 2021) worldwide and in Nepal as a part of this research. Furthermore, data on solid waste from the Central Bureau of Statistics (National Statistics Office, 2021) were analyzed, and OM was calculated using the organic fraction of solid waste. Utilizing the concept of Journey to Forever Organic Garden, 2012, one thousand earthworms may produce about 25 kg of vermin-compost per week from 45 kg of wet biomass if the right physical and environmental conditions are met.

The use of the humus-rich OM for open space and rooftop farming would further the idea of a food-green metropolis.

The Kathmandu Valley (KV) was selected as the study area for this research to improve food production and green spaces to meet the demands of the urban population. The KV is comprised of three districts as shown in Figure 1. This study was only confined to a total of eighteen urban municipalities including two metropolitan cities within KV.

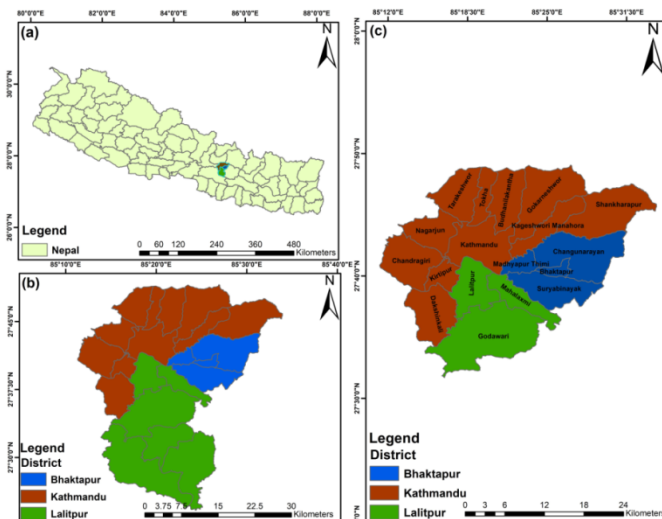


Figure 1: Map of Kathmandu Valley Showing three Districts and Eighteen Municipalities

This study concentrated on the production of OM from the organic portion of the solid waste generated, which could also help to lower the costs associated with solid waste management. The study used the recent census data of solid waste and utilized the organic fraction of solid waste production in the KV for the calculation.

For the urban farming space, the total households of KV where the backyard and front yard are utilized for the urban agriculture are taken into consideration. Whereas, for rooftop farming, only the Reinforced Cement Concrete (RCC) rooftop of buildings are taken as these types of buildings contain the rooftop space.

3. ANALYSIS AND RESULTS

3.1 Composting of Organic Fraction of Solid Waste

Composting is a green technique that allows for the recycling of organic waste and the production of organic fertilizer. Organic matters are naturally broken down in controlled conditions by worms and microbes. Food waste, animal waste, agricultural residues, some municipal wastes, and appropriate industrial wastes can all be used in the soil as fertilizer supplies once they have been composted. An organic substance can naturally become a black nutrient-rich material by composting. Valuable organic components can be found in compost. Soil organic matter is essential for preserving soil fertility and increasing agricultural productivity over the long run. It gives plants the vital nutrients they need while also enhancing the soil's biological, chemical, and physical qualities (FAO, 2002). Paper, textiles, and agricultural waste are the main kinds of organic waste; plastic, glass, rubber, metals, minerals, and other non-agricultural items are classified as inorganic waste.

The use of earthworms for composting organic leftovers is known as vermicomposting. Earthworms can consume almost any type of organic matter and can consume their body weight in residues each day. One kilogram of worms, for example, can eat one kilogram of residues every day. Worm excreta, or castings, contain accessible forms of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) and are high in nitrate, as Table 1 illustrates. The movement of dirt by earthworms facilitates the proliferation of actinomycetes and bacteria. Worm casts contain more than six times the number of actinomycetes found in the original soil, indicating that actinomycetes flourish in the presence of worms (FAO, 2002).

The kitchen waste material (control)³ has a high pH (9.32), organic carbon (7.25%), and organic matter (12.49%), as shown in the data (Table 1). Moreover, it includes trace levels of other nutrients, including exchangeable potassium (0.0086%), accessible phosphorus (0.11%), and total nitrogen (0.241%). Vermicomposting is advantageous for organic farming since it modifies kitchen waste material's physical and chemical properties dramatically. As the vermicomposting duration increases from 0 to 75 days, the pH drops from 9.32 to 8.37 as depicted in Table 1. Increased phosphorus

³Control means without vermiforms.

and nitrogen mineralization into orthophosphate and nitrates/nitrites is the cause of this decline. Likewise, the kitchen waste material's organic carbon concentration, organic matter content, and C:N ratio all steadily decline for up to 75 days. According to Bharadwaj (2010), the levels of organic carbon (7.25%), organic matter (12.49%), and C:N ratio (30.08%) were highest in the control group (0 days) and lowest after 75 days of vermicomposting, at 3.69%, 6.37%, and 4.79%, respectively.

Table 1: Effects of Vermicomposting on Different Physicochemical Parameters of Kitchen Waste (Bharadwaj, 2010)

S. N.	Parameters	Duration of Vermicomposting			
		0 days (Control)	15 days	45 days	75 days
1.	pH	9.32	9.22	8.9	8.37
2.	Organic Carbon (%)	7.25	5.265	5.078	3.69
3.	Total Nitrogen (%)	0.241	0.361	0.361	0.77
4.	Available phosphorous (%)	0.110	0.16	0.16	0.18
5.	Exchangeable potassium (%)	0.0086	0.196	0.196	0.38
6.	C:N ratio	30.08	14.06	14.06	4.79
7.	Organic matter (%)	12.49	8.75	8.754	6.37

3.2 Organic Waste Production across Nepalese Municipalities

The average annual and daily total garbage collected by the municipality in Fiscal Year 2073–2074 B.S. were 2,231 Mt and 6.1 Mt, respectively. The amounts were 2,164.4 Mt and 5.9 Mt in Fiscal Year 2074/75 B.S. and 2,232.7 Mt and 6.1 Mt in Fiscal Year 2075/76 B.S. When compared to other inorganic wastes, the percentage of organic waste was higher.

Table 2: Annual Average Organic Waste Collection Per Municipality by Years in Mt (National Statistics Office, 2021)

FY (in B.S.)	Metropolitan City	Sub-Metropolitan City	Municipality
2073/74	12734	2269.8	829.8
2074/75	13478	3044.2	950
2075/76	10669	4088.2	824.2
Average (Mt/Year)	12293.67	3134.06	868
Average Manure production (Mt/Year)	6829.81	1741.14	482.22

Note: Metropolitan cities: Kathmandu, Pokhara, Bharatpur, Lalitpur, Birgunj, Biratnagar.

Sub-Metropolitan cities: Dhngadhi, Ghorahi, Itahari, Hetauda, Janakpur, Butwal, Tulsipur, Dharan, Nepalgunj, Kalaiya, Jitpursimara.

Municipalities: Budhanilkantha, Birendranagar, Tarakeshwar, Gokarneshwar, Tilottama, Suryabinayak, Chandragiri, Tokha, Kageshwari-Manohara, Mechinagar, Bhimdatta, Sundar Haraincha, Madhyapur Thimi, Mahalaxmi, Birtamod, Nagarjun, Damak, Triyuga, Lahan, Godawari, Kohalpur, Tikapur, Siraha, Bhaktapur, Godawari, Barahachhetra, Kapilvastu, Lamki

Chuha, Bardaghat, Ghodaghodi, Banganga, Lumbini Sanskritik, Chandrapur, Vyas, Ratnanagar, Barahathwa, Rajbiraj, Barbardiya, Banepa, Shivaraj, Gulariya, Gaushala, Bardibas, Belbari, Kirtipur, Bhadrapur, Dudhauli, Kamalmai, Buddhabhumi, Shivasatakshi, Inaruwa, Siddharthanagar, Pathari-Shanischare, Kawasoti, Krishnanagar, Arjundhara, Ishwarpur, Rajapur, Ramgram, Lalbandi, Gaindakot, Jaleshwar, Nilkantha, Baglung, Rapti, Suryodaya, Krishnapur, Duhabi, Katari, Khairhani, Bansgadhi, Sainamaina, Changunarayan, Sunwal, Ratuwamai, Gauriganga, Maharajanj, Urlabari, Mahagadhimai, Bidur, Madhyabindu, Punarbas, Belauri, Devdaha, Gauradaha, Rangeli, Bhajani, Ramdhuni, Waling, Golbazar, Sunawarshi, Garuda, Tansen, Mirchaiya, Simraungadh, Manara Shiswa, Bedkot, Kalyanpur, Gorkha, Phidim, Chaudandigadhi, Ilam, Shuklagandaki, Godaita, Lamahi, Dhangadimai, Rupakot Majhuwagadhi, Shuklaphanta, Bhangaha, Paunauti, Gujara, Malangwa, Chautara Sangachokgadhi, Madhuwan, Sabaila, Bhanu, Hanumannagar Kankalini, Dhanushadham, Manthali, Khadak, Melamchi, Balara, Mithila, Putalibazar, Dakneshwari, Thakurbaba, Surunga, Hariwan, Gurbhakot, Sitganga, Bodebarsain, Kolhabi, Shahidnagar, Brindaban, Devchuli, Chhreshwarnath, Belaka, Balawa, Kabilasi, Kalika, Thaha, Dullu, Ishnath, Bheriganga, Sandhikharka, Rajpur, Gadhimai, Bagmati, Kankai, Belkotgadhi, Bahudarmai, Kushma, Loharpatti, Besisahar, Mahakali, Purchaudi, Hansapur, Kamala, Pyuthan, Kathariya, Palungtar, Parsagadhi, Shambhunath, Panchkhal, Madi, Sukhipur, Paroha, Hariapur, Ganeshman Charanath, Galyang, Dhankuta, PhatuwaBijayapur, Baudhimai, Bangad Kupinde, Haripurwa, Rampur, Chhedagad, Kanchanrup, Parshuram, Nagarain, Dasharathchand, Nijgadh, Madhav Narayan, Gaur, Pacharauta, Bagchaur, Sanphebagar, Shaarda, Aathabiskot, Mithila Bihari, Bheri, Beni, Bungal, Galkot, DipayalSilgadhi, Musikot, Deumai, Pokhariya, Musikot, Rolpa, Mandandeupur, Bhumikasthan, Mai, Resunga, Mangalsen, Bideha, Panchapuri, Dhulikhel, DewahiGonahi, Letang Bhogateni, Shikhar, Aurahi, Shadanand, Bhimeshwar, Jaimini, Bhimad, Rajdevi, Khandbari, Dhunibeshi, Matihani, Karjanha, Swargadwari, Patan, Lekbeshi, Ramgopalpur, Halesi Tuwachung, Namobuddha, Aathabis, Ramechhap, Siddhicharan, Panchadawal Binayak, Chaurjahari, Chainpur, Bhojpur, Narayan, Sundarbaz, Barhabise, Maulapur, Taplejung (Phungling), Dhorpatan, Chamunda Bindrasaini, Chapakot, Nalgad, Bhirkot, Shankharapur, Mahalaxmi, Phalewas, Dakshinkali, Kamalazar, Madhya Nepal, Melauli, Jaya Prithvi, Pakhribas, Shailyashikhar, Budhiganga, Amargadhi, Mahakali, Saptakoshi, Solu Dudhkunda, Khandachakra, Chhayanath Rara, Myanglung, Chandannath, Budhinanda, Rainas, Tribeni, Dharmadevi, Panchkhapan, Laligurans, Badimalika, Raskot, Tilagupha, Jiri, Madi, Tripura Sundari, Thuli Bheri.

The highest percentage of organic wastes i.e. 54.0% collected in Fiscal Year 2075–2076 B.S. was followed by 33.3% inorganic waste and 12.7% of other wastes. Among the various sectors, residential regions of metropolitan cities had the largest daily waste collection (15,900 kg/day), followed by business complexes (7,700 kg/day) and educational institutions (4,680 kg/day). Households continued to be the largest source of waste generation in municipalities (1,440 kg/day) and sub-metropolitan cities (3,300 kg/day) (National Statistics Office, 2021).

Table 2 shows that a Nepalese metropolitan city can produce 6,829.815 Mt/year of organic manure from 12,293.67 Mt/year of organic waste on average over three years. In the case of a sub-metropolitan city, 1,741.148 Mt of organic manure can be produced from 3,134.067 Mt of organic garbage. Similarly, municipalities can convert 868 Mt of annual organic waste into 482.22 Mt of organic manure.

With the ability to create 640.72 Mt of organic manure, the average production of organic waste in Fiscal Year 2073–2074 B.S. was 1153.3 Mt, as indicated in Table 3. In Fiscal Year 2074–2075 B.S., the output of organic waste increased by 5%, but in Fiscal Year 2075–2076 B.S., it declined by 0.7%.

Table 3: Annual Average Organic Manure Production Potentiality by Years in Mt (National Statistics Office, 2021)

<i>FY (in B.S.)</i>	<i>Metropolitan City (Mt)</i>	<i>Sub- Metropolitan City (Mt)</i>	<i>Municipality (Mt)</i>	<i>Annual Average (Mt)</i>	<i>Average OM Production (Mt)</i>
2073/74	12734.00	2269.80	829.80	1153.30	640.72
2074/75	13478.00	3044.20	950.00	1214.60	674.77
2075/76	10669.00	4088.20	824.20	1206.10	670.05

Table 4: Daily Average Household Organic Waste Collection and Potentiality of Organic Manure Production in the Individual Metro, Sub-metro, and Municipality in Kg

<i>City Type</i>	<i>Total Waste Collection Kg/day (CBS, 2020)</i>	<i>Organic Fraction (kg/day) (CBS, 2020)</i>	<i>Total of Organic Waste (kg/day) (CBS, 2020)</i>	<i>Total OM (kg/day)</i>
Metro city	15900	9540	57240	31800
Sub-metro city	3300	1980	21780	12100
Municipality	1440	864	238464	132480
Total			317484	176380

As illustrated in Table 4, metro cities produce 57,240 kg of organic waste daily, from which 31,800 kg of organic manure can be produced. Similarly, 21,780 kg of organic waste is produced daily in sub-metropolitan cities this waste can be composted to produce 12,100 kg of organic manure daily. It is predicted that Nepalese municipalities produce 2,38,464 kg of organic waste per day, with a potential daily generation of 1,32,480 kg of organic manure. Table 4 illustrates that a total of 3,17,484 kg/day of organic waste can be transformed into 1,76,380 kg/day of organic manure.

The amount of waste collected daily in metropolitan areas is higher (37,300 Kg/day) than in sub-metropolitan cities (11,000 kg/day) and municipalities (3,700 kg/day) (National Statistics Office, 2021). According to the national survey, families generate 38.6% of total waste, which makes up the highest portion of waste generation (National Statistics Office, 2021).

3.3 Organic Manure Production and Rooftop Farming Potential in Kathmandu Valley

The estimated daily production of organic waste in the KV is 105411.82 kg, as Table 5 illustrates. One thousand earthworms may produce about 25 kg of vermicompost per week from 45 kg of wet biomass if the right environmental circumstances are met. Worm castings are an important source of nutrients for plant growth since they contain five times the nitrogen, seven times the phosphorus, and eleven times the potassium present in ordinary soil (Journey to Forever Organic Garden, 2012).

By composting the organic component of solid waste instead of disposing it as municipal waste, approximately 58,562 kg of organic manure can be produced daily from KV. This valuable manure can be utilized to enhance urban agriculture and reduce the reliance on chemical fertilizers, pesticides, and hormones in food production, promoting the concept of a “Food Green City”.

The KV is home to a total of 784,608 families, or 2,936,462 people with 83% of Households in KV being of RCC roof type i.e. 649,220 (National Statistics Office, 2021). Each home has roughly 84 square meters of potential rooftop space accessible for urban agriculture (Shrestha, 2020). If only 67% of the available space is considered for the agro purpose each house has approximately 600 square feet of productive green space (400 square feet on the roof (67% of total agro potential space) and 200 square feet (33% of total agro potential space) in the front and backyard). While considering total RCC roof type houses for rooftop space, front and backyard space, and other houses for front and backyard space only, it is found that approximately 39 square kilometers of area in the valley can be utilized for productive green growth. This indicates that each person can have 13.28 square meters of free space for their use for farming purposes. Additionally, it accounts for approximately 5 percent of the entire area of the KV, which is valuable fertile land for vegetable production.

Furthermore, the KV has the potential to produce approximately 58,562 kg of organic manure per day, which can be utilized in urban agriculture to replace the need for chemical fertilizers.

According to the World Health Organization (WHO), an adult should consume 400 grams of vegetables and fruits (excluding potatoes) daily (WHO and FAO, 2003). Similarly, the Nepalese government recommends a daily vegetable consumption of 375 grams (excluding potatoes) (Ministry of Agriculture and Livestock Development, 2020). Table 4 demonstrates that the valley’s population requires 1174.58 Mt of vegetables per day based on WHO standards, and 1101.17 Mt of vegetables per day based on National standards. If the organic component of waste is converted into manure and used for urban vegetable production, the valley can meet its vegetable needs.

In a valley with an average family size of 3.75 persons (National Statistics Office, 2021), each household requires 1.40 kg of green vegetables per day. Additionally, on average, each household produces 0.13 kg of organic waste and 0.074 kg of organic manure daily based on the calculation. It is estimated that one kilogram of cauliflower production in their own open space requires 8.36 kg of manure per household per season (90 days) which produces 169.35 kg of cauliflower from each household per season (Devkota *et al.*, 2021). Taking cauliflower as an example, organic manure derived from the KV’s organic fraction of solid waste can potentially produce 106,754.76 Mt of green vegetables per season. This production can fulfill the vegetable requirement of KV as guided by WHO standards and Nepalese standards resulting in surplus production of 1% and 8% as per the WHO and Nepalese standards respectively as depicted in Table 6.

Table 5: Daily Average Household Organic Waste Collection and Potentiality of Organic Manure Production in Individual Cities within Kathmandu Valley

S. No.	Cities of Kathmandu Valley	Average Organic Fraction of Waste (kg/day)	Average Organic Manure (kg/day)	Area (sq. Km)	Population (Census, 2021)	HHs (Census, 2021)	Vegetable Need/day (WHO) in Kg	Vegetable Need/Day (GoN) in kg	Waste Generational/ HH/day (kg)	Organic Manure/ HH/day (kg)
1.	Kathmandu	33681.27	18711.82	49.45	862400	238966	344960	323400	0.140945867	0.078303259
2.	Budhanilkhantha Mun	2378.08	1321.156	34.8	177557	46930	71022.8	66583.875	0.050672917	0.028151621
3.	Tarakeshwor	2378.08	1321.156	54.95	151479	41362	60591.6	56804.625	0.057494318	0.031941288
4.	Gokarneshwor	2378.08	1321.156	58.4	149366	39771	59746.4	56012.25	0.059794322	0.033219068
5.	Tokha	2378.08	1321.156	17.11	133755	37025	53502	50158.125	0.064229034	0.035682797
6.	Kirtipur	2378.08	1321.156	14.76	81578	24150	32631.2	30591.75	0.098471222	0.054706234
7.	Changragiri	2378.08	1321.156	43.9	136860	35994	54744	51322.5	0.066068789	0.036704883
8.	Kageshwari Manohara	2378.08	1321.156	27.38	130433	33764	52173.2	48912.375	0.070432413	0.039129118
9.	Nagarjun	2378.08	1321.156	29.85	115437	31301	46174.8	43288.875	0.07597457	0.042208094
10.	Shankharapur	2378.08	1321.156	60.21	29318	7140	11727.2	10994.25	0.333064426	0.185035792
11.	Dhakchinkali	2378.08	1321.156	42.6	26372	6489	10548.8	9889.5	0.366478656	0.203599253
12.	Lalitpur Metro	33681.27	18711.82	36.12	294098	77159	117639.2	110286.75	0.43651771	0.242509839
13.	Mahalaxmi	2378.08	1321.156	26.51	123116	32106	49246.4	46168.5	0.074069644	0.041149802
14.	Godawari	2378.08	1321.156	96.11	97633	24045	39053.2	36612.375	0.098901227	0.054945126
15.	Changunarayan	2378.08	1321.156	62.98	88083	21588	35233.2	33031.125	0.110157495	0.061198608
16.	Suryabinayak	2378.08	1321.156	42.45	140085	35865	56034	52531.875	0.066306427	0.036836904
17.	Madhyapur Thimi	2378.08	1321.156	11.47	119756	31966	47902.4	44908.5	0.074394044	0.041330024
18.	Bhaktapur	2378.08	1321.156	6.89	79136	18987	31654.4	29676	0.125247801	0.069582112
Total		105411.82	58562.12	715.94	2936462	784608	1174584.8	1101173.3	2.369220883	1.316233824

Table 6: Total Vegetable Requirement and Production Possibility in KV Using Organic Fraction of Solid Waste

<i>Standards</i>	<i>Per day Vegetables Require (Mt)</i>	<i>Requirements/ Season (Mt)</i>	<i>Total Production in KV in Mt/ Season</i>	<i>% Fulfill Veg. Demand</i>	<i>% Difference</i>	<i>Remarks</i>
WHO	1174.58	105712.63	106754.76	101	1	Surplus
Nepalese	1101.17	99105.59	106754.76	108	8	Surplus

If we consider the available space for cultivation in the context of KV, the total vegetable production potential per season is calculated to be 109,946.03 Mt as illustrated in Table 7. This quantity of vegetable production contributes not only to serving the vegetable requirement of KV but also allows surplus production by 4% as per the WHO standards and by 10% as per the Nepalese standards. The surplus production may be exported to adjoining other places around KV and might be the source of the economy as well.

Table 7: Total Vegetable Production and Comparison of Vegetable Production Possibility with Standards as Per the Available Space for Cultivation in KV's HHs

<i>Standards</i>	<i>Vegetable Requirement (Mt)/day</i>	<i>Requirement/ Season (Mt)</i>	<i>Total Production in KV in Mt/Season (Space-wise)</i>	<i>% Difference</i>	<i>Remarks</i>
WHO	1174.58	105712.63	109946.03	4	Surplus
Nepalese	1101.17	99105.59	109946.03	10	Surplus

The total OM required per season for vegetable cultivation in the available space of KV's HHs is found to be 5428.12 Mt as demonstrated in Table 8. The production of OM from the organic fraction of solid waste generated in KV is calculated to be 5270.59 Mt per season, which is a deficit of 3% as depicted in Table 8.

Table 8: Organic Manure Requirement for the Cultivation in Available Space of KV's HHs

<i>OM Requirement (Mt/hector)</i>	<i>OM for Open Space (Mt)</i>	<i>OM Production (Mt/season)</i>	<i>% Difference</i>	<i>Remarks</i>
1.5	5428.12	5270.59	3	Deficit

Thus, by adopting the concept of a "Food Green City", the utilization of underused rooftops and land areas around houses can promote sustainable urban agriculture. This contributes to feeding the city's population while also creating a greener environment that balances built and natural spaces. Furthermore, it helps prevent surface sealing, reduces air pollution, provides emergency spaces during disasters, improves household food security, maintains the groundwater table, and aids in waste management.

Additionally, urban agriculture plays a crucial role in preserving urban ecology and serves as a key component in maintaining urban biodiversity.

Therefore, by utilizing the organic portion of solid waste to produce organic manure and applying it to the cultivation of green vegetables in open spaces within individual households, it is possible to transform a hazardous city into a healthy one, uplift the underprivileged, enhance livability, and transition from polluted to planned city, as depicted in Figure 2.

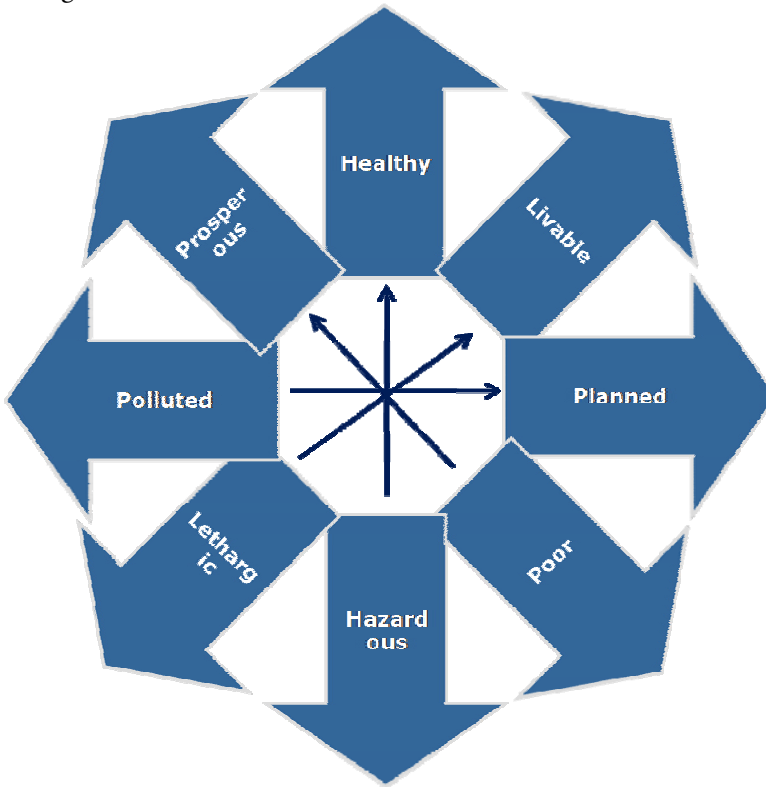


Figure 2: Conclusive Framework of Food Green City and City Life

This approach addresses multiple challenges faced by cities, particularly in developing countries like Nepal.

1. **Environmental Benefits:** Recycling organic waste into organic manure, reduces the amount of waste sent to landfills, thereby decreasing methane emissions and overall environmental pollution.
2. **Health Benefits:** Growing green vegetables locally can provide households with fresh, nutritious food, promoting better health outcomes and reducing dependence on commercially grown produce that may have been treated with pesticides.

3. **Social and Economic Benefits:** This initiative can empower underprivileged communities by providing them with a sustainable source of food and potentially creating local employment opportunities in waste management and urban farming.
4. **Livability and Urban Development:** Transforming urban spaces into productive green areas enhances the overall aesthetics and livability of the city. It can also contribute to community cohesion and pride in maintaining cleaner and greener surroundings.
5. **Long-term Sustainability:** By promoting such initiatives, cities can move towards more sustainable development practices, reducing reliance on external food sources and improving overall resilience to environmental challenges.

In summary, this approach not only addresses waste management challenges but also promotes health, community empowerment, and sustainable urban development, thereby contributing to a healthier and more livable city environment.

4. DISCUSSION

Urban agriculture can contribute substantially to the management of urban waste for food production. It supports low-income families, improves public health through increased vegetation, and enhances urban management (MoUD, 2017). The promotion of urban agriculture for greenery and food production is also addressed in Nepal's 14th plan. Many cities currently produce over 20% of their vegetable needs within their municipal boundaries (MacRae *et al.*, 2010). Hence, as per the findings of this study, if people are utilizing their open spaces, particularly rooftops, front yards, and backyards, and organic manure derived from the organic fraction of the solid waste for cultivation, it is not only fulfilling their vegetable needs but also there is the opportunity of surplus production.

The Livability Index is a composite number based on factors such as social infrastructure, workability, public transportation, public open space, housing affordability, and local employment (Arundel J. *et al.*, 2017). According to India's Urban Development Ministry's city livability index, every city resident should have access to at least 10 square meters of open space (MoHUA, 2018). From this study, it is found that each person can have access to 13.28 square meters of open space, where they can grow green vegetables and fruits utilizing their organic waste.

Based on calculations done by Afshin *et al.* (2019), we only eat almost two-thirds of the minimal amounts of fruit and vegetables that are advised by WHO. Tropical fruit consumption is highest in the Caribbean, and lowest in southern Africa. Consumption patterns differ significantly: those in sub-Saharan Africa and Oceania consume approximately one-third of what is advised, whereas those in Central Asia, North Africa, and the Middle East consume slightly more. Considering this fact, Nepalese people are consuming less amount of fruits and vegetables in comparison to the amount need to consume per day for a healthy life. With this lower amount of consumption also people in Nepal are solely dependent on imported vegetables from

other cities including from India. In the case of KV, the amount of imports is higher in comparison to other cities of Nepal. In this context, if people are utilizing their spaces inside their own homes for fruit and vegetable cultivation, it provides the opportunity to fulfill their daily fruit and vegetable requirements as advised by WHO as well as by the government of Nepal.

The FAO (2018) states that nations with low domestic fruit and vegetable production must rely on imports to meet their nutritional needs. Based on the result of this study, if the organic fraction of waste is utilized as OM in an individual's house open space for the cultivation of vegetables and fruits, it contributes to fulfilling the nutritional challenges of the city dwellers. Moreover, it can also help in promoting the food-green city approach among cities.

Methane is released into the environment when bacteria decompose OM in anaerobic conditions, such as in landfills and open stockpiles like manure mounds. Methane, a greenhouse gas, is approximately 27 times more potent than carbon dioxide and significantly contributes to global greenhouse gas emissions (EPA, 2024). Since 1970, global emissions from waste have nearly doubled, accounting for approximately 3% of all anthropogenic (human-caused) emissions (IPCC, 2014). Anaerobic fermentation of solid waste disposal on land is responsible for approximately half of these emissions. Alternative to this, if the organic waste is utilized as OM, it mitigates the unnecessary methane flare up into the atmosphere due to waste. This study provides clear insights into how OM can be produced from the organic fraction of Solid Waste that can be utilized in an individual's HH garden.

On the other hand, air pollution is still a serious problem in many urban areas around the world, especially in the urban areas of developing countries (Van Khuc *et al.*, 2020; 2022). The National Urban Development Strategy (NUDS), 2017 mentions that one of the guiding principles for strategizing urban development is ensuring that the cities are green and cool (Ministry of Urban Development, 2017). For this purpose, specific areas within Kathmandu Valley need more Urban Green Space (UGS). UGS has the potential to lessen air pollution and lessen the impact of Urban Heat Island (UHI). The NUDS, 2017 places a strong emphasis on using land and technology to minimize ambient temperature, carbon emissions, and the UHI effect. The findings of this study would also help fulfill the NUDS by utilizing organic waste for open-space gardening and rooftop farming.

In 2012, Western Australia composted approximately 700,000 tons of organic waste. Each ton of organic waste disposed of in a landfill and decomposed through anaerobic fermentation releases approximately one ton of CO₂-e greenhouse gases, primarily in the form of methane.

However, aerobic composting processes do not produce methane because methane-producing microorganisms are not active in the presence of oxygen. Composting is an effective method to reduce methane emissions from organic waste that is currently stored or disposed on landfills. Composting strategies that minimize anaerobic conditions while promoting aerobic conditions offer the greatest potential for reducing

greenhouse gas emissions. Microbes such as bacteria and fungi utilize carbon for energy and break down organic waste in the presence of oxygen and water. This process generates heat, which eliminates germs, resulting in a stable humus that is free of weeds and suitable for agriculture, landscaping, gardening, and other applications.

The Environmental Protection Agency (EPA) states that a variety of buildings, including private homes and commercial buildings, can have green roofs built (EPA, 2018). By lowering the need for air conditioning in buildings, green roofs can absorb air pollutants and hence lower pollution and greenhouse gas emissions. Because they provide a home for a variety of creatures, they also benefit the ecosystem. Stormwater runoff is slowed and reduced with the aid of green roofs. Furthermore, by preventing heat transfer and preserving a more pleasant temperature, they serve as building insulators, minimizing the need for heating and cooling.

In this context, rooftop farming as conceptualized by Food Green City also acts as a green roof for reducing air conditioning costs, absorbing air pollutants, slowing stormwater runoff, utilize the compost from organic waste to produce fruits and vegetables supplying healthy and affordable food to the city dwellers.

5. CONCLUSIONS

Both, the environment and the growing population's access to food in cities are seriously threatened by the KV's fast rate of land fragmentation and urbanization. Encouraging individuals to grow fruits and vegetables that can satisfy demand in readily available areas, such as front yards, backyards, and rooftops, as advocated by Food Green City Concept, is one strategy to solve this problem. Furthermore, the organic waste produced in the valley can be transformed into beneficial organic manure, which will encourage the growth of nutrient-dense, organic fruits and vegetables. This strategy supports the Food Green City Concept in the Kathmandu Valley and has the potential to lower waste treatment and management expenses while simultaneously improving the city's general greenery, livability & health and providing locally produced food to the citizens.

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ABBREVIATIONS

C: N	: Carbon Nitrogen
Ca	: Calcium
CBS	: Central Bureau of Statistics
CO ₂ -e	: Carbon dioxide equivalents
EPA	: Environmental Protection Agency
FAO	: Food and Agriculture Organization
GHG	: Green House Gases
HHs	: Households
IPCC	: Intergovernmental Panel on Climate Change
K	: Potassium
KV	: Kathmandu Valley
Mg	: Magnesium
MoHUA	: Ministry of Housing and Urban Affairs
MoUD	: Ministry of Urban Development
Mt	: Metric tone
OM	: Organic Manure
P	: Phosphorus
RCC	: Reinforced Cement Concrete
RGA	: Roof Garden Association
SGUFS	: Sprouting Good Urban Farming Sydney
USA	: United States of America
WHO	: World Health Organization

Composting for Kitchen Garden: Alternative Way of Managing Household- Level Solid Waste in Kathmandu Valley

Bishnu Raj Upreti¹ and Yamuna Ghale²

ABSTRACT: In this chapter, we present evidence of the increasing use of kitchen-based decomposable waste in making compost for the use of vegetable gardening. One of the main problems of urban areas is waste management. Different concepts are discussed and practiced to address this problem. One of the concepts and practices of this type is reducing waste by segregating decomposable waste and using it as raw material for compost. This study aims to explore the segregation of decomposable waste to use for compost for vegetable gardens in Kathmandu Valley. This study applied qualitative methods of data collection and used a descriptive approach to analysis. Focused group discussion, in-depth interview, key informant interview, field observation and review of key documents were some of the methods used in collecting data for this study. The study found that households in inner cities have increasingly used segregation of kitchen-based decomposable waste for compost-making to grow vegetables. Several factors, such as the COVID-19 pandemic, the Indian blockade, the earthquake, environmental commitment, the realization of health risks, public awareness, incentive provisions of government, peer sharing and learning, and climate change pressures, have contributed to expanding compost-based kitchen gardens. The most common forms of vegetable production for household consumption are kitchen gardens, rooftop gardens, and grow bags in the inner urban residences of Kathmandu Valley. This practice has contributed to reducing the burden of managing municipal solid waste at Kathmandu Valley.

Keywords: Compost, Decomposable, Kitchen Garden, Municipality, Rooftop-Garden, Solid Waste, Urban.

1. INTRODUCTION/BACKGROUND

Urban areas are facing numerous challenge and one of them is the unsustainable way of use of resources, which often contradict with the principle of harmonizing human behavior with nature, culture and future to ensure rational use of

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resources (Mugambwa and Katusiimeh, 2018; Awale, 2023; Timsina, 2020). Further, the concept of a 'food green city' very much aligns with the notion of sustainable management of urban waste through the 3Rs (reduce, reuse, recycle) principle, which is the reuse of decomposable waste to produce compost for agricultural activities in urban areas. Agriculture in general, and vegetables production in particular, in urban areas are suffering from rampant use of chemical fertilizers, insecticides and pesticide, which are not only immediately health hazard but also adding long term burden to urban societies by creating various health risks. Instead, if healthy, locally produced vegetables are consumed, these risks could be minimized. Therefore, the process of converting grey (waste) into green (compost for vegetables) can help improve public health (Lohani, 2017).

The process of converting grey (waste) into green (compost for kitchen garden) is a win-win solution to be promoted in urban areas. Some of the municipalities within the Kathmandu Valley are working to advance this process. Especially, some deliberate efforts are going on in Lalitpur Metropolitan City². Increasingly households in the Kathmandu Valley are applying 3Rs principles and separating decomposable wastes and used for kitchen garden, rooftop garden, and flower production. Based on our four years of study of solid waste management in the Kathmandu Valley, we present one of the findings related to the options of household level compost making and its use in kitchen garden as integral part of small-scale urban agriculture.

In Nepal's urban areas, the price of vegetables is going high and in other side, and it is difficult to find land to grow vegetable of all residents. Hence, Kausi kheta (rooftop kitchen gardening), intensive cultivation of vegetables in available open spaces in the resident areas, is emerging as one of the attractive options for urban resident who have none or limited land for growing vegetables.

In this paper, we have defined various types of small-scale vegetables grown by individual household for the purpose of consumption as 'kitchen garden'. Kitchen garden covers rooftop gardening, plants grown in the yards and any open space around the houses, or vegetables grown in small plots of land available to urban households.

One of the most important inputs needed for kitchen garden is compost. Making compost from decomposable solid waste for the purpose of domestic use such as vegetable, fruits, flowers, or other ornamental plants grown by individuals.

This research is being part of the broader project; we have extracted relevant information collected during the period of 2018–2024.

2. RESEARCH QUESTION AND ASSUMPTIONS

Overtime, use of decomposable solid waste for composting and its use for kitchen gardening is increasing (Lohani, 2017; Upreti *et al.*, 2022). In this context, it is important to explore the following questions:

²Interview with an agriculturist responsible for kitchen garden programme of provincial Ministry of Agriculture on 15 May 2024.

Research questions:

- What is the current state of the application of compost produced from decomposable solid waste in the kitchen garden?
- What are the major factors affecting use of compost from decomposable solid waste?

In this study, we had the following assumptions (hypotheses) that we want to test:

- Compost making from household-level biodegradable solid waste is increasing in the Kathmandu Valley.
- Use of compost prepared from biodegradable solid waste in kitchen gardening in the Kathmandu Valley is increasing.
- There must be some motivating factors for enhancing use of compost produced from biodegradable solid waste in kitchen gardening in the Kathmandu Valley.

3. METHODS USED IN COLLECTING DATA

We used qualitative methods for the study. The main methods used were focus group discussion: key important interviews, mini-round table discussion, in-depth interview of the respondents identified from snowball sampling, and on-the-spot-site observation to identify the state of solid waste-based compost production for kitchen garden. Further, this chapter has used the relevant qualitative information collected from the four-year regional project, “Transformation of waste management practices and policies in South Asia during and after the COVID-19 pandemic: Impacts on gender equality and sustainability”.

4. DATA ANALYSIS

We use descriptive-interpretative approach for analyzing data within the broad conceptual framework of 3Rs principle of SWM (solid waste management). We first categorize the collected qualitative data according to the research questions stated above considering the 3R principle. The 3R principle is briefly define below:

1. **Reduce:** Here, reduce means that individual households produce a minimum level of trash in general through conscious and deliberate efforts. Hence, a low volume of waste will be generated from individual households and from businesses and offices.
2. **Reuse:** For the purpose of this chapter, reuse is to explore all possibilities to use and use waste materials, which otherwise would have been thrown away as waste to landfill sites. Composting is one of the best alternate ways for decomposable waste, which could be used for agriculture, especially kitchen gardens.
3. **Recycle:** In this chapter recycle means changing solid waste into new, useable materials that can be used for small-scale, or commercial uses.

5. RESULTS/FINDINGS

The rapidly growing population in urban areas, especially in the Kathmandu Valley is producing increasing amount of urban waste and posing complex challenges (Upreti

et al., 2020). Hence, in addition to a few private waste-based enterprises, some individual households, with the help of municipalities, have started reuse of solid waste for kitchen gardens. Even if individual households have limited land areas in Kathmandu Valley, they are using kitchen waste and other decomposable waste for the production and use of kitchen gardens and rooftop gardening (RTG), an increasingly common practice in Nepal.

In the following section, we are presenting the current state of the arts on the use of solid waste for compost for kitchen gardens:

5.1 State of the Art Practices on Use of Solid Waste for Compost for Kitchen Garden

The phenomenon of growing of vegetables in the kitchen garden and roof top garden by using compost prepared from decomposable waste has been increasing, particularly, after the unofficial Indian blockade of 2015 (Aryal, 2019; Bohara, 2020), 2015 earthquake (Matthew and Upreti, 2018), and covid-19 (Ministry of Health and Population, 2020; Adhikari *et al.*, 2020).

Key actors engaged in using decomposable waste-based compost for kitchen garden, rooftop garden and small ornamental plants at individual household levels are environmentalists, agriculturists, professionals, educators, bankers, artists, and retired officials. Now some commercial enterprises working in broad municipal waste management sector have also started commercial production of decomposable waste-based compost, mainly because they have to segregate decomposable waste for their commercial viability. They sell the compost pack of 1 Kg, 5 Kg, 10 Kg, 20 Kg, 50, and 100 Kg bags and distribute them to retailers or sell them from their own factory (waste collection center). Even if it is relatively costly, customers are buying it. In this context, one person in charge of the resource recovery center of the Shankarapur municipality, Sakhu, said, “We have no problem marketing compost as there are many individuals and companies coming and collecting the compost. We are sometime not able to meet the demands.”

The start of kitchen gardens and rooftop garden by using compost from decomposable waste are spread across the urban areas of the Kathmandu Valley, but are practiced more widely in Lalitpur Sub-metropolitan and Kathmandu Metropolitan cities. The major reasons for a growing number of uses of waste-based-compost (WBC) in these two cities were a) the special rooftop/kitchen garden policy of Bagmati province (with subsidy), b) Supportive provision of local government, c) increased awareness of the residents.

In the Kathmandu Valley, there is a growing trend of residents living in the gated communities, apartments, and housing. In this context, segregation of waste and reuse, and recycle is institutionalized in community practices. The residential committees provide incentives to those segregating decomposable compost. Kathmandu Metropolitan City has also encouraged individual households to make

provisions for waste segregation. These provisions were helpful in segregating decomposable waste and use for compost for vegetable gardens on rooftops and surrounding houses (Lohani 2017).

The practice of rooftop farming is increasing fast in Kathmandu, mainly for growing vegetables. The main motivation for having a kitchen garden on rooftops is to prevent consuming possibly contaminated vegetables with chemicals that often flood the market.

During our extensive consultations with respondents, we asked them the main reasons for opting for waste segregation and the use of decomposable waste for kitchen garden, they highlighted that some of the main causes are chemical contamination and possible health hazard, sky rocketing vegetable prices, use the residents' availability of time and physical space, and the recent covid-related restrictions.

5.2 Factors Enhancing the Use of SWM for Compost Making for Kitchen Garden

As presented above, the use of decomposable waste for compost for vegetable gardening (kitchen garden and rooftop garden) is growing. The following factors were identified as main contributors' to the growth and expansion of kitchen gardening and rooftop gardening and the use of compost:

5.2.1 COVID-19 Pandemic

The relationship between the 2019–2021 Covid-pandemic and urban solid waste management has been studied in recent years. Both authors of this chapter were engaged in a four-year long research project entitled, "*Transformation of waste management practices and policies in South Asia during and after the COVID-19 pandemic: Impacts on gender equality and sustainability*". This study has covered metropolitan cities of Nepal (Kathmandu), India (Kerala) and Sri Lanka (Colombo). This research has confirmed that the COVID-19 pandemic has forced the use of some innovative measures in managing municipal solid waste.

Increasing use of decomposable waste for composting in inner city areas was motivated by both pull (subsidy by municipalities for composting) and push (waste collection stopped due Covid-19 pandemics) factors as well as increased awareness among the consumers.

The Covid-19³ was originated in Wuhan Province of China in late 2019 (Sharma, Banstola and Parajuli, 2021; Wu *et al.*, 2020). This disease was declared as pandemic by the World Health Organization (WHO) on 11 March 2020. Covid-19 was widely spread all over the world and appeared as a major challenge not only for public health but also for the economy (Tmang *et al.*, 2022; Pun *et al.*, 2020). It took the lives of millions of people and posed a serious public health crisis in the world. The

³It is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

WHO developed various guidelines and priority response actions and appealed to the national governments to take proactive and reactive measures (Adhikari *et al.*, 2020; Sharma *et al.*, 2021).

COVID-19 was identified in Nepal in late January 2020 (Pun *et al.*, 2020). Nepal also severely suffered from COVID-19, which affected solid waste management practices (Upreti *et al.*, 2020). One of the serious concerns of municipal solid waste management (MSWM) in Kathmandu during the COVID lockdown was the drastic reduction of waste collection frequency (Ghale *et al.*, 2023).

At the beginning (until April 2020), patients did not isolate themselves and infected patients showed no symptoms (Pun *et al.*, 2020). However, to manage potential risks of COVID-19, Government of Nepal issued a nationwide lockdown from 24 March for few weeks which was later continued until 21 July 2020. The strict lockdown regime enforced by the government included reducing even domestic and international air travel and local transportation systems except for most essential services (Sharma, Upreti, and Pant, 2079BS). However, collection of municipal waste was not prohibited because it was categorized by the government as an essential service⁴. Hence, principally, the collection of municipal waste was less affected by the COVID-19 pandemic in Nepal in general, and Kathmandu Valley in particular (Pun *et al.*, 2020) during the early period of COVID-19. However, in reality there were so many operational issues that had severely affected the municipal solid waste management process. Hence, individual households had started managing their waste themselves through the 3R principles, especially by reusing and recycling.

5.2.2 Indian Blockade Push for Household Compost Making and Kitchen Gardening

Another factor contributing to the push for segregation of non-compostable wastes, and the use of decomposable waste to make compost for growing vegetables at household levels was the Indian blockade (September 2015 to March 2016), which had several negative effects on society (Bohara, 2020; Lohani, 2017; Matthew & Upreti, 2018). The blockade forced the introduction of innovative waste management practices like waste segregation for composting.

Regarding the impacts of the Indian blockade, research findings of Jhabakhar Aryal from Norwegian University of Life Sciences states, “*not only on household, educational and medical sectors, but the impacts of blockade were seen in agriculture, environment and social psychology as well*” (Aryal, 2019: v). Likewise, Dina Bohara based on her research elaborate the situation of Indian blockade as, “*the protest was accompanied with blockade which created crisis in earthquake crippled country*” (Bohara, 2020:2).

One of the major sources of vegetables for Nepal is India, and Indian vegetables dominate the Nepali produce market. India unofficially imposed blockade to express

⁴Essential services include but not limited to ambulance, fire fighters, medical inputs delivery, milks and food item, insurance, banks, and electricity.

dissatisfaction on the promulgation of the constitution of Nepal in 2015. The hidden reason of the blockade seemed to be the rejection of Indian interests by Nepal's Constituent Assembly. Authors have suggested that India wanted to postpone the date of promulgation of the constitution (Thapa, 2024). Consequently, Nepal is general, and specifically the Kathmandu valley, seriously suffered from lack of fuel, which resulted in no vehicle movement, and no transport of vegetable to Kathmandu Valley. All vegetable stocks were exhausted. Residents of the Kathmandu Valley were not able to get their daily needs including vegetables. To counter the problems of supply, some households started growing vegetable in their kitchen garden or rooftop. Growing vegetables required manure. In this process, these vegetable growers started making compost from decomposable waste produced in their own houses. This act turned out to be beneficial in multiple ways, such as the availability of organically grown vegetable. In this way, even the difficult situation created by the blockade contributed to the promotion of growing vegetables on rooftops and kitchen gardens, which is continuing and expanding now.

5.2.3 *Earthquake: Changed the Habit of People in Dealing with Solid Waste Management*

The devastating earthquake of 27 April and 12 May 2015 in Nepal (Matthew & Upreti, 2018) severely affected the normal life of people (NPC, 2015) and also the regular solid waste management practices of Nepal (Upreti *et al.*, 2022). The normal schedule and practices of waste collection and transport to land field sites were obstructed. Hence, individual households started managing waste in their own (Upreti *et al.*, 2022; Ghale *et al.*, 2023) largely by applying 3R principles: reduce, reuse, and recycle. As the normal market supply chain at that time was also disrupted by the earthquake in Kathmandu Valley and another part of the country for several weeks, households were not able to get fresh vegetables regularly. Hence, the process of producing some vegetables by urban residents in small garden began for many. Some concerned residents were also promoting compost-making from the segregated waste to use in their farms and kitchen gardens. It proved to be one of the attractive options for producing healthy vegetables from the use of compost. Many respondents we talked to referred to this situation. One of the key informants said⁵,

“Before the earthquake, I was not growing vegetables in my garden. I had a small open area next to my house, but it was barren and used to keep waste and other unused materials. Once there was a big earthquake, we were not able to get vegetables in nearby vegetable shops, and the vegetable vendors were also stop coming. Hence, one day, our neighbors discussed the problem of getting fresh vegetables, and one of our neighbors suggested growing green leafy vegetables that grow faster. So, all of us started growing coriander, chili, cucumber, brinjal, onion chili, cucumber, brinjal, onion, and garlic. We need irrigation water and compost to grow vegetable. We

⁵ Interview by one of the authors on 2022 January 28.

used the kitchen wastewater for irrigation and decomposable waste of our kitchen for compost. Since then, we are regularly growing vegetable in our kitchen garden and now in roof top once plastic pots made for vegetable growing are available. The vegetable produced in our kitchen garden is almost enough for my family of four members (including two kids). Now I hesitate to buy vegetable form outside and my family members are also supporting me to grow vegetable”.

Natural calamities not only create disasters with great negative impacts on society (Matthew & Upreti, 2018) but also create opportunities for promoting specific interventions. This argument is proved in the case of solid waste management in the Kathmandu Valley, where the 3Rs were practiced during the disasters.

5.2.4 *Commitment of People on Environmental Issues*

One of the main reasons for the expansion of the production of compost from decomposable solid waste and its use in kitchen gardens was the initiation of some people committed to environmental issues. These individuals were mainly educated professionals, environmentalists, organic agriculturists, health professionals, innovators, and people working in the solid waste sector. They started segregation of decomposable waste and its use as organic fertilizer directly or making compost from it. This phenomenon was more common in the Kathmandu Valley. In this context, one of the respondents said⁶,

“I knew importance of segregation of waste as source from my master study in environmental studies. I also became aware of the cost of non-segregation, composting from segregated decomposable waste, and its use on farms. Hence, I have practiced it since my master’s study 10 years ago, and now I have several segregation bins in my house; I use the wastewater from the kitchen for the vegetable plants grown in my garden and use compost made from segregated decomposable waste. I am also sharing my experiences with the members and participants of Solid Waste Management Association of Nepal. Now, it has become my hobby to segregate waste, make compost from decomposable segregated waste, and use it in the kitchen garden”.

Another expert growing fruit trees, vegetables, and flowers in his big garden explained the importance of incorporating earthworks into soil to make vermicompost. He is producing and selling earthworms and training people in vermicompost.

Rodale Institute, a promotor of organic products from waste, explains vermicompost and its benefits as follows.

“Vermicompost is the product of earthworm digestion and aerobic decomposition using the activities of micro- and macro-organisms at room temperature. Vermicomposting, or worm composting, produces a rich

⁶ Interview with respondent.

organic soil amendment containing a diversity of plant nutrients and beneficial microorganisms. There are several benefits for vermicomposting but the two most popular are (1) diverting organic residuals from the landfill and reducing trash collection fees and (2) creating resources from waste materials”.

Vermicompost, a product of decomposable solid waste mainly coming from kitchens, is becoming popular for kitchen gardens and container cultivation of vegetables such as radish, beans, carrots, peas, herbs, potatoes, chilies, garlic leaves, tomatoes, and coriander.

5.2.5 Fear of Health Risks and Public Awareness

One of the frequent responses of our respondents on the question ‘Why are you growing vegetables in our kitchen garden and even in the rooftop garden?’ was the possible health risks of using contaminated vegetables available in the market. Seasonal vegetables available in the market are often contaminated with polluted water (as most of them are washed in polluted rivers/streams), containing chemicals (use of high doses of pesticides) in vegetables and their potential health hazards.

Heavy use of chemical fertilizers, insecticides, and pesticides, as well as contamination of soil due to construction and demolition work, have contaminated the crops and vegetables grown and consumed by residents of the Kathmandu Valley.

About the seriousness of contamination of vegetable in Kathmandu Valley Prasain (2020), writes,

“Vegetable growers have been using toxic chemicals to speed up growth and keep away pests that may cause serious health problems for the people, officials said. High levels of pesticide residues have been found in five vegetable items sold in the Kathmandu Valley, a lab test conducted at the Kalimati Fruits and Vegetable Market showed. The lab restarted rapid bioassay testing of pesticide residues in vegetables and fruits from mid-June after the government relaxed the lockdown restrictions. Tests of tomato, cauliflower, eggplant, black eye bean and sponge gourd conducted between mid-June and mid-July showed a high concentration of harmful chemicals”⁷.

It was reported that 70 percent of the waste generated in Kathmandu Valley is organic waste (Upreti *et al.*, 2022), which is the raw materials for compost. In this context, composting is the best opportunity for addressing the rampant waste problem in Kathmandu Valley.

We found that people sensitive to environmental concerns and health hazards from contaminated vegetables were people already engaged in the segregation of waste and

⁷ <https://tkpo.st/2B7MqHp>

utilize decomposable/kitchen wastes for growing vegetables in their houses. One of the growers of kitchen garden in his house using compost said,

“We were fed up with frequent strikes that caused halting collection of waste from houses for several years. Piles of waste in front of the home were producing a bad smell. Colleagues in my office suggested making compost by getting the subsidized compost bin from KMC. They were practicing it. So, I started exploring options and came to the conclusion to start composting from decomposable waste in my little garden. The manure produced from compost was so good for vegetables. Now, I am producing enough vegetables for my 4-member family. As you also witnessed, most of the vegetables available in Kathmandu were washed in the dirty water of rivers, kept on roadsides and highways for sale, used polluted water for irrigation vegetable gardens, and vegetables contaminated from excessive doses of chemical fertilizers, insecticides, and pesticides. So, I am satisfied with stopping the consumption of contaminated vegetables”.

5.2.6 *Incentive Structures*

The Solid waste management section of the Environment Division of Department Environment Management of Kathmandu Metropolitan City promotes segregation, reuse and recycle with different incentive structures.

There are some incentives available for segregation of waste and reuse/recycle and they are related to composting too. For example, if individual households make compost in their houses, municipalities provide incentives (e.g., direct subsidies for segregation bins), better price for sale of compost (e.g., upto 100 per kg for compost), thereby saving of money to be spent in fertilizers for vegetable production).

After the policy of promoting segregation linked with incentive provisions, the emergence and operation of several compost-making plants from organic wastes have increased and provided employment opportunities to local peoples and contributed to improving their livelihoods. The Bagmati Province even brought a specific policy for rooftop gardens and kitchen gardens and linked it with specific incentives. Hence, incentive structures have also contributed to promoting composting and rooftop and kitchen gardening.

In this context, one of the respondents said, when the Kathmandu metropolitan city announced the subsidies for compost bins,

“I bought compost bins and started compost making. I also attended the orientation program and learned about the importance of segregation of decomposable kitchen waste and started composting. Now, almost 90 percent of my kitchen waste is used in compost; only some plastic bags, meat bones, and other non-decomposable and hard objects are segregated and sent to waste collectors. The compost prepared in my three compost bins is enough for vegetables grown in my garden. Now, we do not need to buy

vegetables, and we are nearly self-sufficient. So, all members of my family are happy”.

5.2.7 *Positive Peer Influences*

During our data collection period, it was understood that many educated household members were impressed with the kitchen garden and rooftop gardens using decomposable waste-based compost by their friends, close acquaintances, working colleagues and peers. We identified, through snowball sampling many techniques for adapting the practice of using waste-based compost for kitchen gardens and rooftop gardens. One of the respondents said that,

“My very close friend was practicing segregation of decomposable compost and using it for the kitchen garden. When I visited her, she showed me her kitchen garden and explained the importance of being convinced to start a kitchen garden. I was trying to skip from her proposal saying that I do not have suitable land like yours and she suggested me to have it in roof. She referred me few of nice rooftop kitchen garden and even bushy fruits grown in the roofs of houses. But still I was not ready because of bad smell of compost, time required to make compost and kitchen garden. I also knew that many of my friends from college time off early professional careers were growing vegetables on rooftops or in small polyethylene bags or in small open areas next to houses. At the same time, there was a repeated incidence of contamination of chemicals in the vegetables sold in the market. Hence, I decided to grow vegetables and even small fruit trees on my rooftop a few years ago. How I am so happy that the vegetable required for my small nuclear family is produced from the kitchen garden. By doing so, I could save my family from poison, and I can contribute to addressing climate change effect by segregating waste and using organic waste for kitchen gardens. If I was not separating the organic, kitchen waste it would go to landfill sites and produce methane gas⁸”.

In the process of conducting research in several sites in the Kathmandu Valley, we met several educated middle-class professionals having separate kitchen gardens and rooftop gardens. Most of them were also segregating their kitchen waste and preparing compost in one to three compost bins and using it for growing vegetables. Some respondents were also growing vegetables in plastic bags or other containers in their houses.

5.2.8 *Climate Change Related Issues and Incentives*

Some innovative urban residents with their commitment to addressing climate change challenges, have started private companies to process organic waste into compost for economic incentives as well as reduce methane emissions, a greenhouse gas. For example, a private company Biocomp Nepal, with the help of Myclimate (not-for-

⁸ Interview with her on 20 May 2023 at her house at Lalitpur Metropolitan City Ward No. 28.

profit company), is producing compost from organic waste as a project which aims to explore the possibility of carbon credit financing in the future. Such an initiative is a win-win solution for municipalities, farmers (to improve soil structure and texture), and policymakers.

5.2.9 Societal Recognition and Role Model in Society

Social media is becoming an important platform for popularizing the practice of kitchen gardening, rooftop gardening, and container gardening. Many had started sharing experiences of their kitchen garden, the products and procedures in social media like Facebook, X (formerly known as Twitter), Instagram, WhatsApp, and Viber that motivated many of their social media network friends to grow vegetables. They started sharing experiences and exchanging vegetable seeds, seedlings, and products. Some of them are now known as role model for kitchen gardening and rooftop garden.

Since a decade, vegetable cultivation in a 'grow bag' has been quite common in middle-class households, where they use special plastics, jut bags, fish containers, and other paper products. Recently, a grow-bag culture is emerging in gated communities, joint housing (colonies and real estate buildings), and other places.

5.2.10 Other Factors

Environmental non-governmental organizations (NGOs), lobbyists and advocacy groups, and government organizations have launched awareness programs on waste reuse, reuse, and recycling to reduce the waste load to land-field sites. Consequently, segregation of waste for composting and its use in agriculture was started.

The most common vegetables grown by using waste-generated compost in the inner city of Kathmandu Valley are beans, brinjal, green leafy vegetables, chilies, and radish, which are grown in buckets, cardboard boxes, and rice sacks without using chemicals.

5.3 Main Actors in Compost-Based Kitchen Garden

During our field visit, we found that the urban farmers support the concepts of green cities, urban agriculture, environmental sustainability in mega cities, alternate ways of managing waste, ecological agriculture, etc. In specific, women of individual households, and small private companies are actively engaged in decomposable waste compost making and using it for gardening.

It is found that women are more committed to and practicing composting than male members. In this context, one female respondent said,

'We are in the nuclear family of four with one daughter and one son. My husband and son are not interested in kitchen gardens, even being agriculturists. He helps me if I ask him to do some specific tasks in the kitchen garden, but he does not voluntarily engage in the kitchen garden. My son is also not so interested. She also shared that many of her female friends have similar experiences.

Some climate-focused organizations and their employees and collaborators have also contributed to promoting compost-based Kitchen gardens in later years.

6. CONCLUSION

This paper concludes that the practice of composting from organic waste for the use in kitchen and roof-top gardens is rapidly increasing in the inner city of Kathmandu due to a) the Covid-19 lockdown, b) Special efforts of municipalities (subsidy and support) and c) awareness that 60–70% of biodegradable waste produce in the Kathmandu valley can be composted.

Before starting this study, we had a hypothesis that composting from household-level decomposable solid waste is increasing in Kathmandu Valley, which was confirmed. Similarly, another assumption was that the use of waste-based compost in kitchen gardens is increasing, which was also verified.

There must be some motivating reasons/factors for enhancing the use of compost produced from decomposable solid waste in kitchen gardening in Kathmandu Valley.

Crisis and calamities can also sometimes bring new innovations or alternative options to deal with day-to-day problems.

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Conflict of Interest Statement

The authors declare no conflict of interests.

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Urban Agriculture in an Era of Anthropogenic Climate Change and Rapid Urbanization

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ABSTRACT: The world today is living in the age of urbanization and the era of anthropogenic climate change. Nepal is also one of the fastest urbanizing and the most climate change affected countries of the world. The trends of urbanization are unplanned and haphazard in many developing countries including Nepal. Existing urban services, socio-cultural practices, and public spaces appear far from being adequate and these are further shrinking. Urban ecosystems are worsening on a daily basis due to the result of the rapid and haphazard model of urbanization. Kathmandu, the capital city of Nepal, has also been experiencing rapid and haphazard trends of urbanization. Challenges such as rapid increase of urban population resulting in overcrowding and informal settlements and environmental degradation are rapidly rising while the standard and adequacy of urban physical and social infrastructures are gradually declining. Haphazard and unplanned land use change turning fertile agricultural land into plotting for housing has brought forward the concerns of urban food security in the nexus of climate change and availability of the productive land. In this context, this chapter investigates the diversified urban agricultural practices being used by households and identifies how such practices can contribute to the urban food security of Kathmandu. We employed a qualitative research method for collecting and analyzing data gathered from four communities of Kathmandu. The preliminary findings suggest that the land use change practice in Kathmandu is undergoing an irreversible pattern of change and urban food security is immensely being threatened. Most households have small pieces of land, enough for building a house and they practice roof-top and gallery garden farming which is found to be contributing to a minimal level of urban food security. More innovative practices of farming and land use change are inevitably

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necessary for urban food security in the era of anthropogenic climate change and haphazard urbanization.

Keywords: Urban Agriculture, Climate Change, Urbanization, Nepal.

1. INTRODUCTION

The land for agricultural production has been declining due to the rapid worldwide population growth and urbanization. The increasing population along with rapid urbanization has impacted the social, environmental and ecological system (Deelstra & Giraedet, 1999). Rapid and haphazard increase of urbanization, in the era of climate change, has affected social, economic and environmental systems along with the change in land use patterns, and urban food security (Akaeze & Nandwani, 2020). Land use change is a process through which human activities change the natural landscape for economic activities and in this context, the conversion of agricultural land (from one type of economic activities) to urban settlements (other types of economic activities) has adversely impacted the capacity of urban food production and food security. Urban agriculture plays a crucial role in making cities sustainable by providing food, employment, and economic opportunities (Prové *et al.*, 2016). However, shrinking of urban agriculture land and practices for other economic choices has raised the question of sustainable and resilient community development in the urban regions.

The concept of urban agriculture has been transformed since the Industrial Revolution, founded in new scientific theories developed by the Enlightenment thinkers, which shaped the way of the overall food system from production to consumption (Darly & Torre, 2013; Krishnamoorthi *et al.*, 2024). Urban farming is the practice of cultivating crops, fruits, vegetables, and rearing livestock including various types of food within urban areas (Bhattarai & Adhikari, 2023). The practice of urban farming has a long history: Mesopotamian city dwellers would set aside land for cultivation while post World War II era cityscapes had victory gardens. In recent years, urban farming has been an important subject of agricultural sustainability, social justice and positive change. There has also been a growing trend towards transforming concrete roofs in developed countries into productive green roofs, which is a noteworthy advancement in both protected and unprotected areas (Asad & Roy, 2014; Thapa *et al.*, 2020). These practices have been widespread in developing countries with the emergence of rooftop gardens; however, the adoption is limited to small scale (Rawal & Thapa, 2022).

Among the total population of eight billion people on earth, more than 55% already live in urban areas where agriculture is the source of food, income, and employment. Studies have projected that over 68% of the global population will be living in urban areas by 2050 (Rolf *et al.*, 2018; UN DESA Population Division, 2019). The urbanization trend of Nepal shows that it is following global trends and it has been placed in the top ten fast-growing urbanized countries in the world (Pandey, 2023; Sapkota, 2022). The rapidly increasing urban population along with increased human

settlements led to the transformation of fertile agricultural land into concrete urban roads, buildings and other built-in environments. The increasing urbanization possesses, declining agricultural land, changing climate systems along with traditional methods of food production have become challenges of urban food production and consumption (Jagganath, 2022).

Anthropogenic climate change and rapid urbanization have created domino effects, threatening the agricultural practices, therefore, the practice of sustainable agriculture to counter the impacts of multiple-challenges, needs to be a priority. Sustainable agriculture does not only ensure food security but also reduces poverty by creating job opportunities and increasing income. In urban context, urban agriculture provides fresh, healthy and culturally appropriate food to ensure food and nutrition security, hence, it is important to proliferate environmentally sustainable urban agriculture production tackling the impacts of climate change (Piorr *et al.*, 2011; Pandey, 2012; Jagganath, 2022; Krishnamoorthi *et al.*, 2024). Urban agriculture supports strengthening the local food system and building resilience within metropolitan areas. Rooftop gardens and other forms of food production help in bridging the gap between supply and demand contributing to climate change mitigation and adaptation efforts. Haphazard and unplanned land use change turning fertile agricultural land into plotting for housing has brought forward the concerns of urban food security in the nexus of climate change and availability of the productive land. In this context, this chapter investigates the diversified urban agricultural practices being used, challenges and opportunities encountered by households and identifies how such practices can contribute to the urban food security of people living in the communities and community development in Kathmandu.

2. URBANIZATION NEXUS TO URBAN FARMING

Urbanization is a process in which a large number of people live in relatively small areas and the course of human history shows that the process of urbanization has been accelerating since the eighteenth century. Only 3% of the world's population had lived in urban areas/cities by 1800. There was about one-quarter of the increase in urban population by the 1960s while more than half of the world's population resided in urban centers in the twenty-first century (Britannica, <https://www.britannica.com/topic/urbanization>). Agriculture and transportation played key roles for rural-urban linkages in the development of the cities as agriculture was highly productive and many rural areas produced surplus food, which were transported to urban centers to feed the urban population--to a larger extent this practice continues till the date questioning the sustainable development of the cities. However, the ongoing rapid urbanization has caused gradual decline of agricultural land, passing early warning signs of urban unsustainability. This suggests that strengthening urban sustainability needs a strong network of local food production systems, ensuring the food security of the residents (Piorr *et al.*, 2011; Jagganath, 2022; Lal, 2020; Krishnamoorthi *et al.*, 2024).

The history of civilization shows that there have been pragmatic changes in production and consumption patterns including in the areas of agriculture. The Industrial Revolution marked the new advancements in agricultural production technologies and even introduced some kind of mechanization in agricultural practices. The use of modern tools has contributed farming to be less intensive profession with increased production, and these developments have expanded consumption opportunities and distribution systems. Prior to the Industrial Revolution, consumption was largely limited to the locally produced food and manufactures, and the surplus production was shared between and among neighbors (Unmüßig *et al.*, 2016). The increase of urban population shows the transformation of farmland to larger urban areas impacting food production, food supply, food security, and social, economic and environmental system (Timilsina *et al.*, 2020; Akaeze & Nandwani, 2020), demonstrating the greater requirements of innovative resources and technologies needed for growing more food (Chatterjee *et al.*, 2020; Wong *et al.*, 2020). It shows the increasing migration has enhanced the demand of food and services in urban regions whereas it intensified the stress on agricultural systems to meet the dietary requirements of the increased population.

The increasing urbanization process has resulted in a reduction of agricultural land and is promoting environmentally unsustainable development practices (Jagganath, 2021; Pandey, 2023). Environmentally sustainable urban agriculture connects to the balanced interactions of economic, social, environmental resources and the food system. It emphasizes that cities can and should produce a significant amount of their own food to reduce their dependence on commercial agriculture and its negative environmental impacts including pesticides, pollution and fossil fuel consumption (Gosh, 2021). Urban agriculture covers a wide range of initiatives such as community gardens, green roofs, rooftop gardens, plant cultivation on top of buildings, medium to large scale urban farms within city limits using innovative technologies like hydroponics and aquaponics, and vertical farms, applying methods of growing crops indoors using artificial lighting in stacked layers and controlled climate. There are also interesting debates on the benefits and challenges of urban farming. The positive features are associated with numerous benefits while the negative features expose the challenges. Proponents of urban farming highlight that it reduces food dependency and negative environmental impacts including reduced water usage and use of pesticides, and improves air quality, provides educational opportunities and promotes community development while opponents argue that there are concerns of feasibility, scalability and sustainability. Critics argue that urban agriculture may not be able to meet the food needs of a large urban population due to unavailability of enough land and economic viability (Land8, 2015). Urban farming poses potential risks and challenges such as odors from composting activities, flies and worms from soil and plants, and conflicts among neighbors (Bhattarai & Adhikari, 2023).

Rooftop farming practices have been coming to be popular in urban areas of Nepal from the early twenty-first century. These urban farming practices are carried out at various locations like balconies, windowsills, indoor spaces, and open spaces available

in residential properties comprising both traditional as well as innovative approaches to the production system. The innovative production system includes, among many others, vase planting, vertical farming, and hydroponics where a variety of fruits and vegetables can be grown (Mok *et al.*, 2014; Bhattarai & Adhikari, 2023). In the meantime, urban agriculture production promotes community self-sufficiency and social justice improving health conditions. However, there are still debates on promotional strategy to enhance food security through agriculture production as the production is limited to home consumption (Sroka *et al.*, 2019).

3. CLIMATE CHANGE NEXUS TO URBAN FARMING

Climate change has been one of the biggest threats of the twenty-first century (Pandey, 2016; IPCC, 2022). Urban areas are increasingly experiencing food and water insecurities and climate change is playing the role of amplifier to further exacerbate the situations (Dubbeling *et al.*, 2017; FAO, 2018; IPCC, 2022). Increasing climate change effects and impacts are threatening food security by rising temperatures resulting in hydro-meteorological consequences such as flooding, drought, wildfire, and extreme weather events. The haphazard and rapid urbanization, urban population growth and climate change have become the tripartite challenges for sustainable urban development (Pandey, 2023). These tripartite challenges have affected urban water, livelihood and food security. Urban agriculture contributes 15 to 20 percent of the global food supply although it would not provide all food requirements of city residents. Studies report that approximately thirty percent of urban land would need to be converted to agricultural land to meet the current urban food requirements (USDA, U.D.).

Orsini *et al.* (2013) noted that urban agriculture enhances food security, and vulnerable urban populations can have improved access to fresh and nutritious productions. Locally produced food, fruits, vegetables, chickens, eggs, goat, milk, and honey for urban consumption do not require long-distance transportation. These locally produced food supply systems aligned with promoting local consumption can immensely contribute to the mission of addressing climate change. Several studies have emphasized the benefits of urban agriculture, for example, local food production reduces the carbon footprint of the food system by shortening supply chains and decreasing transportation-related greenhouse gas emissions (Kulak *et al.*, 2013). The promotion and advocacy for making cities sustainable in terms of food production and consumption does not only provide new opportunities and fresh food but also promotes environmental sustainability and improves social networks for community engagement and empowerment for effective community development (Hodgson *et al.*, 2011). Urban farming can help families save income by reducing the expenditure on purchased food which is good for the lower income households (Bhattarai & Adhikari, 2023). Yet, the rapid expansion of urban regions encroaching agricultural land in the era of climate change constraints urban agricultural expansion and sustainability in the globe which diminishes the capacity of urban food sustainability and resiliency (Orseni *et al.*, 2014). Studies have also noted that urban water scarcity

continues to increase in the era of climate change and that has been one of the major constraints to flourish urban farming initiatives significantly (Pandey, 2021; IPCC, 2022). Green roofs and other localized environment friendly urban agricultural systems support regulating temperature, mitigating urban heat effects, and improving stormwater management thereby contributing to mitigating climate change (Russo *et al.*, 2018). The load-bearing capacity of the building roof is an important consideration in ensuring technical integrity to promote urban agricultural systems (Orsini *et al.*, 2014; Jha *et al.*, 2019).

4. URBANIZATION, LAND USE PLAN, AND URBAN AGRICULTURE

The rapid global expansion of urbanization has transformed natural landscapes into built environments (Ghani *et al.*, 2023; Dadashpoor *et al.*, 2019), threatening food security and environmental sustainability (Lama & Kumpakha, 2023). Developing countries are more vulnerable due to climate change and ineffective land use zoning resulting in the loss of fertile land to rapid and haphazard urbanization, reduced crop production, and intensifying other issues like soil degradation. This trend shows that urbanization has been driven by policy failures and elite interests, intensifying concerns about food security, climate resilience and environmental sustainability (Shrestha, 2010; Haack & Rafter, 2006). Studies projected a 1.8–2.4% decline in cropland by 2030 that would diminish crop yield by 3–4% affecting fertile croplands and food security (d'Amour *et al.*, 2017; Nuissl & Siendentop, 2020; Bhattarai *et al.*, 2023). This changing context demands a fundamental transformation of land use management to achieve a food secure sustainable urban future.

Land use policies are recognized as important instruments of sustainable land management. Nepal ranks among the most urbanizing nations with a population growth rate of 18.2% showing notable land use cover conversion (Devkota *et al.*, 2023). Nepal *et al.* (2020) and Sharma (2012) emphasize the importance of land-use policies in Nepal for sustainable land management, emphasizing the importance of land-use planning for achieving sustainable development goals. In this context, Nepal's 2015 Land Use Policy and The Land Use Act 2019 promote integrated land use aligned with population growth, infrastructure development, and environmental conservation, conferring power to local governments to develop guidelines for land use plans (MoLMCPA, 2015; 2019). The Land Use Regulations (LURs) was brought into life in 2022 for the implementation of the visions of the Policy and Act. The LURs 2022 do not allow land of one category to be used for another purpose, although the classification can be altered through a due process. The regulations promote any other category of land to be used for agricultural purposes until it is used for its specified purpose, but not the other way around which note that commercial plotting of land and its sale are prohibited on any land other than classified for residential purposes (*The Kathmandu Post*, 3 June 2022). The regulations control land

fragmentation, prohibit construction of new houses or any physical structures on agricultural land and promote land pooling, mechanization of agriculture. However, as the land zoning authority is conferred to local government with the assumption that local governments better know the context about the land use and land use change, in practice the result is otherwise and ineffective primarily in urban areas. The increased Real-state price has changed the mindset of the urban landowners and are categorizing their land as commercial or residential, leaving no agricultural land in the urban areas.

Despite the challenges posed by rapid urbanization, urban agriculture has been recognized as a viable remedy to counteract the negative impacts of urbanization and food security (Zezza & Tasciotti, 2010). Urban agriculture, for example, is encouraged as a means of ensuring food security within urban areas while reducing the environmental footprint of cities. An approximate of 800 million individuals practice urban and peri-urban agriculture contributing to local food supply, poverty reduction, improved nutrition and environmental sustainability globally (Monroy *et al.*, 2023; Erwin, 2022). However, the increasing demands of food, reduced agricultural urban land, increased haphazard land use change, land plotting for housing and climate change pressures associated with urban areas have been creating mounting challenges of urban food security and sustainable urban development.

5. RESEARCH METHOD

We carried out a substantive review of the relevant secondary academic literature related to urban agriculture, urbanization, climate change and food security and this has been complemented through primary data. Qualitative research method was used to explore the contribution of urban agriculture in the context of anthropogenic climate change and unplanned urban development. Twelve in-depth interviews (6 males and 6 females) and two focus group discussions (mostly females) were conducted in four different urban communities of Kathmandu. The data were collected through semi-structured questions with urban households practicing urban farming to understand their perspectives on the current state of urban agriculture, its challenges, and potential contributions to urban food security. Kathmandu was purposively selected for this study as a research site due to its rapid growth of urban population, haphazard urbanization and increasing external dependency of food and any other resources. Another reason for selecting Kathmandu is that the practice of urban agriculture is getting popular in the region. Formal data was collected from the communities of Koteshwor, Gongabu and Kuleshwor and informal conversations were also held with people practicing urban farming in Duwakot. All these communities engage in active urban agricultural practices including the adoption of rooftop farming and home gardening which provided an appropriate context of the study. The data collected was analyzed employing thematic analysis and the findings have been presented in the following three themes: *Urban Residents' Motivation for Urban Farming; Impact of Climate Change and Urbanization on Urban Farming; Challenges and Opportunities/Benefits of Urban Farming.*

6. FINDINGS AND DISCUSSION

In this section, we present the findings of the primary data and interact the primary data with secondary data for interpretation. As discussed in the method section above, we present the findings in three interconnected themes and provide overall challenges, prospects and implications of urban farming in Kathmandu.

7. URBAN RESIDENTS' MOTIVATION FOR URBAN AGRICULTURE

The findings suggested that urban households engaged in urban agriculture believe that the practice brings important benefits to their family and the community, therefore they are motivated to practice urban agriculture. These benefits include utilization of underutilized land and home spaces including the roof, help reduce food transportation and environmental impacts, educate generations (inter and intra-generational) about urban food production and consumption systems along with providing fresh and healthier food. All the participants engaged in urban agriculture were found to be accustomed to agricultural practices for long with the understanding that rapid and haphazard urban growth and pattern of urbanization led to scarcity of agricultural land to grow enough food and vegetables for cities and/or rapidly urbanizing regions.

The study also found that urban residents with their interest in growing food and vegetables at their homes started the urban agricultural practice from vase and poly pots for their home consumption for long time however ever since the COVID 19 pandemic engulfed the world along with the global and national lockdown, it triggered urban residents to engage more and utilize their free/captive time in the real practice of urban agriculture. One of the participants shared:

Even though my interest in farming goes back to my childhood, I began urban agriculture during the COVID 19 pandemic. Before the pandemic, I used to grow vegetables in pots and containers occasionally. At that time, I didn't have much time to dedicate to it, and my interest was not as strong. However, when the pandemic hit and movement restrictions were imposed, it made me realize the importance of growing my own food at home. We avoid using pesticides and focus on growing organic vegetables at home, which ensures healthier food for us (IDI participant 2).

The urban agriculture inclusive of rooftop farms provide an opportunity to grow various types of crops, vegetables, flowers and fruits, however, the practice depends upon the availability of areas, and thereby the production. Thapa *et al.* (2020) stated that rooftop gardening is one of the means of promoting sustainable agriculture that solves urban food security problems. Most participants shared that the initial idea about the urban agriculture engagement for them was to utilize the unused space productively to grow some kind of food or vegetables instead of leaving the area or land unused. However, one of the participants shared that vegetable products were sufficient to meet the basic demand of the vegetables up to a maximum of 70%.

I felt uncomfortable while consuming vegetables bought from the market, suspecting them to be contaminated with pesticides. Therefore, I decided to start urban farming at home. I set up stands systematically on the rooftop, managed to make compost from kitchen waste, and began planting in grow bags. Since then, I do not have to buy garlic and ginger. This year I did not have to buy onions as well. I also grow potatoes, although I still buy some of them from the market. I prefer consuming the vegetables grown in my urban farm, which make up about 70% of our household vegetable consumption (IDI participant 3).

Another participant also shared:

Since starting urban farming, I no longer need to purchase certain produce like Jimbu, kiwi, or dragon fruit, as I can grow a sufficient amount of seasonal vegetables to meet my needs. However, there are times when I still need to buy additional vegetables from the market, either due to running out or wanting to try something new or sometimes due to extreme weather as well (IDI participant 6).

The practitioners of urban agriculture also noted other reasons for their engagement, as rooftop farming provides a good platform for them to walk and relax on the green roof, helps them to improve their physical health, supports recycling of the disposable waste to organic manure, and saves time of going to vegetable markets for the consumers. The findings show that such practices help most of the participants to reduce depression, anxiety, and keep them physically active. In the same line, the FGD participants shared:

During the pandemic, we did not have the opportunity to socialize only by staying at home. Instead, it provided an opportunity to engage in meaningful activities like urban agriculture. It is both interesting and a necessity and has proven helpful for many individuals suffering from depression and anxiety (FGD participants).

The growing interest of urban agriculture is fundamentally associated with getting fresh and healthy green fruits and vegetables for fearless and safe consumption. Therefore, the participants were found to be attracted towards urban agriculture due to other contributions besides vegetable security such as the opportunities for physical exercise to reduce their state of anxiety. Adding to what has been presented above, one of the participants shared:

Our environment is becoming highly polluted due to various reasons, such as factories. Likewise, urbanization is also increasing, with many houses and few open spaces, fewer trees, and declining oxygen levels. In such a polluted environment, I believe that rooftop farming is a good solution. As a result it has become one of my interests (FGD participant 6).

Additionally, all the participants shared that they engaged in urban agriculture for the reasons of health consciousness, hobby, fresh food and means of exercises while only one participant shared that it was useful for income generation. One of the participants shared that fruits and nuts provide more economic value compared to producing vegetables and he has been economically benefited by selling many saplings ever since the pandemic.

I believe that growing nuts is more beneficial than fruits because selling nuts generates more profit. I have benefited economically by selling nuts. We spend a significant amount of money importing nuts, so our government should designate specific areas for different crops to optimize production (IDI participant 5).

It was also found good in reducing depression and anxiety. Rooftop farming is self-sufficient for the seasonal vegetables and mint leaves, coriander and garlic whereas most of the participants indicated vegetables such as potatoes, onions and other vegetables if they want to change the taste then only they should buy from the market. One participant shared:

As a dietician, I have gained practical knowledge and applied it to myself. Thus, I can relate the dietary value as well as the economic value while discussing the benefit of rooftop gardening. This activity has enhanced my identity beyond the dietician and people have acknowledged me as an active rooftop gardener as well (IDI participant 1).

8. IMPACT OF CLIMATE CHANGE AND URBANIZATION ON URBAN AGRICULTURE

Urban agriculture contributes to increased green spaces within urban environments to remain in harmony with nature (Yilmaz, 2009). It also contributes to reducing climate change while climate change itself continues and will continue to affect urban agriculture. Climate change is affecting the sustainable growth of cities and worsening the environmental challenges faced by rapidly urbanizing regions (Pandey & Bajracharya, 2017; Pandey, 2021). The rapidly increasing emissions of greenhouse gasses/pollution deteriorate the urban environment. Industrialization and rapid and haphazard urbanization have caused declining oxygen level and elimination of historical open and/or green spaces. The increasingly degraded environmental condition is the direct consequence of climate change and its impacts on cities. The participants explain that there is no direct impact of climate change on their agricultural practices however they have noticed the broader influence of climate change which ultimately hampers urban agriculture. A participant concurring to the impacts of climate change noted:

There have been changes in the climate compared to before. Weather has become a challenge for us. If there's a lack of timely water or if there's excessive heat, it becomes difficult to protect the crops. Therefore, we need to

pay close attention and ensure timely watering. I discuss these challenges with my friends and seek their advice on how to solve them (IDI participant 3).

The urban development pattern of Kathmandu valley is haphazard and rapid (Pandey, 2023). The fertile land of the valley is being converted into concrete roads and buildings. As the availability of the land shrunk, social and agricultural specialists recommend rooftop farming as an alternative model to the full-fledged agriculture practices as it has emerged to be a viable and recommended solution. Indeed, by leveraging the underutilized spaces like corners of houses, rooftops and kitchen gardens, urban agriculture contributes to availability of fresh food and balances the environment through cultivating vegetables and horticultural crops by increasing the greenery. Urban agricultural practices not only increase oxygen production but also provide access to organic, locally grown produce to the residents which ultimately mitigate the detrimental effect of climate change. One of the participants shared:

The Kathmandu Valley is gradually dropping its greenery and is turning into a concrete jungle. Rooftop farming might serve as an alternative to traditional forests and could provide some support in maintaining greenery. It is possible that rooftop farming is contributing positively in this regard (IDI participant 5).

The urbanization has disturbed traditional farming practices and limited the cultivation in the small plots or vertical farming. In this changing scenario, the urban agriculture, community has adopted a more sustainable approach and adopted sharing of planting materials such as local, open pollinated seeds along with employing natural pest control measures. These adaptive strategies emphasize the resilience and resourcefulness of urban farmers in the face of climate induced agricultural challenges. The FGD participants shared:

The adaptation of natural pest control measures such as the use of Neem leaves, Titepati and natural homemade solutions has begun and was considered as a satisfactory method to mitigate the adverse impact of climate variability on urban farming. The measures applied were based on the findings from agricultural research of various universities. We only applied organic pesticides. If the remedies did not work we removed and discarded the plants to save other healthy plants (FGD participant 5).

A few respondents denoted that climate change is observed as erratic precipitation patterns disrupting rainfall patterns with excessive rainfall and prolonged droughts causing detrimental effect on the growth and productivity of the crops. Urban agriculture raises community engagement and has served as a powerful tool to enhance environmental resilience, food security and public health within the changing climate landscape. It also contributes to reducing the excessive heat to protect plants, they use mulching to provide favorable conditions for plant growth. One participant noted:

I have experienced a temperature difference between the room and the rooftop. In my view the rooftop is cooler due to the cultivation of various plants (IDI participant 3).

Furthermore, urban agriculture is also affected by water shortage. Even natural rainfall sometimes needs to be managed by installing the roofs to protect from sunlight and hailstorm. A participant from the Gongabu, the new bus park area shared:

The new bus park area is mostly the residential area of businessmen and most of the houses are rented out and home owners live elsewhere. Thus, people outside the valley have rented and have settled temporarily as a result we can see less greenery and open spaces. The temporary settlers do not have attention to urban farming, however a few might understand the importance of growing organic vegetables at home (IDI participant 9).

9. CHALLENGES AND OPPORTUNITIES/BENEFITS OF URBAN FARMING

The majority of the participants shared that they encountered diseases and pests problems because they were having limited knowledge and skills for effective urban farm management. A few of the urban farmers explained that they had limitations of the structures which hindered vertical farming considering the load bearing capacity. A study on urban agriculture illustrates that roof configuration determines the impressions of the available space and structural load bearing capacity and confirms that flat roofs are good as they offer greater accessibility and surface area, particularly suited for the cultivation (Shrestha *et al.*, 2020). However, the FGD and IDI participants shared uncertainty regarding the prospects of urban agriculture in the hands of the next generation. Furthermore, few of them highlighted the policy and regulatory barriers including low level of recognition by the local government. The promotion of green roofs was considered as the effective strategy to increase urban sustainability and a means against fighting too much and too little water countering climate change. Therefore, several studies recommended that the government of Nepal promote roof top gardening (Pandey & Bajracharya, 2017; Thapa *et al.*, 2020). Likewise, Shrestha *et al.* (2020) identified the benefits of urban farming and requested the government to consider rooftop farming in their plan to convert urban roofs to greenery roofs by providing subsidies and intensives. They assumed that the increasing trend of urbanization is one of the key factors hindering overall agricultural practices by converting fertile farmland into concrete.

Besides environmental benefits, urban agriculture was considered as the key initiative in the sectors of waste management, vegetable sufficiency and social capital. Majority of the respondents described that urban agriculture creates strong social connections as most of the urban growers were connected and shared the plants, seedlings and seeds with each other. Sometimes, they charge small amounts intentionally to force the grower to value and take care of the plants. This activity proves them an opportunity to build better social relationships reflecting upon strong social benefits and support within the community. This shows that the farming activities strengthen the social ties and social capital within the community with tangible economic benefit. It helps to balance the environment, especially in polluted urban areas and provide access to organic, seasonal produce. A participant pointed out:

With increasing urbanization, waste management has become an important issue. It is essential to manage biodegradable and non-biodegradable waste separately. If biodegradable waste is managed at home, it can be turned into compost, which is beneficial for urban farming. I believe the government should prioritize this and provide training to people on managing biodegradable waste at home. Proper management of biodegradable waste would also reduce the overall amount of waste that needs to be disposed of (IDI participant 9).

The other findings illustrate the diverse benefits mainly the socio-economic benefits as illustrated by the participants. It enhances the social inclusion and community development thus by increasing the involvement of urban farmers into new connections where they can share their gardening experiences which help to inspire new farmers to initiate the journey to urban agriculture. Complementing these findings, a participant remarked:

Rooftop farming fosters social connections as friends share plants, seedlings, and seeds, providing opportunities to get to know each other better. This practice offers significant social support. Seeing my rooftop farming efforts, others have been inspired to start their own. Additionally, it provides substantial economic benefits (IDI participant 6).

We explored the motivations, practices, challenges and benefits of urban agriculture in Kathmandu valley through the experiences of residents who practice urban farming. The findings presented on the three themes concurred that urban residents practicing farming have a number of reasons to be engaged in practicing urban farming (Poulsen, Neff and Winch, 2017). Urban agriculture, as the data suggested, is being practiced by the residents for a number of reasons which include the desire of producing and getting fresh and organic vegetables and fruits, utilization of underutilized and degraded spaces, keeping them physically fit and healthy, creation of new businesses and reducing their expenses on vegetables and the desire for environmental sustainability. COVID 19 pandemic appeared to be an amplifier as it made people captive resulting in the intensified farming practices utilizing the rooftop spaces, galleries and even unused land of other people.

All concurred that urban farming provides multiple benefits, including fresh produce and physical and mental health benefits. However, challenges include adverse climate change impacts, limited space, frequent occurrences of diseases and pests, and knowledge constraints regarding the urban agricultural practices, and the family dynamics. However, one of the pressing challenges facing urban agriculture and food security is the rapid decline of fertile agricultural land due to its conversion into real estate developments, unplanned urbanization, and the uncontrolled, haphazard expansion of urban areas. This trend, driven largely by the absence of an effective Land Zoning Policy in Nepal, is undermining the long-term viability of urban agriculture. Therefore, literal actualization of land zoning policy has been the

paramount need of the time without any further delays to maintain agricultural land in the urban areas.

In the context of rapidly reducing urban agricultural land, alternative ways of practicing urban agriculture have a greater prospect as it provides significant benefits including improved waste management, partial self-sufficiency, and promoting sustainable vegetable production and consumption. It was also considered as emerging social connectors contributing community engagement and social capital (Sharp and Smirth, 2003). Overall, the findings suggest that promoting rooftop farming can reduce the adverse effects of climate change by reducing the practice of food transportation and urban environmental sustainability; by improving human health with fresh food/vegetables, exercise and the clean environment; and by consolidating urban social capital (Mousa *et al.*, 2019). Government can promote these initiatives further by providing necessary support and policy recognition so that every urban house becomes a garden with multifaceted benefits.

10. CONCLUSION

The increasing trend of urbanization with pressing challenges of anthropogenic climate change have placed Nepal among the rapidly urbanizing and highly climate affected nations. Particularly urbanization has massively affected the fertile land of Kathmandu valley in the lack of effective land zoning policy, resulting in overcrowding, informal settlements, environmental degradation leading to inadequacies in existing services, social cultural norms and public spaces. This study concludes that urban residents practicing urban farming comprehend diversified benefits of it although it has not still been a powerful city-wide trend in Kathmandu. The study indicates that urban agricultural practices are essential to boost food security of the urban settlements thereby contributing to mitigating the impacts of climate change and to promoting environmental sustainability. By making some efforts, the urban residents engaged in urban agriculture utilizing the unutilized spaces within their house premises can cultivate local food produce to fulfill their desire to consume safe food in better environment among many other benefits.

The COVID-19 pandemic and the lockdown conditions served as the catalyst to increase the interest of urban settlers in urban agriculture. The roller-coaster urban life had come to standstill in terms of mobility and people had abundance of leisure time in captivity. Today, in the context of reduced agricultural land, new and innovative practices of urban farming is being acknowledged as a resilient response to enhance environmental sustainability, food security and community interrelationship addressing the challenges in the changing environmental landscape of the valley. However, for promoting this, collaborative efforts in the areas of knowledge sharing, and training along with urban agriculture friendly policies are to be introduced to encourage more households to connect to the mission of sustainable urban development and urban sustainability.

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Urban Sustainability Assessment in the Kathmandu Valley for Sustainable Urban Agriculture Practices Based on a Theoretical Optimization Study

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ABSTRACT: Urban agriculture, a system of food production within or near the city spaces using controlled or non-controlled environmental practices, is adopted widely depending upon its desired benefits. Urban agriculture has several social, economic, and environmental benefits, especially in developing countries. However, research and data to back these claims are limited. The aim of this paper is to characterize the features of urban agriculture currently in vogue vis-à-vis the features developed through optimization, and provide policy and program recommendations for sustainable urban agriculture practices based on five key features namely mechanization, purpose, crop value, market mechanism and area, respectively adopted from a previously accomplished theoretical optimization study in the Kathmandu Valley of Nepal. The most common urban agriculture practices in Nepal are rooftop, and back and front yard farming with or without a controlled environment vegetable production mainly for household consumption. Recent expansion and availability of climate control technology, availability of more crop species and variety options, and soil less cultivation technology are promoting urban agriculture as local farmers market opportunity or even at a commercial scale. Almost all local government authorities—Municipalities and their Wards - are supporting the adoption of urban agriculture practices in the Kathmandu Valley through program support and skill development activities. Gardening on rooftops, and front and backyards, and commercial urban farming with or without controlled environmental settings in vacant spaces are common practices recently observed in the Kathmandu Valley. For the overall viability, sustainability, and replicability of Urban Agriculture in other urban areas of the country, the government should invest in urban agriculture focused research and policy development programs. Program interventions focusing on technology development, capacity enhancement of households, farmers and entrepreneurs, and strengthening of local input suppliers by the relevant stakeholders - government authorities and

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NGOs, are recommended to complement the enormous urban supply needs by gradually replacing with local urban fresh produce and minimizing long distance imports that have a big carbon footprint.

Keywords: Urban Agriculture, Features, Kathmandu Valley, Urban Farming, Vacant Lots.

1. INTRODUCTION

Urban agriculture is defined in the scientific literature based on the contexts but is broadly related to the production and supply of nutritious and fresh food to the urban population at a reduced distance and in an environmentally friendly manner (Kafle *et al.*, 2023). The urban agriculture is a practice of growing and distributing food in and around cities that benefits people in various ways, directly or indirectly (McDougall *et al.*, 2018). Based on the purpose of farming, variation exists in types and urban farm size. Urban farms of many different sizes and production types can be found in different parts of the world. Urban Agriculture has economic, social and environmental functions, and the outcomes of those functions are critical for wider replicability. Asurban agriculture is a dynamic and multifunctional concept, its sustainability depends on the interaction of different social, economic and environmental factors, all of which may depend on the type and scale of operation. The major goal of urban agriculture is to optimize food production through effective land utilization and sustainable crop intensification (Souto, 2017). The social dimension of urban agriculture may be the key interest of the government for employment generation, food security and crisis management, whereas economic and environmental dimensions may be of prime importance for growers and consumers (Kafle, 2023). The major intention of urban agriculture is to feed urban residents with varieties of safe and quality food at a reduced cost and hauling distance through production technologies suited for human health and the environment. Factors such as rapid urbanization, concerns about climate change impacts on conventional agriculture systems, food insecurity and the need for healthy and diversified foods and sustainable lifestyles have encouraged growing foods in or near cities in the form of urban farming (Martellozzo *et al.*, 2014; Tornaghi, 2014).

Some researchers have categorized urban agriculture practices in different ways based on farming practices. The variation in urban agriculture is mainly governed by the types of economic activities, location and tenancy, crop types, scale and technology, destination markets, and types of people involved (Zeeuw, 2004). Hodgson *et al.* (2011) categorized urban agriculture as food production in a city area using non-commercial, commercial, and hybrid production technologies. He has reported eight non-commercial (gardening activities), four commercial (market-oriented production), and one hybrid-urban agriculture (integrated farming) type in different parts of the world.

Generally, urban agriculture includes diversified forms of production from uncontrolled to controlled environment systems (Game and Primus, 2015). The

common uncontrolled environmental urban agriculture practices cover farming in the community, allotments, farms, gardens on housing areas and rooftops, organisational gardens, market-driven vegetable production, and growing food in public parks (Hakansson, 2019), while hi-tech farming, including indoor, greenhouse and vertical farms (hydroponics, aquaponics, aeroponics), represent controlled environment urban agriculture practice (Kafle, 2023) that have social, economic, and environmental objectives of different scales (Sanye-Mengual *et al.*, 2018; Dobbins *et al.*, 2020). The non-commercial type of urban agriculture is intended for household consumption, human health and well-being, and environmental motives and is generally practised in an uncontrolled environment. Commercial (market-oriented production) and hybrid (combination of soil and soilless-intensive farming, including vertical farms) are commonly practised controlled urban agriculture practices across the world. Uncontrolled urban agriculture is common in most cities' food systems, and most developing countries practise this as a source of income and employment, along with perceived environmental benefits (Kafle *et al.*, 2023). The specific types of urban agriculture prevalent in an area largely depend on the context and country. Understanding the context in which urban agriculture is practiced is crucial to comprehending the various approaches adopted by individuals and households in urban farming. The potential benefits of urban agriculture can vary largely with the type of urban agriculture. However, its practices require growing spaces (free or priced), labour for production and a food distribution mechanism (Kafle *et al.*, 2023).

The benefits of urban agriculture are supported by some evidence-based studies that interrogate the claims in a comprehensive manner (Daftary-Steel *et al.*, 2015). If we only look at the economic dimensions of sustainability, in some cases, urban agriculture cannot be properly justified because the economic returns of prime city land are higher when used for non-agricultural purposes (such as commercial or industrial) (Voicu and Been, 2008). Meanwhile, as a more localized and diverse food production system, urban agriculture can bring agricultural production closer to the consumer, provide access to cheap and nutrient-rich food, and is therefore, considered helpful in mitigating adverse effects associated with the long-distance global food supply chain (Burton *et al.*, 2013). Likewise, urban agriculture is claimed to offer urban employment prospects (Glover *et al.*, 2005; Orsini *et al.*, 2014). Most urban agriculture research to date appears to have been conducted as a single-dimensional assessment of either economic, social or environmental aspects. Yet conclusions are typically drawn based on all potential benefits, with or without firm foundations. The motives for farming in urban areas are largely governed by population characteristics, policy, institutional setup, and the productive resources available in the nearby area (Kafle *et al.*, 2022a). In this regard, a review study was carried out to further investigate the sustainability of urban agriculture based on the features identified through an optimization study reported by Kafle *et al.* (2023).

Because of favourable soil, community involvement and demand from the sprawling population, urban agriculture in the Kathmandu Valley is expanding (Mitchell and

Iglesias, 2019). The farming of diverse vegetables on a small scale (kitchen gardening to market-led production in a relatively small piece of land) for self-consumption and supply to local farmers' market consumers using low external inputs is an age-old practice of urban agriculture. In the Kathmandu Valley, the Kathmandu Metropolitan City has also been promoting rooftop farming since 2012 (Kafle *et al.*, 2022a). There is a variation in the scale in terms of the area of urban farming in Nepal. Rooftops and backyard farming in Nepal are largely practiced in gardening styles of urban agriculture, and are done prominently in uncontrolled environments with space limited to 15–111 m² with a mean of 67.27 m² in Kathmandu Valley (Marasini *et al.*, 2022) where non-mechanized cultivation practices are commonly followed. The mixed crop-dominated production system (fruits and herbaceous to bushy fruits along with a combination of leafy, fruit, root and leguminous vegetables) for fulfilling self-demand and direct retail sales from the production site is the common feature of this type of urban agriculture in Nepal, as evident from the many rooftops or backyard farms in the Kathmandu Valley. Now-a-days, some innovative urban farming practices like small-scale hydroponics (nutrient-based soilless culture), aeroponics (nutrient-based pressurized mist spray in the root zone) and aquaponics (cultivation of crops using aquaculture effluent as a source of nutrients) are also adopted by some farmers in the Kathmandu Valley.

However, there is a limited understanding of knowledge on standard types, food production practices, and demand and supply scenarios despite different levels of government involvement in urban agriculture support activities (Kafle *et al.*, 2022a). The five key features of urban agriculture (area, purpose, mechanization, market mechanism and crop value) presented by Kafle *et al.* (2023) are discussed in the context of current urban agriculture practices in the Kathmandu Valley, and this forms the basis for making recommendations of policy and programs for sustainability.

1.1 Objectives

The major objective of this study is to characterize the features of urban agriculture currently in practice vis-à-vis the features developed through optimization and provide program and policy-level recommendations for sustainability, replicability, and viability, focusing on the Kathmandu Valley as a case example.

1.2 Conceptual Framework

In this paper, the study of urban agriculture reported by Kafle *et al.* (2023) for quantifying growth potential for viability, sustainability, and replicability has been taken as the basis for the discussion about urban agriculture in the Kathmandu Valley. The present urban agriculture practices that are common in Nepal are discussed based on the five idealized features of urban agriculture, namely area, purpose, mechanization, market mechanism and crop value, under previously investigated three best-case scenarios (maximizing net margin and employment and minimizing carbon emission). The conceptual framework adopted for this study is presented in Figure 1. Based on these five criteria, the best-case scenarios for profit, employment and

carbon emission are identified as typical characteristic features of urban agriculture in Kathmandu Valley. Those features are discussed in relation to the current urban agriculture practices of backyard/rooftop urban agriculture and vacant lot urban agriculture. Finally, the policy and program-level recommendations for the sustainability of UA practices in the Kathmandu Valley are made.

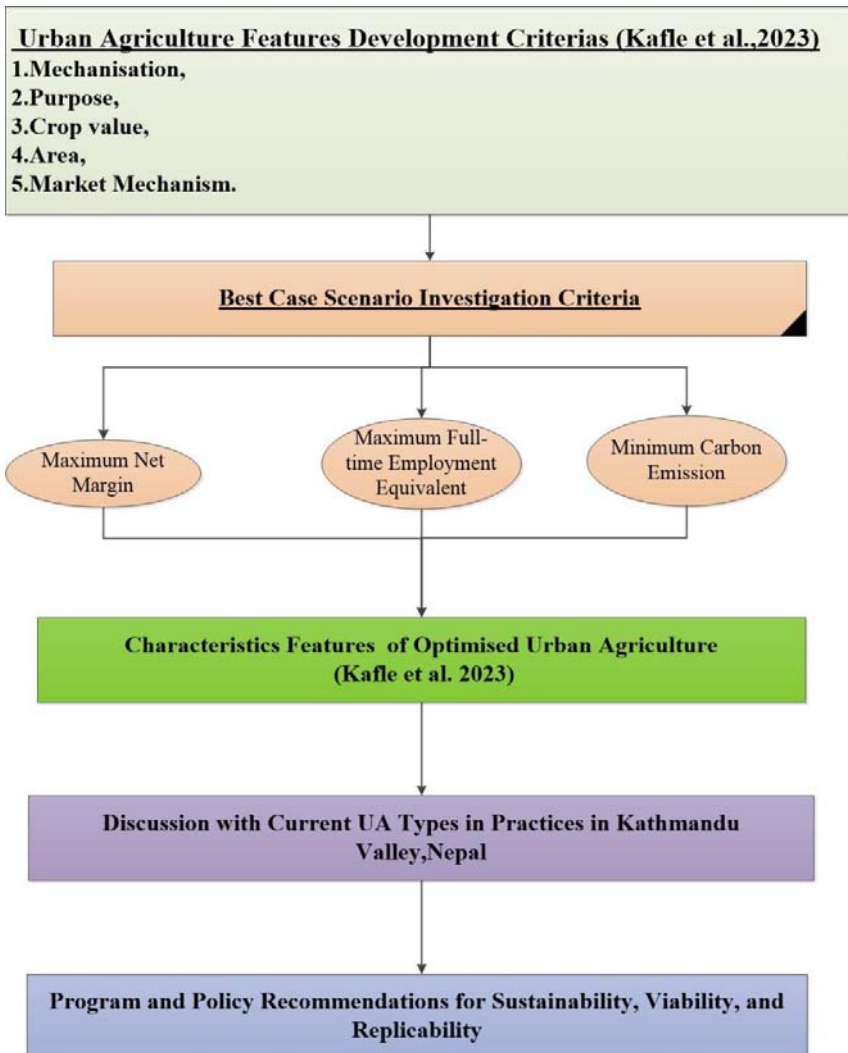


Figure 1: Conceptual Frame of the Study (UA, Urban Agriculture)

2. METHODOLOGY OF ASSESSMENT

In the study reported by Kafle *et al.* (2023), the authors have considered net margin (NM), Full-time Employment Equivalent (FTE), and carbon emission (CO₂)

emission) reduction potential from mechanizing production and food distribution as proxy variables for urban agriculture's economic, social and environmental potential. They calculated the net margin based on the income from vegetable production under mixed and mid to high-value vegetable scenarios in a specified area and costs associated with accessing land, labour machinery and distribution. Likewise, they considered the number of working days (labour days), the number of people fed by the vegetables, and effective working days in a year to analyze the FTE potential expressed as the number of producers needed to feed the consumption of vegetables based on population and recommended serving. The analysis of CO₂ emission per kilogram of food production was done based on the estimated carbon emission from a machine during production and food distribution activities by a small petrol-operated vehicle. They developed an optimized feature of urban agriculture based on the level of mechanization (non-mechanized/small petrol-operated), purpose (gardening/commercial farming), crop value (mid to high value or low value based on the market value of vegetables), area, and market mechanism (directly distributed produce and wholesaling inner city markets). Based on the above five criteria, the idealized features of Urban Agriculture for better margin, maximum FTE, and low CO₂ were identified. We took the idealized features as reference points (for maximizing benefit, employment, and minimizing carbon emission) and corroborated them with the most common urban agriculture type in the Kathmandu Valley. Finally, program and policy-level interventions were recommended for the overall sustainability, viability, and replicability of UA practices in the Kathmandu Valley.

3. RESULTS AND DISCUSSION

Figure 2 presents a triad of the features of Urban Agriculture under the three major characteristics indicators (margin, employment and carbon emission) of urban agriculture as determined through an optimization study reported by Kafle *et al.* (2023). In the expanded model, the maximum net margin favoured a relatively larger area (1000 m²) with a small machine (garden tiller) and retailing of the high value produce (direct sales from the farm) where land is available for free gardening. The maximum employment generation scenario also favoured a larger farming area, non-mechanized farming with free land gardening) and direct distribution from the farm. The low carbon emission scenario favoured a smaller farming area (almost one-third of the standard), with non-mechanized urban agriculture where land is free, and produce is distributed directly from the farm. It is evident from this study that the maximising margin favours mechanized farming in a larger piece of land with high-value commodities where land is available for free. While, the minimum carbon emission favours non-mechanized mixed crop cultivation and direct farm distribution from a small piece of land as emission is directly proportional to the level of mechanization and distribution distance. For better employment, non-mechanized cultivation of mixed crops in a relatively larger area with direct distribution is preferable.

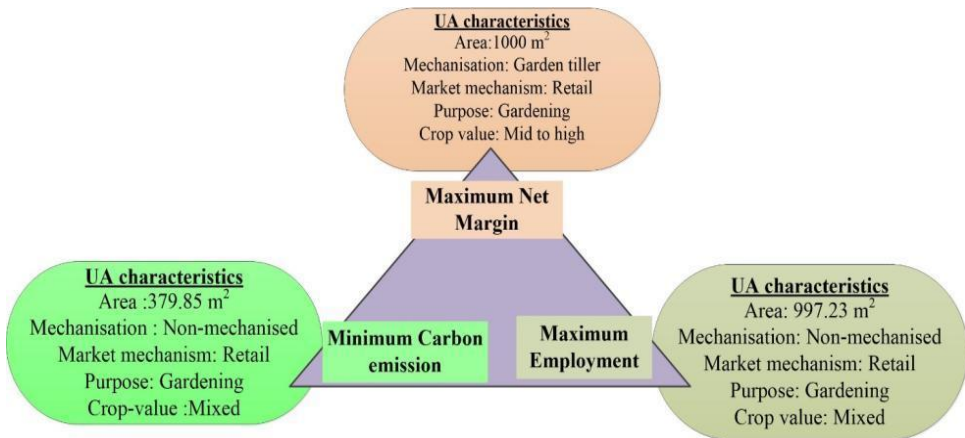


Figure 2: Characteristic Features of Urban Agriculture (UA) in the Kathmandu Valley, Nepal (Adopted from Kafle *et al.*, 2023)

Kafle *et al.* (2023) analyzed 30 different vacant parcels of land from within the 19 km periphery of Durbarmarga, which can be considered Kathmandu's city centre. The proposed model chooses the gardening style of urban agriculture (under all scenarios due to the high land price in The Kathmandu Valley) compared to cities in developed countries-such as Adelaidejn Australia, where land prices are relatively lower. The cost of land is identified as the primary limiting factor to the scalability of urban agriculture in the Kathmandu Valley (Kafle *et al.*, 2022b). To maximize the net margin, the proposed model chooses a larger land size to take additional advantage of mechanization for reducing labour costs and a combination of high-value crops.

The higher participation in the food system (full-time employment equivalent) requires less mechanization and favours more time spent in sales and distribution. The potential to reduce CO₂ emissions depends critically on the transportation and distribution mechanisms. Consumers' access close to the point of production appears to be key to both better social and environmental outcomes. This study shows urban agriculture's added social and environmental benefits through the improvement in the distribution system, as shown by Kafle *et al.* (2023).

Authors have investigated various types of urban agriculture across the world. A major emphasis has been given to economic aspects, especially the operational cost in urban agriculture practices, without accounting for the land and labour, which are the critical cost factors in urban agriculture (Kafle, 2023). Much is said about the social and environmental benefits of urban agriculture, but no studies have quantified these benefits and explicitly defined what these mean in a scalable urban agriculture system. For example, if a key social benefit comes from greater time spent in participating in the food system, then the opportunity costs of time spent should be accounted for in some ways. Similarly, if a key environmental benefit comes from CO₂ emission reduction potential, then this should be accounted for and where possible, compared with large-scale food production.

In the proposed model, the styles of urban agriculture such as gardening (where land used includes only the free- backyard and rooftops, as the commercial land is costly) are key to determining economic viability, and the cost of land is identified as a major bottleneck to the viability of urban agriculture in the Kathmandu Valley. The policy measures, including appropriate subsidies for land, or free access to land, may impact the economic viability of urban agriculture in the cities of developing countries like Nepal.

The Full-Time Employment (FTE) in urban agriculture is influenced by the number of consumers per grower, which depends on the types of food grown and the level of mechanization. Distribution and marketing of produce are also potentially significant determinants in terms of labour costs, particularly for small-scale urban agriculture. So, labour management is another critical issue as low mechanization in larger parcels of land favours more employment but has to trade off for economic factors due to increased labour costs.

Reduction of CO₂ emission is influenced by the distribution distance if transported by fossil fuel vehicles. For reducing greenhouse gas emissions, it is important to support market mechanisms that allow urban agriculture produce to be directly distributed to local consumers very close from the point of production.

The Net Margin (NM) is primarily influenced by the efficiency of work (mechanisation), crop value, input cost (land and labour), marketing mechanism and area under cultivation. Likewise, full time employment (FTE) is largely influenced by mechanization level, crop types, market mechanism and farm area. Ultimately, CO₂ emission per kg of crop production is significantly influenced by the distribution distance, mechanization level, yield and how produce is marketed (locally or in distant markets).

The most significant gap identified in the economic analysis of urban agriculture practices (Kafle *et al.*, 2023) was the lack of a consistent and comprehensive cost accounting framework. Previous viability studies have generally neglected land and labour costs. The urban agriculture practices sometimes seem unviable even without accounting for labour costs. For the viability of urban agriculture, a full and consistent cost accounting framework is necessary (Pollard *et al.*, 2018). The land and labour costs-especially in the high wage setting, are critical for, and have shown to be key influences on the viability of urban agriculture (Kafle *et al.*, 2022 b). The introduction of scale-appropriate mechanization may be one of the most feasible options for the vacant lots that are larger (Kafle *et al.*, 2023). The purposes of urban agriculture, either for family gardening or commercial venture, are influenced by the availability of land and the price of land. A commercial form of urban agriculture is feasible if the land is available for lost cost, or the land cost is subsidized. For the high value land area, urban agriculture is naturally squeezed into backyards or rooftops (Kafle *et al.*, 2023). The distance of the urban farm from the city centers and the size of the farming lot are the most important components that influence land costs and, hence, the overall viability (Kafle *et al.*, 2022b).

The nature and extent of employment in urban agriculture is largely influenced by productivity gained through mechanization (Kafle *et al.*, 2023). Urban agriculture has been studied for its potential for employment opportunities, considering seasonal and permanent labour, market, and opportunity costs (Glover *et al.*, 2005; Orsini *et al.*, 2014). The economic and social benefits of urban agriculture, especially from the job creation and income generation perspective, are important, and those aspects are, in turn, heavily influenced by the purpose as higher income is anticipated in commercial farming while gardening is oriented towards self-consumption, distribution and the market mechanism. In a previous study (Kafle *et al.*, 2023), FTE was used as a proxy measure for participation in the food system. As more person-hours are involved in food production, production costs increase, reducing economic viability, if the labour is not available for free. However, higher person hours may still be positive in terms of intangible social outcomes in some circumstances. No study has explicitly explored employment and job creation aspects of urban agriculture, particularly in terms of the broader social benefits as it may provide in developed or developing country contexts.

Urban farming is emerging in different forms depending on the population density in Nepal. Intensive farming practices like rooftops, balconies, and vertical farming, including hydroponics, are becoming increasingly common, followed by front, side and backyard along with rooftops in the urban cores or inner city areas, while community parks and gardens are common in the peri-urban areas in Nepal (Bhattarai and Adhikari, 2023). However, the most prevalent forms of urban agriculture in the Kathmandu Valley are rooftop farming, farming in the backyard, farming in vacant lots in an open field, and construction of low-cost protected structures in vacant lots for growing high-value vegetables (Kafle *et al.*, 2022 a). According to Mitchell and Iglesias (2019), the Bagmati riverbank area in the Kathmandu Valley has a huge potential for promoting urban farming practices for social, economic and environmental purposes. The traditional urban agriculture practices using local resources and indigenous knowledge oriented towards organic farming have been common for a long time for growing food to feed the people (Mitchell and Iglesias, 2019).

Urban agriculture on vacant lots is mainly intended for semi-commercial or commercial production with a land leasing agreement or self-owned land. The lots may vary in size, ranging from at least 500 m² to more, depending upon the space available. These are mainly concentrated around suburban areas (>10 km from the urban centre) and targeted for high-value vegetable commodities. Controlled environmental farming through the construction of low-cost bamboo frame plastic houses and uncontrolled environmental practices in vacant lots, rooftops and backyards are common features of urban agriculture observed in the Kathmandu Valley. The local urban agriculture produces are distributed commonly by retail sales in the local food markets.

Nowadays, vertical farming systems like rooftop farming and small-scale hydroponics and aquaponics in vacant lots are adopted in Nepalese contexts. Some government farms and research centers have also demonstrated this technology focusing on small-scale production. A detailed cost-benefit of such technologies of such food production has not yet been analysed. However, one study focusing on the Kathmandu Valley-Godawari area showed a high potential for utilizing rooftops for food production and greenery maintenance (Shrestha *et al.*, 2020).

4. CONCLUSION

Objectives and practices of urban agriculture vary with economic development settings. The urban agriculture in low-income cities like the Kathmandu Valley is primarily driven by economic objectives, specifically food security and livelihood promotion through income generation and better employment opportunities for households.

The cost of land and the distribution system for the produce are important variables affecting the economic, social and environmental sustainability of urban agriculture practices. It is evident in the Kathmandu Valley that urban agriculture is more commercially viable in peri-urban and suburban areas, while subsistence urban agriculture is common in inner city areas. The improvement in production and productivity through proper selection of crop mix based on market demand along with the availability of free, subsidized or cheaper land in close proximity to the point of distribution seems to be the ideal condition for sustainability, viability and replicability of urban agriculture.

In order to maximise the potential benefits of urban agriculture in cities like the Kathmandu Valley, a set of recommendations can be made considering the following criteria:

1. Scale-appropriate mechanization based on crop suitability and area (especially for vacant lot urban agriculture),
2. Selecting an optimal crop mix (a combination of high-value crops), efficient labour planning, and
3. Exploring alternative distribution mechanisms (direct farm distribution and local farmers' market) that reduce reliance on emission-intensive distribution.

5. POLICY RECOMMENDATIONS

Rapid loss of productive agricultural land for infrastructure and residential development is a serious issue that is attributed largely to weak regulatory mechanisms in the Kathmandu Valley. In the last three decades, the rate of urbanization has increased by 412%, with a loss of 31% of productive agricultural land (Ishtiaque *et al.*, 2017). This has created a land shortage for food production, though the issue is not unique to Nepal. Innovations to improve urban livelihoods, waste management, and nutrition to combat increasing urban poverty and food insecurity are recognised

as urgent needs in most countries (FAO, 2007). Policies and approaches to promote urban agriculture depend upon the purpose of urban agriculture. Governments should design policies and programs based on these factors.

The programs that were implemented to promote urban agriculture have not yielded the expected results due to a lack of coordination, continuity and technical backstopping. In order to get the desired results, an urban agricultural policy should be included in the city and regional planning processes (Dixit *et al.*, 2014). The local level governments in the Kathmandu Valley are concerned about the urban food system along with concern for greenery in the public spaces. To promote urban agriculture sustainably in Nepal, a clear guiding policy and planning tools are needed. City region food planning requires addressing institutional and marketing challenges along with driving forces of production (inputs, demand and supply, and management). Other influencing factors such as research, institutional framework, land use and specific areas of interventions should also be considered for sustainable, viable and replicable urban agriculture practices (Kafle *et al.*, 2022 a). The following specific policy and program-level interventions are recommended for promoting urban agriculture in the Kathmandu Valley:

- The economic viability is largely governed by land and labour costs along with the extent of mechanization and selection of crop mix and production location. The government should develop a policy for utilizing the available public spaces to harness economic, social and environmental benefits based on the feasibility. Community gardening plots can be allotted to landless urban dwellers interested in farming.
- The controlled environmental urban agriculture practices through land leasing/purchasing a vacant lot by the households for growing high-value vegetables have been the most common practices in and around the Kathmandu Valley. The government should protect such agricultural land through the effective implementation of agricultural land protection mechanisms as per the Land Use Policy and Land Use Act to ban the conversion of agricultural land into non-agricultural land.
- Rooftop farming also, known as kitchen gardening for self-food consumption, has been increasing across the Kathmandu Valley as a means to promote greenery and to utilize organic waste. The government should provide proper programmatic support through provisioning for input supply, training and technology support through the establishment of dedicated government institutions along with support to private enablers.
- Currently, advanced urban farming techniques such as vertical farming technologies, including hydroponics, aeroponics, and aquaponics, are adopted by some enthusiastic farmers in the Kathmandu Valley. The Government should focus on research and development of technological packages along with food safety and quality control mechanisms for sustainable up scaling and adoption of such technologies in other urban areas of Nepal.

- Local governments in urban areas are promoting urban agriculture to the communities, along with public parks, recreation spaces, and urban forestry development. Federal and provincial governments should also support local governments in developing policies, standards, and guidelines for sustainability, viability, and replicability to support the initiatives taken at the local level.

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Investigating the Current State of Rooftop Gardening in Lalitpur and Bhaktapur Municipality: Opportunities and Challenges

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ABSTRACT: This book chapter examines the current situation of rooftop gardening, exploring its associated opportunities and challenges, in Lalitpur Metropolitan City and Bhaktapur Municipality in Nepal. It scans the rooftop gardening practices in those two urban areas and recognizes vital factors influencing its implementation. Further, it explores the socio-cultural and environmental benefits as well as the challenges confronted by practitioners. Data was gathered through a questionnaire surveys conducted by visiting the sites. A comprehensive analysis of rooftop gardening in the study areas was carried out, using the survey data and field observations. The findings revealed that there is high potential for rooftop gardening operations to boost local food production, expand urban green spaces in urban areas, and promote community engagement. However, challenges such as lack of residents' practical skills; unfamiliarity with techniques, tools, materials related to roof top gardening; financial constraints; and a lack of access to services for managing diseases of plants hinder the widespread adoption of rooftop gardening. Based on this analysis, it is recommended that there is a need for training programs to improve technical skills in practicing roof top farming, monetary subsidies to lessen costs, and municipal support in providing information regarding roof top gardening tools, fertilizers, medicines and other related matters. Additionally, providing the disease management services to those who are experiencing disease problem at their rooftop gardening through the municipality services can encourage practitioners to take up the rooftop gardening. For improving food security and community resilience, Lalitpur and Bhaktapur municipalities can promote rooftop gardening growth by addressing these challenges and seizing the opportunities that have been identified.

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1. INTRODUCTION

Urban agriculture has gained significant attention worldwide as a sustainable approach to address household food insecurity (Shrestha, 2021) (Opitz *et al.*, 2016), environmental degradation (Buehler & Junge, 2016) and social well-being (Hallett *et al.*, 2017) in rapidly urbanizing cities. Among various urban agricultural practices, rooftop gardening (Then & Hong, 2022) has emerged as a promising strategy to utilize underutilized spaces and promote localized food production. Rooftop gardening involves the cultivation of plants for fruits, vegetables and herbs on rooftops of buildings, providing numerous benefits such as improved air quality, enhanced urban aesthetics, and increased access to fresh produce.

Lalitpur Metropolitan City and Bhaktapur Municipality are two major cities of the Kathmandu Valley adjacent to the capital city of Nepal, is experiencing rapid urbanization and faces various challenges related to food security, environmental conditions, and urban livability (Pradhan, 2004). The city's high population density, limited agricultural land, and increasing demand for fresh food produce make it imperative to explore innovative approaches to enhance local food production and mitigate the adverse effects of urbanization. Rooftop gardening has the potential to contribute to the urban resilience and sustainability (Ferreira *et al.*, 2018) in Lalitpur Metropolitan City and Bhaktapur Municipality by utilizing its vast rooftop spaces for food production.

However, despite its potential, the current state of rooftop gardening in Lalitpur Metropolitan City and Bhaktapur Municipality remain relatively unexplored (Bhattarai & Adhikari, 2023) (Rana *et al.*, 2015). Understanding the opportunities and challenges associated with rooftop gardening is crucial for effective policy formulation, planning, and implementation of initiatives that promote its adoption and maximize its benefits (Wadumestrige Dona *et al.*, 2021) (Specht & Sanyé-Mengual, 2017) (Pearson *et al.*, 2010) (Harada & Whitlow, 2020). This research aims to investigate the current state of rooftop gardening in Lalitpur Metropolitan City and Bhaktapur Municipality, focusing on associated opportunities it presents and the challenges that hinder its widespread implementation.

2. RESEARCH OBJECTIVES

The overall objective of this research was to explore the adoption of rooftop gardening in Lalitpur Metropolitan City and Bhaktapur Municipality, identify the key factors driving its growth, assess its social and environmental benefits, and understand the challenges faced by gardeners in these areas, promoting sustainable urban development and community well-being. The specific objectives were as given below.

1. To assess the extent of rooftop gardening adoption in Lalitpur Metropolitan City and Bhaktapur Municipality.

2. To identify the key factors influencing the implementation of rooftop gardening initiatives.
3. To examine the socio-cultural and environmental benefits of rooftop gardening in the urban context.
4. To explore the challenges and barriers faced by rooftop gardeners in Lalitpur Metropolitan City and Bhaktapur Municipality.

By addressing these objectives, this research will contribute to the existing knowledge on urban agriculture, specifically rooftop gardening, and provide insights into the current status of this practice in Lalitpur Metropolitan City and Bhaktapur Municipality. The location map of the study area is presented in figure 1. The findings of this study will inform agricultural technocrats, policymakers, urban planners, and other stakeholders about the potential of rooftop gardening as a sustainable urban agriculture practice and guide them in the development of strategies and interventions to overcome the challenges and promote its widespread adoption.

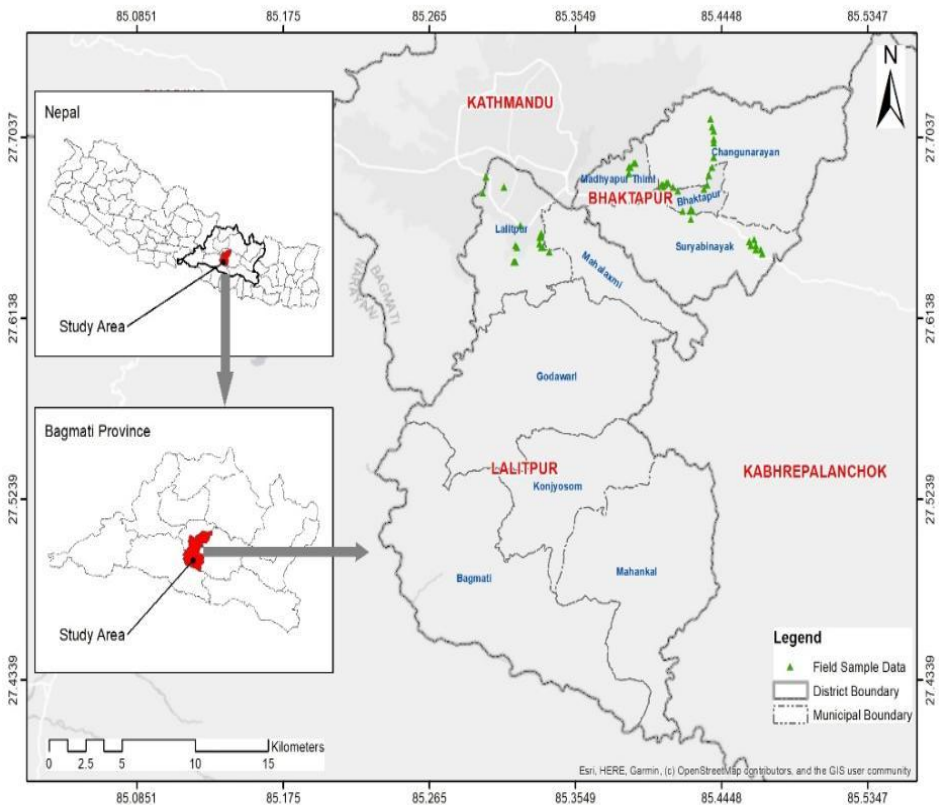


Figure 1: Location Map of Study Area

3. METHODOLOGY

The representative sample locations were taken to gather data on rooftop gardening, employing a random sampling method. A total number of 56 rooftop gardeners were identified within the study areas for research purposes among which 36 were from Bhaktapur and 20 were from Lalitpur. The field survey was conducted to collect quantitative data that allow to answer the research questions and to gain an understanding of the respondents towards rooftop gardening (Shrestha *et al.*, 2021). Individual interviews were conducted face-to-face by the researchers to ensure comprehensive data collection. KoBo Toolbox, a free, open-source software, was utilized for location-based field survey data collection, analysis, and management (Kumar Poloju *et al.*, 2021). A structured interview schedule was prepared containing both open-ended and closed-ended pretested questionnaire developed in kobo platform. The questionnaire aimed to explore the opportunities and challenges associated with practicing rooftop farming in urban areas.

The questionnaires were organized into six broad categories. The first category covered demographic information, encompassing the age group, gender, and family size of the respondents. Social variables such as ethnicity, religion, educational level, and living environment were also identified. Similarly, economic information was gathered, including the status of house ownership and the monthly income of interviewed rooftop gardeners. Another category focused on the specifics of rooftop gardening, such as the types practiced, the duration of involvement, and the area utilized. This provided insight into the current landscape of rooftop gardening practices. Furthermore, respondents were asked about their motivations for starting rooftop gardening and the benefits they observed, shedding light on the opportunities it presents. The final category delved into challenges in rooftop gardening, including the initial investment made by rooftop gardeners and whether they received any financial support. The study team has taken approval from the Research Ethics Board to ensure adherence to ethical standards, including confidentiality, voluntary participation, and data protection. Additionally, informed consent was obtained from each respondent before conducting the interviews. Participants were provided with detailed information regarding the purpose of study and their right to withdraw at any time. All collected data is handled with strict confidentiality and used solely for research purposes.

4. ANALYSIS RESULTS

4.1 Various Forms of Rooftop Gardening

An analysis of the current state of rooftop gardening reveals that a diverse range of plants are successfully grown, excluding tall trees and plants with deep and aggressive root systems, which could pose structural risks to the house building. Rooftops are ideal for cultivating a variety of small tree shrubs, herbs and creepers including vegetables such as tomatoes, peppers, and spinach; fruits like strawberries and citrus, herbs including mint, basil, and coriander; and decorative flowers like petunias,

marigolds, and chrysanthemum (Godawari). Both seasonal crops, such as cucumbers in summer, and off-season varieties, grown under the controlled conditions, can be cultivated successfully on rooftops, maximizing the use of urban spaces for food and greenery.

4.1.1 *Vegetables*

Observations of rooftop farming indicate that people grow vegetables because it offers a convenient way to obtain vegetable fresh produce utilizing the free space on their terraces. In Bhaktapur and Lalitpur, commonly grown crops and vegetables include tomatoes, radishes, cucumbers, lettuce, spinach, cabbage, cauliflower, potatoes, eggplants, chilies, and broccoli, primarily for their daily consumption. This practice provides fresh, natural, and pesticide-free vegetables at home.



Figure 2: Vegetable Growing on Rooftop Garden

4.1.2 *Fruits*

Some residents and families grow small fruit plants in their rooftop gardens to cultivate seasonal fruits. These plants are typically grown in large containers or pots. During a field visit, the team observed fruit plants such as lemon, pomegranate, strawberry, and guava. This practice allows them to enjoy the fresh taste of homegrown fruits.



Figure 3: Fruits Growing on Rooftop Garden

4.1.3 Herbs

In rooftop gardening, herbs are among the easiest and quickest plants to grow in pots. Commonly used spice herbs such as coriander, mint, ginger, turmeric, garlic, and onion thrive well on rooftops and require minimal space. Additionally, some people choose to grow other herbs beyond these Nepali kitchen staples, including basil, rosemary, lavender, chives, parsley, and lemongrass. These planted herbs not only enhance the flavor of their food but also bring joy of food delicacy and contribute to a healthier lifestyle.



Figure 4: Herbal Raising on the Rooftop Garden

4.1.4 Flowers

Most households in Bhaktapur and Lalitpur prefer to grow decorative flowers on their balconies and terraces where ample space is available. Popular choices include marigolds, chrysanthemums (Godawari), petunias, ferns, daisies, asters, black-eyed Susan, and low-maintenance succulents like cactus and aloe vera. These plants can be grown in small pots and positioned in bright light or partial shade, depending on

their requirements. While most users grow flowers for decorative purposes to create a pleasant atmosphere and refresh the environment, some also use them for rituals and worship.



Figure 5: Flowers Blooming on Rooftop Garden

The rooftop gardening in Bhaktapur and Lalitpur had comprised six main plant categories: leafy vegetables, flowers, fruits, herbal plants, ornamental plants, and other vegetables. Each respondent had been asked about the percentage of their available rooftop gardening area that had been covered by these plant categories. The results, as shown in Figure 6, indicated that leafy and other vegetables were the most dominant, with a large proportion of respondents having dedicated their rooftop space to cultivating these crops. Leafy vegetables and other vegetables had covered

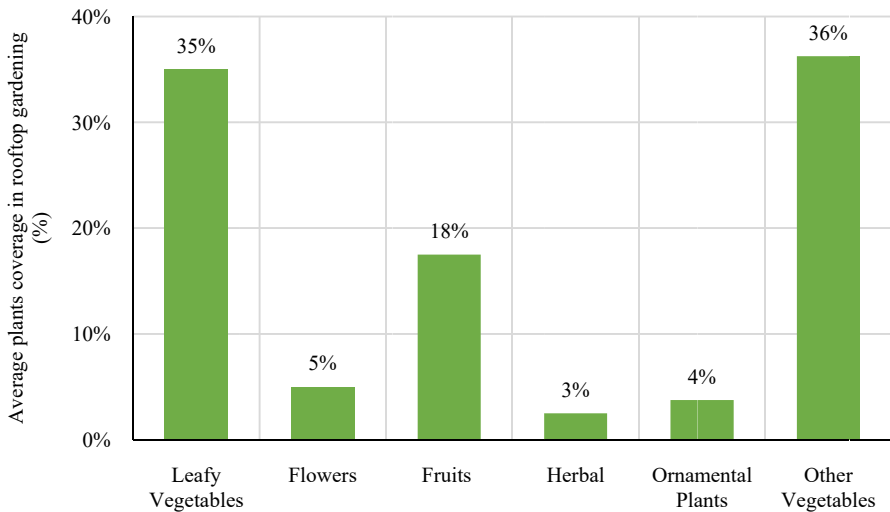


Figure 6: Rooftop Gardening Coverage by Different Categories of Plants

the largest share of rooftop gardens, with an average of 35% and 36% respectively, with common crops like lettuce, spinach, tomatoes, radishes, cucumbers, cabbage, cauliflower, eggplants, and broccoli, had been widely cultivated for household consumption. Fruits, including lemon, pomegranate, strawberry, and guava, had been grown at moderate levels, typically covering around 18% of rooftop gardening spaces. In contrast, flowers, herbal plants and ornamental plants had received the least coverage (up to 5%), with most respondents having grown them only in small portions of their rooftop gardens. These findings suggest that rooftop farmers continue to prioritize growing edible and high-yield crops, particularly vegetables, while placing less emphasis on decorative or medicinal plants.

The analysis of observed comprehensive database reveals various facets of rooftop gardening such as demographic profile of respondents, social and economic status among rooftop gardeners. The analysis and results in various categories are presented below.

4.2 Demographic Variables of Respondents

The distribution of respondents across age groups in rooftop gardening indicates a diverse demographic profile, with significant participation from individuals aged 31 to 60 (71.4% of participants) alongside engagement from younger and older age segments, reflecting an inclusive interest across different generations as shown in table 1. A relatively balanced participation, with slightly higher representation from males (55.4%) compared to females (44.6%), suggesting a shared interest and engagement in this activity across genders. The majority of respondents (71.4%) have a family size of 4 to 6 members.

Table 1: Demographic Information of Respondents

<i>Age Group</i>	<i>Count (No.)</i>	<i>Percentage</i>
≤ 30	7	12.5%
31–40	15	26.8%
41–50	16	28.6%
51–60	9	16.1%
>60	9	16.1%
Gender		
Female	25	44.6%
Male	31	55.4%
Family Size		
≤ 3	6	10.7%
4–6	40	71.4%
>6	10	17.9%

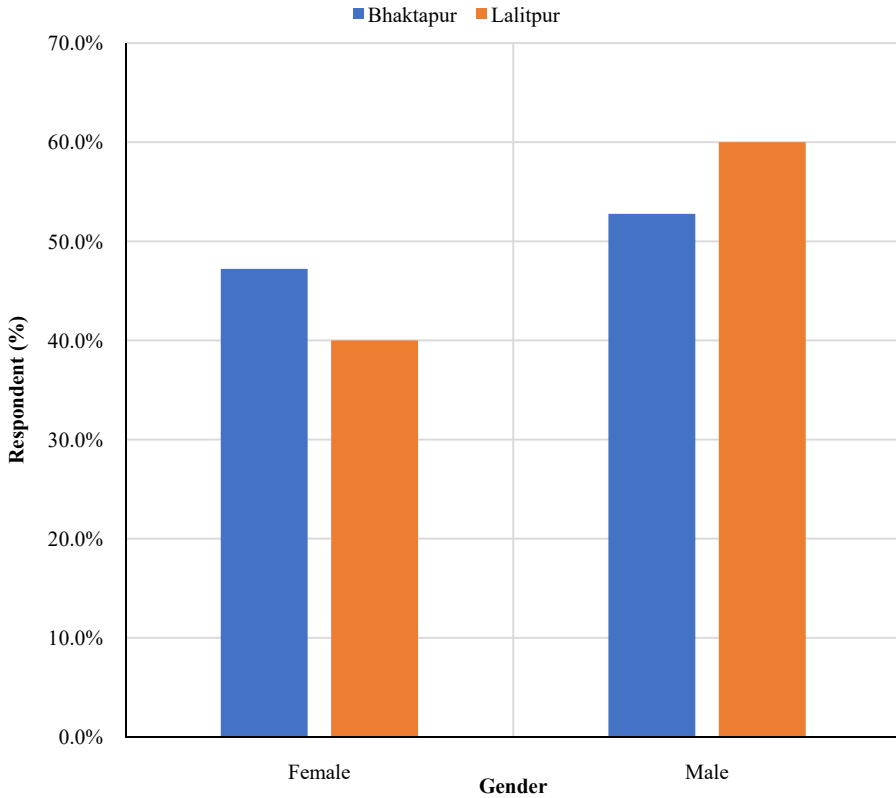


Figure 7: Gender Distribution of Respondent in Study Areas

Among the representative respondent sample, in Bhaktapur, 47.2% of respondents are female, and 52.8% are male. Likewise, in Lalitpur, 40.0% of respondents are female, and 60.0% are male as shown in figure 7. This indicates that in both locations, the male population is higher than the female population involvement in rooftop gardening.

4.3 Social Variables of Respondents

The distribution of household participations based on ethnicity in rooftop gardening includes a significant representation of the Newar ethnic group (55.4%), alongside varying degrees of engagement from other ethnicities such as Brahmin, Chettri, and others (including Janajati and Madhesi), reflecting a diverse social landscape within the rooftop gardening community. The religious composition of respondents predominantly reflects Hinduism, with smaller representation from Buddhists and Christians. Regarding formal education of the respondents, 60.7% had elementary/lower secondary and below educational status, 21.4% people had completed +2 level of education, and only 17.9% had graduated as presented in table 2.

Table 2: Social Information of Respondents

<i>Ethnicity</i>	<i>Count (No)</i>	<i>Percentage</i>
Brahmin	9	16.1%
Chettri	8	14.3%
Newar	31	55.4%
Others	8	14.3%
<i>Educational Level</i>		
Graduate level	10	17.9%
+2 level	12	21.4%
Elementary/lower secondary	26	46.4%
Can read and write	8	14.3%

4.4 House Ownership Status of Respondents

In terms of house ownership, the majority (83.9%) own their homes, while a smaller portion (16.1%) are on rent as presented in table 3.

Table 3: House Ownership Status of Respondents

<i>House Ownership</i>	<i>Count (No)</i>	<i>Percentage</i>
On rent	9	16.1%
Own	47	83.9%

4.5 Monthly Income of Respondents

The survey has also revealed that the monthly income of the respondents involving in rooftop gardening. A significant proportion of respondents (57.1%) earned between NRs. 20,000 to 50,000 per month, followed by 30.4% earning less than or equal to 20,000, and a smaller segment (12.5%) earning more than 50,000 as presented in table 4.

Table 4: Monthly Income of Respondents

<i>Monthly Income</i>	<i>Count (No)</i>	<i>Percentage</i>
≤ 20000	17	30.4%
20000–50000	32	57.1%
> 50000	7	12.5%

The comparative analysis of monthly income of all respondents reveals that in Bhaktapur, about 64% earned between NRs. 20,000 and 50,000. In Lalitpur, both income range less or equal to NRs 20,000 and NRs 20,000 to 50,000 comprised 45% of its respondents as shown in figure 8. This indicates that a majority of

respondents in both areas earned between NRs 20,000 and 50,000, with Bhaktapur having a higher proportion in this range compared to Lalitpur.

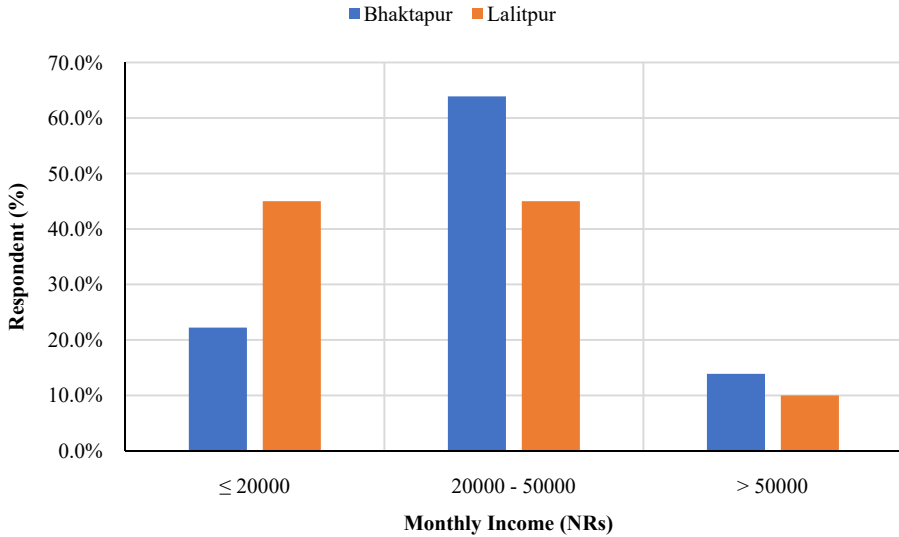


Figure 8: Monthly Income of Respondent in Study Area

4.6 Status of Rooftop Gardening Practices

The status of rooftop gardening practices among respondents indicates a 41.1% have been engaged for over 10 years, followed by 28.6% for 5 to 10 years, and 30.4% for new beginners. In terms of the area covered, 44.6% of respondents cultivate between 100 to 1000 square feet, followed by 35.7% covering areas less than or equal to 100 square feet, and 19.6% covering over 1000 square feet as presented in table 5.

Table 5: Rooftop Gardening Practices of Respondents

<i>Years Involved in Rooftop Gardening</i>	<i>Count (No)</i>	<i>Percentage</i>
≤ 5	17	30.4%
5–10	16	28.6%
>10	23	41.1%
<i>Area Covered (Sq Ft)</i>	<i>Count (No)</i>	<i>Percentage</i>
≤100	20	35.7%
100–1000	25	44.6%
>1000	11	19.6%

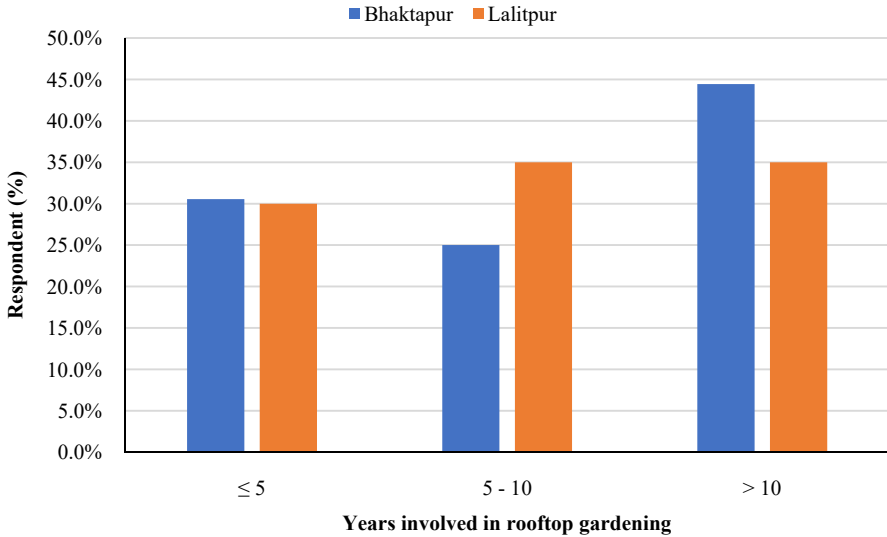


Figure 9: Rooftop Gardening Involvement of Respondent in Study Area

The comparative analysis of years involved in rooftop gardening of all respondents reveals that in Bhaktapur, 30.6% are doing it for 5 years or less, followed by 25.0% for 5 to 10 years, and 44.4% for more than 10 years. In Lalitpur, 30.0% are doing rooftop gardening for 5 years or less, followed by 35.0% for 5 to 10 years, and 35.0% for more than 10 years as shown in figure 9. Thus a larger proportion of Bhaktapur respondents are doing rooftop gardening for over 10 years compared to Lalitpur.

4.7 Opportunities

The opportunities presented by rooftop gardening, as indicated by the respondents, highlight various motivations and benefits. In terms of reasons for starting rooftop gardening, a significant portion (57.1%) were driven by the prospect of saving on grocery costs, while others were influenced by factors such as free of chemical insecticide uses (8.9%), inspiration from neighbors, family, or friends (10.7%), and personal hobbies (14.3%) as observed in table 6.

Table 6: Reason for Starting Rooftop Gardening

<i>Reason for Starting Rooftop Gardening</i>	<i>Count (No.)</i>	<i>Percentage</i>
Feel safer as it has no chemical insecticides	5	8.9%
Inspired by my neighbors/family/friends	6	10.7%
My hobby	8	14.3%
Save grocery cost	32	57.1%
Other reason/s	5	8.9%

Additionally, benefits reported from rooftop gardening include the efficient utilization of free time (27.6%), the ability to harvest fresh vegetables at home (27.1%), and the opportunity to recycle kitchen waste (24.1%) as per observation summarized in table 7. Furthermore, respondents noted gaining knowledge about gardening, increasing awareness about the food production supply chain, and enhancing social connections through sharing experiences on social media. These findings emphasize the diverse opportunities and advantages associated with engaging in rooftop gardening practices.

Table 7: Benefits from Rooftop Gardening

<i>Benefits from Rooftop Gardening</i>	<i>Count (No.)</i>	<i>Percentage</i>
I could use my free time efficiently	55	27.6%
I was able to harvest fresh vegetables at home	54	27.1%
I could recycle my kitchen waste	48	24.1%
I could gain more knowledge about gardening	10	5.0%
I have become more aware about food production supply chain	12	6.0%
I got a chance to learn about growing food	15	7.5%
I could improve my social connection through my posts on SNS about my rooftop garden	5	2.5%



Figure 10: A Female Practitioner is in a Cheerful Mood while Working in her Rooftop Garden

Rooftop gardening offers numerous opportunities for personal, social, and environmental benefits. It provides a safe and chemical-free way to grow fresh vegetables at home, ensuring healthier food consumption. Inspired by neighbors, family, and friends, it fosters community connections and serves as a fulfilling hobby that utilizes free time efficiently. Rooftop gardening also promotes sustainability by recycling kitchen waste and reducing grocery costs, making it both environmentally and economically beneficial. Additionally, it enhances knowledge about gardening and the food production supply chain, offering valuable learning experiences. Sharing gardening progress on social media can improve social interactions, making it a platform for creativity and community engagement. Overall, rooftop gardening is a rewarding endeavor that combines personal growth, sustainability, and social connection.

4.8 Challenges

The challenges faced in rooftop gardening by the respondents, primarily revolve around financial aspects. The data reveals that a significant majority (71.4%) spent up to NRs. 10,000(US\$72, as per Jan 19, 2025) to initiate their rooftop gardening endeavors. However, a notable proportion (16.1%) did invest larger amount between 10,000 to 100,000 and 12.5% investing over NRs. 100,000. Despite these expenditures, all respondents reported receiving no financial assistance, indicating a lack of external support in funding their rooftop gardening projects. Thus, the financial burden and absence of support systems are the key challenges faced by individuals engaged in rooftop gardening, particularly in terms of startup costs and ongoing expenses.

Table 8: Investment and Financial Support in Rooftop Gardening

<i>Money Spent to Start Rooftop Gardening</i>	<i>Count (No)</i>	<i>Percentage</i>
≤ 10000	40	71.4%
10000–100000	9	16.1%
> 100000	7	12.5%
<i>Financial Support</i>	<i>Count (No)</i>	<i>Percentage</i>
No	56	100.0%
Yes	0	0.0%

Furthermore, many residents interested in rooftop farming lack the technical skills required for effective implementation. They need training on various aspects, such as seasonal plantation, seed availability, organic fertilizers, tools and equipment, shed arrangements, and assessing the structural suitability of their rooftops. Without such knowledge, it becomes difficult to sustain and optimize rooftop farming practices. Additionally, financial constraints often hinder residents from investing in necessary materials. Providing subsidies for tools, fertilizers, and seeds can encourage wider

participation. However, many residents are unaware of where to obtain these subsidies, highlighting the need for municipalities to actively share information and facilitate access to suppliers and resources.

In the same way, the absence of support systems for disease management in plants is another challenge. When crops are affected by pests or diseases, residents often lack the expertise or resources to find remedies. The establishment of dedicated shops for rooftop farming supplies within municipalities would simplify access and encourage participation. Municipalities can play a significant role in addressing this issue by offering advisory services and technical assistance to rooftop farmers.

Field observations of rooftop farming respondents as presented in figure 11 show that plant diseases are the predominant challenge, significantly affecting productivity. Instrumental and process-related issues also pose notable operational hurdles. Training gaps and technical problems highlight the need for skill development and better technical support, while financial constraints and with limited subsidy for toolkits reflect resource shortages. Seepage is a minor issue but still noteworthy for building infrastructure maintenance.

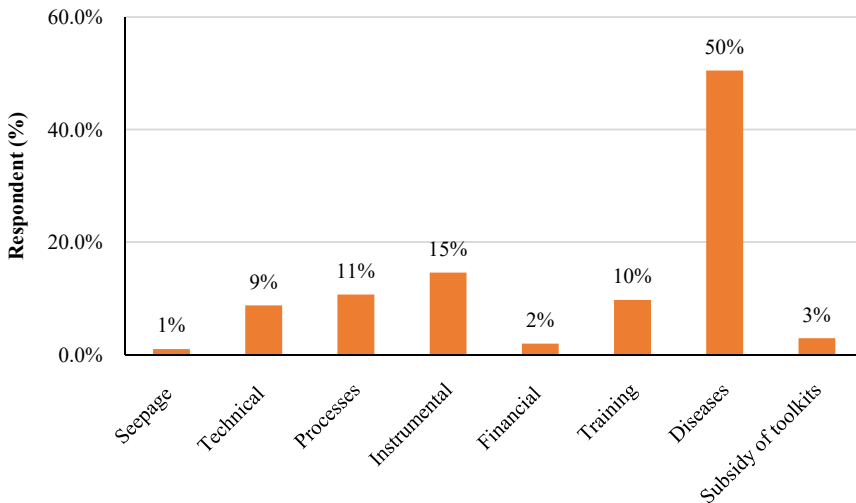


Figure 11: Problems Facing During Rooftop Farming

By addressing these challenges, municipalities, policymakers, urban planners, and community stakeholders can create a supportive ecosystem that promotes rooftop gardening. Targeted interventions and support mechanisms will empower individuals and communities to embrace rooftop farming, contributing to food security, improved urban greenery, and a healthier environment. Such collaborative efforts can transform rooftop farming into a beneficial practice, enhancing the quality of life for residents and fostering sustainable urban living within the municipality.

5. DISCUSSION

Demographic, social, and economic profiles of the respondents involved in rooftop gardening present a diversified interest in rooftop gardening across age groups, with remarkable involvement of respondents within the age bracket of 31–60 years and relatively balanced sex representation, particularly in Bhaktapur and Lalitpur. The Newar group is predominant ethnically, and Hinduism is the main religion. Most respondents had middle school or lower secondary levels of education and had urban residences; a large proportion were house owners; an income group ranged from NRs. 20,000 to 50,000 rupees (US\$144–360, as per Jan 19, 2025) per month, while Bhaktapur had shown a larger share in this range. Similarly, there was a long-time involvement in rooftop gardening among a good number of respondents. The motivations to do rooftop gardening are cost-saving, chemical-free vegetables, influence of peers, and hobby, whereas the benefits are utilizing free time properly, fresh vegetables, and recycling of waste. Financial problems, especially high investment costs and lack of external financial support, are the major obstacles. These are multi-dimensional benefits and challenges for the promotion of rooftop gardening; therefore, incentives are desperately required to create enabling environments for this increasing trend of urban agriculture.

The absence of a comprehensive policy framework and institutional support further reduces the growth of rooftop gardening in urban areas. A lack of standardized guidelines on structural safety, water management, and waste disposal creates uncertainties for potential gardeners. Further, inadequate promotion of rooftop gardening as one of the feasible urban agriculture strategies limits its adoption, while it should be widely embraced due to the potential benefits. The challenges facing the system demand for the implementation of training programs, financial incentives, awareness, and policy frameworks. Multi-stakeholder collaboration among government bodies, private sectors, academic institutions, and community groups is urgently needed for inhibiting the complete realization of rooftop gardening opportunities in Lalitpur Metropolitan City and Bhaktapur Municipality if the barriers are to be overcome.

6. CONCLUSIONS AND RECOMMENDATION

The respondents practicing rooftop gardening were fairly inclusive in demographic, social, and economic profiles, where most of the respondents were house owners in the urban areas studied. Many of them were engaged in rooftop gardening, especially in Bhaktapur, due to motivation of saving on grocery costs, and making good use of free time to get fresh vegetables. The educational backgrounds are varied, with the majority falling within elementary/lower secondary education. While benefits abound, financial constraints dominated with high levels of start-up costs and a lack of access to external sources of finance, technical, and capacity-building support. These conditions highlight potential as well as setbacks for rooftop gardening practices; therefore, supportive measures from the local government are needed to enhance the initiatives' sustainability and growth.

The supportive mechanisms in financial, technical, and capacity building for enhancing access to finance and techniques in rooftop gardening activities should be considered based on analysis of demographic, social, and economic variables among respondents and status, opportunities, and challenges in rooftop gardening practices. Such educational programs and capacity-building programs may be targeted towards various groups to help increase participation and knowledge sharing on sustainable issues of cost savings, chemical-free production, and waste recycling. While social networks can be facilitated for community building through social sites and neighborhood events, local support can be extended. Encouraging community engagement through social platforms and neighborhood rooftop gardening initiatives can foster a supportive environment and could promote many residents in the neighborhood the utilization of existing spaces for rooftop gardening, thereby enhancing food security and community resilience.

The following recommendations are suggested to improve the opportunities and challenges of rooftop gardening in Lalitpur Metropolitan City and Bhaktapur Municipality based on the findings of this research:

Training and Capacity Building: The majority of the respondents showed a lack in the required technical skills on rooftop gardening. It includes seasonal plantation, natural farming practices, and the assessment of suitability of the rooftop. Training in the actual gardening techniques should be imparted over seasonal plantation, management of pests, and other structural concerns towards effective rooftop gardening practices.

Financial Incentives and Subsidies: The greatest challenge that rooftop gardeners face is huge initial investments and continued expenses involved in this culture. Municipalities should offer incentives through subsidies on seeds, fertilizers, and tools and even water systems to reduce the economic load on the participants in rooftop gardening. Municipalities can incentivize for the rooftop gardeners by subsidizing on property tax or municipal drawing approval fee for the new houses which have the design provision for the roof top garden.

Policy and Awareness: It requires the local governments to pursue comprehensive policies that encourage rooftop gardening for urban sustainability in cooperation with policymakers and urban planners. This may involve formulating support policies for urban agriculture, creating awareness of the benefits, and making known the support mechanism towards rooftop gardeners.

Access to Resources: Most of the residents were not aware of any available gardening subsidies or technical support systems. Communication and access to information regarding rooftop gardening opportunities needs to be improved. Municipalities should establish local hubs regarding gardening supplies and also guidelines for receiving subsidies or technical support.

Community Engagement: Rooftop gardening brings more social, environmental, and economic benefits; thus, municipalities need to educate people about these

benefits in order to increase participation. Municipalities should foster social links of their residents by activities of community gardening and sharing information on urban agriculture through social media platforms and events organized at the local level.

Sustainability Practices: Educational campaigns also need to highlight that rooftop gardening ensures environmental sustainability due to air quality improvement, reduction in the heat island effect, and an increase in local food production. Besides, recycled materials and organic farming techniques should be encouraged in order to cut costs and further enhance sustainability in the environment.

By addressing these recommendations through strategic interventions, rooftop gardening has great potential in contributing to the sustainability, resiliency of cities, and wellbeing of the community as a whole.

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Challenges and Opportunities of Climate Adaptation Planning in Growing Cities: Case from Nepal's Cities

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ABSTRACT: As cities expand, they face the dual challenges of rapid urbanization and climate change, heightening urban vulnerabilities and exposing communities to frequent climate-related disasters. This chapter explores the multifaceted challenges and opportunities associated with climate adaptation planning in rapidly urbanizing cities, drawing from case studies of small and mid-sized Nepalese cities. Smaller and mid-sized urban centers in developing countries are increasingly vulnerable due to limited governance structures, financial constraints, and insufficient technical capacity for climate adaptation. These cities often lack comprehensive adaptation strategies, leaving them ill-equipped to cope with both gradual climatic stresses and sudden extreme weather shock events. Despite these challenges, opportunities exist to embed climate adaptation planning into broader urban development frameworks. Nature-based solutions, such as green infrastructure and ecosystem-based adaptation, offer viable pathways for increasing urban resilience while enhancing biodiversity and ecosystem services. Additionally, integrating climate impact assessments into urban planning processes can help cities anticipate and mitigate long-term climate risks. By highlighting both the challenges posed by limited resources and the opportunities presented by innovative approaches to urban resilience, this chapter aims to contribute to a deeper understanding of pathways toward sustainable and resilient urban futures in the face of climate change. This chapter calls for scholarly attention to adaptation practices and the challenges faced by transitional cities, which offer significant opportunities for advancing climate-resilient planning in an urbanizing world.

Keywords: Nepalese Cities; Climate Adaptation; Urban Resilience; Rapid Urbanization; Nature-Based Solution; Ecosystem-Based Adaptation; Climate Impact Assessments.

1. INTRODUCTION

As cities expand, they must navigate the dual challenges of rapid urbanization and climate change, both of which heighten urban vulnerabilities and expose

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communities to increasingly frequent yet often underestimated climate-related disasters. In many regions, especially in the Global South, urban growth outpaces infrastructure development, leaving cities more susceptible to hazards such as floods, landslides, and heat waves (Pelling, 2011). Additionally, smaller and mid-sized urban centers in developing countries, largely in the global south, are increasingly vulnerable due to weak governance structures, financial constraints, and insufficient technical capacity for climate adaptation (Ghosh *et al.*, 2024). These cities often lack comprehensive adaptation strategies, leaving them ill-equipped to cope with gradual climatic shifts and sudden extreme weather events. Meanwhile, the accelerating impacts of climate change are further intensifying these risks, underscoring the urgent need for stronger urban resilience and climate adaptation strategies (Gaillard *et al.*, 2012). As Berke *et al.* (1993) advocate that cities must integrate sustainable development principles into their planning to mitigate disaster risks and improve long-term resilience.

Despite these challenges, there are opportunities to embed climate adaptation planning into broader urban development frameworks. Nature-based solutions, such as green infrastructure and ecosystem-based adaptation, offer viable pathways for increasing urban resilience while also enhancing biodiversity and ecosystem services (Ghosh *et al.*, 2024). Additionally, integrating climate impact assessments into urban planning processes can help cities anticipate and mitigate long-term climate risks (Gaillard *et al.*, 2012).

Before proceeding further, it is essential to clarify the key terminologies climate adaptation, mitigation, and urban resilience as they are fundamental to climate change discourse, each addressing distinct aspects of climate risk management. Climate adaptation refers to adjustments in natural and human systems aimed at minimizing negative impacts and leveraging potential benefits of climate change, particularly in vulnerable regions (Lal *et al.*, 2011). Climate mitigation, by contrast, focuses on reducing greenhouse gas emissions through measures such as renewable energy adoption, carbon sequestration, and efficiency improvements to slow global warming (Abbass *et al.*, 2022). Urban resilience, meanwhile, denotes the capacity of urban systems to absorb, adapt to, and recover from climate-induced shocks, thereby ensuring sustainability and stability in cities facing escalating climate threats (Meerow *et al.*, 2016). These three strategies are inherently interconnected, necessitating integrated policies to achieve long-term sustainability.

The urgency of resilience and adaptation is growing as climate-induced disasters intensify, disproportionately affecting marginalized populations in urban and rural areas. While mitigation addresses long-term climate stabilization, adaptation and resilience are crucial for managing immediate and unavoidable climate impacts, especially in rapidly urbanizing regions. Effective adaptation reduces vulnerability by incorporating climate-responsive infrastructure, water management, and socio-economic policies, yet governance and financial barriers often limit its implementation (Meerow *et al.*, 2016). Urban resilience, meanwhile, requires a shift from reactive disaster responses to proactive planning, integrating social equity and

ecosystem-based solutions (Rockström *et al.*, 2021). Without a cohesive approach, adaptation efforts risk being ineffective, highlighting the need for policies that bridge resilience, adaptation, and mitigation strategies for climate justice and sustainable urban development (Abbass *et al.*, 2022).

This book chapter explores the multifaceted challenges and opportunities of climate adaptation planning in rapidly urbanizing Nepalese cities (Figure 1). It examines how smaller and mid-sized urban areas are addressing the challenges posed by climate change and pursuing opportunities to build urban resilience. In this study, small and medium-sized cities are defined according to the OECD urban classification: small urban areas have populations between 50,000 and 200,000 (often termed *intermediary cities*), and medium-sized urban areas exceed 200,000 (OECD, 2012). Based on this classification, cities like Birendranagar, Ghorahi, and Tulsipur are considered small urban areas, whereas Pokhara and Janakpur are medium-sized. These categories help contextualize Nepal's urban hierarchy and inform planning strategies in line with international standards (OECD, 2012).

2. NEPAL AND CLIMATE CHANGE

Nepal is undergoing rapid urbanization, characterized by significant population shifts from rural to urban areas, particularly from the hills and mountains to the plains. Currently, 66.2% of Nepal's population resides in urban areas, with recent administrative restructuring leading to the expansion of urban centers to include 6 metropolises, 11 sub-metropolises, and 276 municipalities (Bhattarai *et al.*, 2023). Despite this rapid urban expansion, many newly designated urban areas lack the essential amenities mandated by the Local Government Operation Act of 2017, primarily due to limited resources and insufficient governance expertise at the local level. The swift reclassification of rural areas into municipalities has not been matched by necessary infrastructure development and urban planning, leading to challenges in providing adequate services and facilities to the growing urban populace. Beyond demographic shifts, Nepal's urbanization is also driven by socio-economic transformations, particularly the declining share of agriculture in GDP and an increased reliance on remittances. Figure 1 shows the frequency of climate change-induced disasters in Nepal from 2000 to 2024, highlighting higher incident concentrations in southern and eastern districts. Data is more reliable after 2013 due to improved reporting consistency.

Amidst this, Nepal's heightened vulnerability to climate change is underscored by rising temperatures, more frequent extreme weather events, and escalating risks of flooding and landslides, all of which threaten human development and economic growth (World Bank, 2022). Without urgent and comprehensive climate action in cities – including the integration of resilience strategies into national development planning – these environmental challenges will continue to exacerbate socio-economic disparities and undermine Nepal's progress in poverty reduction and sustainable development. As Nepal's urban population continues to grow, particularly in mid-sized cities such as Ghorahi, Nepalgunj, Bharatpur, and Butwal, the increasing density

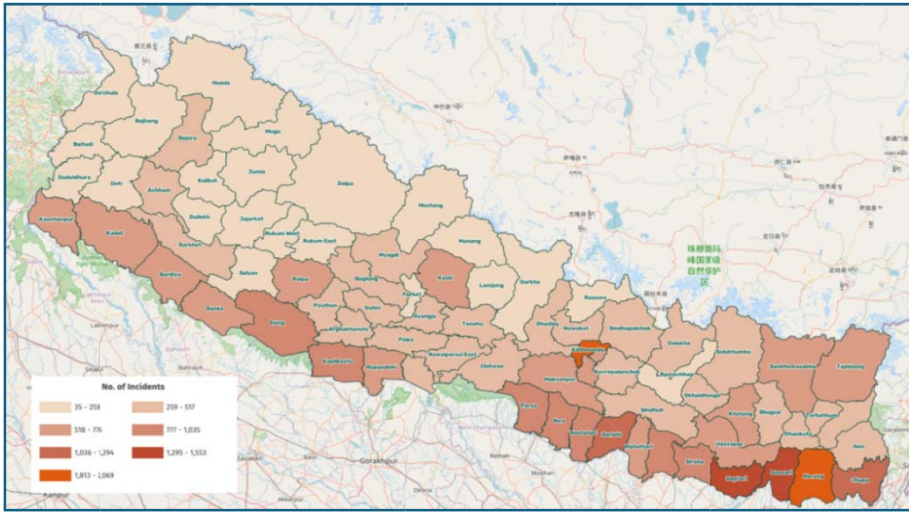


Figure 1: Climate Change Induced Disasters Frequency in Nepal

(Date 2000-01-01 till 2024-12-31) (Source: <https://bipadportal.gov.np/damage-and-loss>)

The data included in the portal is not consistent in earlier date. i.e. 2000 till 2012, hence most comprehensive data is available after 2013.

of settlements heightens exposure to climate hazards, including flooding, landslides, and heat waves. Further, the limited financial and technical resources available to these municipalities exacerbate their vulnerability, making it challenging to implement effective adaptation strategies. This situation is not unique to Nepal; similar challenges are observed in many rapidly urbanizing regions where infrastructure and governance development lag behind population growth. The rapid growth of urban populations often outpaces the provision of essential services, leading to increased exposure to climate risks (Figure 1). Moreover, the lack of financial resources limits the ability of local governments to invest in climate-resilient infrastructure and services, making adaptation efforts even more critical (Kumar *et al.*, 2021; Seto *et al.*, 2012).

According to Nepal's Disaster Risk Reduction Portal, more than 5,000 flood and flash-flood incidents have been recorded since January 1, 2001 till 2025 April (based on DesInventar and Ministry of Home Affairs data). However, these figures do not differentiate between urban and rural areas. Most of these floods have occurred in Nepal's lowland regions, particularly in newly urbanizing areas and high dense population region. Financial losses are uncertain due to inconsistent record-keeping, highlighting the need for standardized data collection and improved disaster reporting. Similarly, over 7,000 landslides were recorded in the same period, with the annual number nearly doubling in the last decade compared to the previous one (Figure 2). Notably, expanding road networks have contributed to more frequent landslides, exacerbated by cloudbursts and erratic rainfall patterns. These trends emphasize the urgent need for comprehensive disaster risk management, improved infrastructure planning, and better data collection to accurately assess and mitigate climate-induced hazards in Nepal.

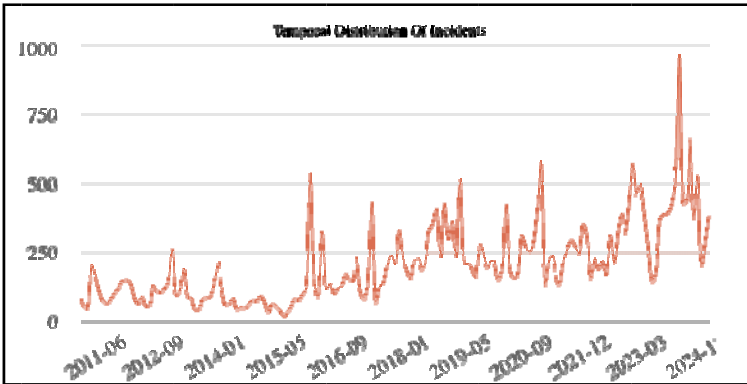


Figure 2: Increasing Frequency of Disaster in Last Decade in Nepal
(Source: <https://bipadportal.gov.np/damage-and-loss>)

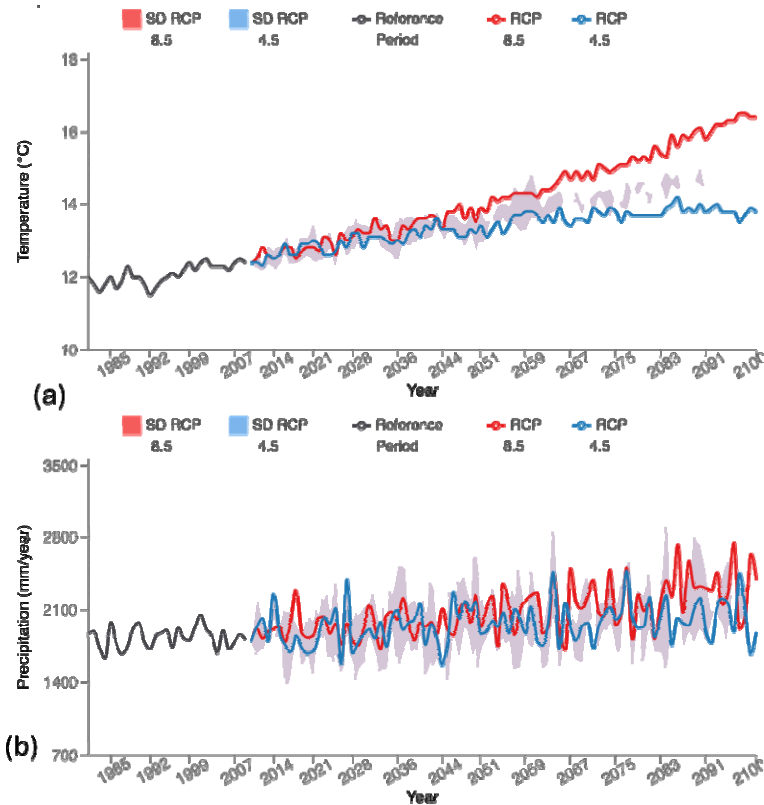


Figure 3: (a) Ensemble Mean of Annual Temperature of Nepal, and (b) Ensemble mean of precipitation of Nepal; Under RCP8.5, the global temperature anomaly could reach nearly 18°C by 2100, with a wider uncertainty band and under RCP4.5, the temperature anomaly increases more gradually and remains below 15°C by 2100, with narrower uncertainty
(Source: <https://bipadportal.gov.np/>)

Nepal faces significant future challenges from the combined effects of climate change and rapid urbanization. By 2060, average temperatures and precipitations in the country are projected to rise by 1.3–3.8°C (Figure 3a), and few hundreds millimeter (Figure 3b), respectively, altering weather patterns with wetter monsoon summers and drier winters (S. Bajracharya *et al.*, 2023). Figure 3a shows projected temperature increases in Nepal, with RCP8.5 leading to significantly higher warming than RCP4.5 by 2100. Figure 3b illustrates increased variability and intensity of precipitation under both scenarios, with more extremes expected under RCP8.5. Figure 4 shows that average monthly temperatures in Nepal have increased across all months, while precipitation has become more variable and intense during the monsoon season (June–September) in recent decades (1999–2016) compared to earlier (1979–1998). The increasing frequency and intensity of hydro-climatic extremes – including floods, landslides, and droughts – will threaten agriculture, water resources, and overall socio-economic stability (K.C. *et al.*, 2024; V. P. Pandey *et al.*, 2021). Simultaneously, Nepal’s cities are experiencing rapid, often unplanned, urban growth, heightening their vulnerability to climate-induced hazards. Fragile urban infrastructure is under growing pressure, necessitating improvements in physical infrastructure, public services, and environmental management (Dixit & Shaw, 2023). The combined effect of climate change and urban expansion will escalate the risk of urban pluvial flooding, especially in areas with extensive impervious surfaces (K.C. *et al.*, 2024). Economically, climate-related impacts are estimated to reduce Nepal’s annual GDP by approximately 2.2% by 2050 (K.C. *et al.*, 2024). The agriculture sector, heavily dependent on monsoon rain, is expected to face disruptions due to shifting precipitation patterns and rising temperatures, raising food security concerns (S. Bajracharya *et al.*, 2023; Shrestha & Dhakal, 2019). These trends highlight heightened climate risks for Nepal under high-emission pathways. Additionally, water resources will be strained, affecting hydropower generation and increasing the risks of glacial lake outburst floods (GLOFs) (Pandey *et al.*, 2021; Shrestha & Dhakal, 2019). To address these risks, Nepal must implement comprehensive, risk-informed urban planning and climate adaptation strategies that integrate infrastructure development, disaster risk management, and sustainable resource use (Dixit & Shaw, 2023; Pandey *et al.*, 2021). Proactive measures will be essential to mitigate the compounded impacts of climate change and urbanization, ensuring long-term resilience and sustainability.

The vulnerability of these cities in Nepal is further compounded by their reliance on outdated infrastructure and insufficient planning mechanisms. For instance, many of these cities lack comprehensive climate adaptation plans, a key tool for coordinating strategic climate action. Research indicates that having such a plan reflects a city’s commitment to climate action, yet many smaller municipalities in Nepal have not developed this framework (Reckien *et al.*, 2015). This planning gap is especially concerning given the rising frequency and intensity of climate-related events, which demand proactive measures to safeguard urban populations and critical infrastructure.

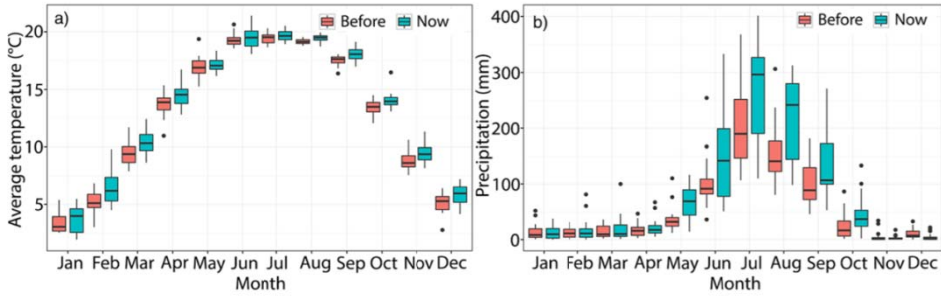


Figure 4: Comparison of the Changes in Average Monthly Temperature (a) and Average Monthly Precipitation (b) between Two Periods: 1979–1998 (before) and 1999–2016 (now)

Source: Shrestha *et al.*, 2019.

Moreover, the financial constraints faced by Nepal's smaller cities hinder their ability to invest in needed adaptation measures. Studies have shown that access to financial resources is a critical determinant of a city's capacity to respond to climate change (Gentle *et al.*, 2014). In Nepal, local governments often struggle to secure funding for climate adaptation initiatives, which limits the implementation of effective strategies. This challenge is exacerbated by the technocratic nature of climate policymaking in Nepal, which often overlooks the needs and knowledge of local communities (H.R. Ojha *et al.*, 2016). Consequently, adaptation efforts may not align with the specific vulnerabilities and priorities of smaller urban areas.

In addition to financial limitations, the technical capacity of local governments is often insufficient to design and execute effective climate adaptation strategies. Many officials lack the training and expertise needed to address the complex challenges posed by climate change (Khatri *et al.*, 2013). Integrating climate adaptation into local development planning is essential for building resilience, yet many cities struggle to establish the necessary institutional frameworks to do so (Paudel *et al.*, 2013).

Despite these challenges, there are also significant opportunities for enhancing climate resilience in Nepal's growing cities. The increasing recognition of ecosystem-based adaptation (EbA) strategies presents a promising avenue for integrating climate resilience into urban planning (Sherpa, 2024). By leveraging natural systems and local ecosystems, cities can boost their adaptive capacity while also addressing biodiversity and environmental sustainability. Furthermore, the involvement of local communities in adaptation planning leads to more contextually relevant and effective strategies, as community members possess valuable knowledge about local conditions and vulnerabilities (Regmi *et al.*, 2016).

3. CHALLENGES

3.1 Haphazard Urbanization and Risk-Sensitive Development

The intersection of urbanization and climate change presents significant challenges for land use planning, particularly in hazard-prone areas. The expansion of unplanned

settlements, coupled with inadequate zoning laws, increases exposure to risks such as flooding and landslides, especially in regions with fragile ecosystems (Burby *et al.*, 1999). Unplanned urban growth in smaller and mid-sized cities in Nepal faces similar challenges in the context of climate adaptation and increasing disaster frequency. This is evident in cities like Kathmandu, Pokhara, and Bharatpur, where haphazard urbanization has led to inadequate infrastructure, insufficient open spaces, and heightened exposure to environmental risks. The flood in 2024 in Kathmandu Valley and Nepalgunj highlights the consequences of haphazard urbanization and lack of risk-sensitive development planning (Figures 5 and 6).

One of the primary challenges in these cities is the lack of effective land use planning. In many smaller municipalities, the absence of comprehensive zoning regulations has resulted in the proliferation of settlements in flood-prone areas, increasing the risk of flooding and landslides during extreme weather events. For instance, the Kathmandu Valley has experienced significant urban sprawl, with many new developments occurring in vulnerable locations (e.g., along the Bagmati River and its tributaries) without adequate risk assessments (Sapkota, 2022). This unregulated expansion not only threatens residents' safety but also places additional strain on already limited municipal services such as waste management and emergency response (Dangi *et al.*, 2017). Similarly, settlements near foothills and on steep slopes face a high risk of landslides.



Figure 5: Photographs of the Nakhkhu River, Located about 500 meters Upstream of Its Confluence with the Bagmati River, taken during the Flood Event on September 28, 2024

Source: <https://www.npr.org/2024/09/30/g-s1-25389/nepal-floods-deaths-recovery>



Figure 6: Fish Food in Nepalgunj, Banke, Caused by Heavy Rainfall and Insufficient Drainage in October 2022

Source: <https://english.lokaantar.com/news/detail/29609>.

Joshi (2024) observes that integrating climate resilience into urban land use planning in Nepal remains at a nascent stage. The lack of clear zoning laws and risk-sensitive planning exacerbates environmental degradation, particularly as cities expand into floodplains and onto unstable hill slopes. Rapid urbanization often occurs without adequate planning frameworks, leading to increased vulnerability to natural hazards. In cities like Butwal and Bharatpur, unregulated expansion has resulted in the encroachment of residential and commercial development into flood-prone zones. For example, Bharatpur's urban sprawl has led to homes and businesses being constructed in low-lying areas that are prone to seasonal monsoon flooding (Rimal *et al.*, 2020). This poor zoning practice places residents at risk and also strains local infrastructure, as drainage systems are often inadequate to handle the increased runoff from impervious surfaces (Uddin *et al.*, 2018). In Nepalgunj, rapid urban growth has similarly converted agricultural land into urban areas, diminishing the region's natural water absorption capacity and increasing soil erosion and landslide risk on nearby slopes (Rimal *et al.*, 2018). The National Land Use Policy of Nepal emphasizes the need for integrated land use planning; however, implementation remains inconsistent across municipalities, resulting in fragmented and ineffective land management (Wang *et al.*, 2020).

Moreover, the scarcity of open spaces in rapidly urbanizing areas compounds these challenges. A study highlighted that in Kathmandu, only 0.3% of urban land is designated as open space, severely limiting recreational areas and emergency evacuation sites (S. Manandhar *et al.*, 2019). This lack of open space not only

reduces quality of life but also impairs effective disaster response during emergencies. The impacts of unplanned urbanization extend to water security as well. Rapid urban growth has driven up demand for water resources, while inadequate infrastructure and governance have led to severe water scarcity in many urban centers (H. Ojha *et al.*, 2020). Climate change further exacerbates water stress by altering precipitation patterns and increasing the frequency of droughts and floods, straining already limited supplies (C.L. Pandey *et al.*, 2019). In Bharatpur, for example, urban expansion has outpaced the development of water management systems, resulting in acute water shortages that impact public health and sanitation.

Janakpur and Biratnagar likewise illustrate the challenges of ineffective land use planning. In Janakpur, the lack of designated green spaces and drainage areas has impaired the city's ability to manage stormwater, leading to localized flooding during heavy rains (Gyawali *et al.*, 2016). Biratnagar has experienced rapid industrial growth without parallel infrastructure upgrades, causing increased pollution and environmental degradation (Anup, 2017).

Hence, the challenges posed by unplanned urban growth in Nepal's smaller cities are multifaceted, encompassing inadequate land use planning, a lack of open spaces, water insecurity, and related socio-economic issues. These issues present significant barriers to climate adaptation and urban sustainability.

3.2 Limited Resources and Weak Institutional Capacity

Governance and institutional capacity remain significant barriers to climate adaptation in many Nepalese cities. Harman *et al.* (2015). Highlight the importance of multi-stakeholder partnerships, including public-private collaborations, to foster urban climate adaptation. Without such cooperative governance models, cities struggle to implement proactive adaptation measures.

Joshi (2024) points out that weak governance structures, political instability, and limited inter-agency collaboration create major roadblocks in climate adaptation planning. Many urban resilience initiatives remain underfunded and lack long-term commitment from policymakers. Gentle and Mainaly (2024) note that contested interests among federal, provincial, and local governments further complicate adaptation efforts. For instance, while the Ministry of Forests and Environment (MoFE) leads climate governance, sectoral ministries and local governments often have unclear mandates and limited decision-making authority, resulting in inefficiencies in adaptation planning and implementation (Gentle & Mainaly, 2024). Ghimire and Chhetri (2022) identify power asymmetries within institutions as another challenge: climate adaptation initiatives tend to be top-down, leaving local communities with limited agency in decision-making. This diminishes the effectiveness of measures and can widen socio-economic disparities in urban resilience efforts.

Further, the Ministry of Forests and Environment (2021) emphasizes that a critical barrier to effective climate finance allocation and adaptation implementation at the

local level is the weak technical and administrative capacity of local governments. Despite significant decentralization, the local bodies lack robust systems and tools to manage and monitor climate-specific financial resources efficiently. The current Public Financial Management (PFM) system at the local level is not sufficiently advanced to handle targeted climate funds, exacerbating challenges in resource allocation, expenditure tracking, and ensuring accountability (Ministry of Forests and Environment, 2021).

Limited resources and weak institutional capacity compound climate adaptation challenges in smaller and mid-sized cities in Nepal. As urban areas expand rapidly, immediate demands for infrastructure and services often overshadow long-term planning and sustainability considerations. This is particularly evident in cities like Kathmandu, Bharatpur, and Biratnagar, where inadequate resources, ineffective governance, and weak planning frameworks have led to a host of issues, including insufficient drainage systems, lax enforcement of building regulations, and a lack of innovative policies to address urban risks.

One pressing issue is the failure to incorporate hydrological considerations into urban planning. Many smaller cities in Nepal lack comprehensive drainage systems capable of managing increased rainfall and runoff, which are becoming more frequent due to climate change. Research indicates that climate change is significantly increasing flood susceptibility in South Asia (including Nepal) as extreme precipitation events intensify under various scenarios (Janizadeh *et al.*, 2024). Moreover, urban areas in Nepal, particularly smaller municipalities, struggle with inadequate stormwater management and drainage infrastructure, leading to waterlogging and heightened flood risks (Dixit & Shaw, 2023). The absence of a robust building permit system further complicates this issue, as unauthorized constructions often occur in flood-prone areas and increase residents' vulnerability to climate hazards (Satterthwaite *et al.*, 2020).

Nepal's institutional landscape is also characterized by overlapping responsibilities among various agencies, resulting in inefficiencies and a lack of coordinated action in tackling urban challenges. A study in Dhulikhel and Dharan showed that the complexity of water governance, with multiple institutions involved, often leads to conflicting roles that hinder effective water management (C.L. Pandey *et al.*, 2019). This fragmentation impedes risk-sensitive land use planning, which is essential for mitigating climate change impacts in urban areas. Tachamo-Shah *et al.* (2023) note that fragmented governance and weak coordination similarly hamper Nepal's wetland conservation efforts. While multiple agencies (local governments, conservation bodies, etc.) share responsibility for wetland management, unclear divisions of authority lead to inefficient policy implementation. The absence of integrated urban wetland policies further exacerbates this problem.

Furthermore, the common focus on short-term urban needs often comes at the expense of long-term sustainability. Local governments frequently prioritize immediate solutions, such as expanding road networks or increasing housing supply,

without adequately considering environmental implications or the need for resilient infrastructure. This reactive approach to urban development fails to address vulnerabilities associated with rapid urbanization, such as the loss of open space and inadequate emergency response systems. For example, in Bharatpur, the fast expansion of settlements has greatly reduced green space that would otherwise serve for flood mitigation and community recreation (Yadav *et al.*, 2023).

The lack of innovative policies and adaptive governance frameworks also limits local authorities' capacity to respond effectively to climate change. Many cities in Nepal have yet to develop comprehensive climate adaptation strategies that integrate environmental, social, and economic considerations into urban planning. The absence of such frameworks not only hampers responses to immediate urban challenges but also undermines long-term resilience-building. Ghimire and Chhetri (2022) point out a persistent disconnect between climate adaptation strategies and local development plans. Despite initiatives like Nepal's Local Adaptation Plans of Action (LAPA), urban planning remains largely reactive rather than proactive, failing to integrate climate resilience measures effectively. Immediate pressures of urban growth often take precedence over long-term planning and innovation, making sustainable development difficult to achieve. Consequently, cities struggle to incorporate climate resilience measures, adaptive infrastructure, and risk-sensitive land use planning, which ultimately exacerbate environmental vulnerabilities and reduce their capacity to cope with climate-induced hazards.

3.3 Encroachment on Floodplains and Inadequate Drainage Systems

Unregulated urban expansion and poor land-use management have led to the encroachment of settlements onto natural floodplains in many Nepalese cities, severely undermining their resilience to flooding. These problems are exacerbated by the absence of climate-resilient infrastructure. Rapid growth in cities like Biratnagar and Nepalgunj has pushed residential and commercial developments into flood-prone areas, disrupting natural drainage patterns and amplifying flood hazards (D.P. Poudel *et al.*, 2023). Shah *et al.* (2023) reported that reduced floodplain capacity due to encroachment and unregulated development has intensified urban flood risks in Nepal. In addition, a lack of proper flood management strategies and inadequate drainage infrastructure has made these cities increasingly vulnerable to extreme rainfall events (B. Manandhar *et al.*, 2023). The consequences are evident in the frequent floods that disrupt lives and livelihoods, particularly for marginalized, low-income communities that often settle in high-risk areas (Danegulu *et al.*, 2024). Figure 7 shows widespread urban expansion across Nepal from 1990 to 2020, marked by a significant increase in built-up areas and a corresponding decline in vegetation and agricultural land. This rapid and often unplanned urbanization has led to extensive encroachment on natural floodplains, which are critical for absorbing and channeling excess rainfall. As a result, inadequate drainage systems, combined with the loss of permeable surfaces, have made cities more vulnerable to flooding. These land use

changes, especially in growing urban centers, underscore the urgent need for risk-sensitive planning and flood-resilient infrastructure development.

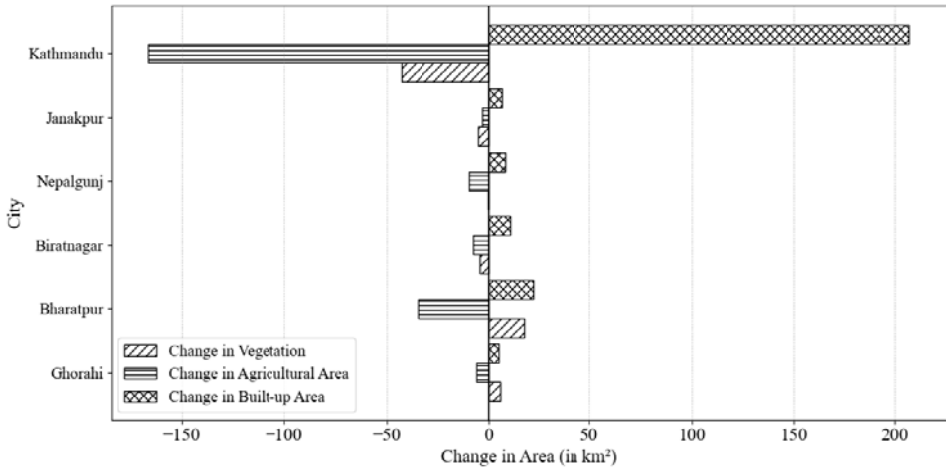


Figure 7: Bar Chart Illustrating the Change in Vegetation, Agricultural Area, and Built-up Area (in km²) from 1990 to 2020 Across Growing Cities in Nepal. The Positive Axis Represents an Increase in Area, while the Negative Axis Represents a Decrease in Area.

In Biratnagar, the expansion of neighborhoods into low-lying zones near the Koshi River has significantly increased the city's flooding vulnerability. Seasonal floods pose a recurring threat, exacerbated by lenient zoning regulations that permit construction in areas known to be high-risk (Jha, 2007). Over recent decades, many new developments have arisen in Biratnagar's flood zones with little flood-mitigation infrastructure, thereby heightening exposure to climate hazards (Rijal *et al.*, 2020). Furthermore, Biratnagar's drainage systems are underdeveloped; stormwater often overwhelms the existing infrastructure, causing frequent waterlogging that disrupts economic activities (Adhikari, 2013).

Similarly, cities like Nepalgunj, Janakpur, and others have experienced rapid urbanization that converted former agricultural land into urban settlements (P. Devkota *et al.*, 2023). This land-use change has reduced the land's natural capacity to absorb water and intensified surface runoff during heavy rainfall (Paudel *et al.*, 2013). Nepalgunj's drainage infrastructure is often underdesigned and poorly maintained, rendering it incapable of handling growing stormwater volumes. The absence of a comprehensive drainage management plan further exacerbates the city's flood vulnerability, especially as climate change brings more erratic and intense rainfall (Danegulu *et al.*, 2024).

The financial burden of upgrading drainage infrastructure poses another significant challenge, as the cost of large-scale improvements often exceeds municipal budgets and necessitates external funding (Bhattarai & Conway, 2021). Cities like Biratnagar and Nepalgunj require substantial investment to modernize their stormwater

management systems, and they frequently depend on national or international funding mechanisms to proceed with such projects.

3.4 Focus on External AID

International support for climate change adaptation has predominantly targeted larger cities and well-established city networks (e.g., C40 and 100 Resilient Cities), enabling those cities to benefit from knowledge sharing and collaboration. However, this focus often leaves smaller cities and towns, especially those outside prominent networks, at a disadvantage. The unique challenges faced by these smaller urban areas are frequently overlooked in global climate discussions. Cities like Biratnagar, Nepalgunj, and Janakpur, which are not part of major climate networks, struggle to access the same resources and expertise as their larger counterparts. Lacking visibility in global climate agendas means these cities miss out on critical knowledge-sharing opportunities that could bolster their climate resilience. For instance, while larger cities can leverage international funding and technical support for adaptation projects, smaller cities are often constrained by limited budgets and inadequate institutional capacity. This disparity in resource allocation exacerbates the vulnerabilities of smaller cities, which may face climatic challenges that differ from those of coastal mega-cities or other high-profile areas.

Moreover, the global climate agenda tends to prioritize high-profile regions, such as the Himalayan glacier belt or densely populated coastal zones at risk of sea-level rise, when allocating research and funding. While addressing those vulnerabilities is important, the challenges faced by smaller inland cities and towns (e.g., unexpected landslides, flash floods, droughts, and heat waves) often receive less attention. Research indicates that these areas suffer substantial socio-economic consequences from climate variability, yet they remain largely overlooked in climate adaptation research and funding programs (Kafle *et al.*, 2022). The lack of targeted studies and financial support limits their ability to implement effective resilience strategies, leaving vulnerable populations at heightened risk of climate-induced disruptions. Additionally, many climate adaptation initiatives demand substantial investment that exceeds the financial capacity of local governments. Without consistent national or international funding, smaller cities cannot implement long-term resilience strategies, making them disproportionately vulnerable to climate-related disasters. Insufficient data, limited institutional capacity, and a lack of technical expertise further hinder these municipalities' access to international climate finance (Fischer *et al.*, 2024).

In addition, while the Government of Nepal's National Climate Change Policy (NCCP, 2019) has mandated that at least 80% of international climate finance should reach the local level, prioritizing direct community-level interventions, it is not well practiced. Ministry of Forests and Environment (2021) identified significant ambiguity and gaps in the practical implementation of this policy provision, noting inconsistencies in tracking, monitoring, and reporting mechanisms. Local government stakeholders remain largely unaware of these policy specifics, resulting in inconsistent compliance and fragmented implementation. This limitation highlights the need for

improved institutional coordination and clearer regulatory frameworks to ensure policy compliance and transparency (Ministry of Forests and Environment, 2021).

3.5 Existing Vulnerabilities

Nepal's geographic landscape, particularly the Terai plains, faces extreme vulnerability to flooding, which has intensified due to climate change. Dulal *et al.* (2010) highlight that during the monsoon season, heavy precipitation coinciding with glacier melt from the Himalayas exacerbates flood risks. This has led to the destruction of agricultural lands, infrastructure, and livelihoods, particularly for poor rural populations. Further, the inadequate infrastructure and limited access to adaptation resources have further exacerbated urban vulnerabilities, leaving many municipalities unprepared for extreme weather events. Socio-economic disparities amplify climate risks, as marginalized populations often reside in hazard-prone zones with minimal government support (Aksha *et al.*, 2019). In between 1998 and 2002, floods and landslides affected an average of 24,264 families annually, while the 2007 floods rendered more than half a million people food-insecure (Dulal *et al.*, 2010). Additionally, the 2008 Koshi River flood displaced over 70,000 people in Nepal, demonstrating the severity of climate-induced disasters in the region (Dulal *et al.*, 2010).

Additionally, the significant vulnerability in the Terai region is the reliance on highly flammable building materials like hay/thatch roofing, which can lead to catastrophic outcomes during disasters like fires. In cities like Biratnagar, where rapid growth has outpaced regulatory oversight, many structures are built using materials that pose a high fire risk in densely populated neighborhoods. The combination of poor construction practices and inadequate fire safety measures can result in devastating urban fires (Bhattarai & Conway, 2021). This issue is compounded by weak emergency response systems that are often overwhelmed during crises.

Indeed, poverty remains one of the greatest barriers to climate change adaptation in Nepal, as low-income communities lack financial resources, access to climate information, and adaptive capacity. Poor households are often forced to live in high-risk areas such as floodplains and unstable hillsides due to economic necessity, where they face repeated exposure to climate-induced hazards (Regmi & Bhandari, 2013). Additionally, economic constraints limit their ability to invest in disaster-resilient infrastructure or climate-smart agricultural practices, making them more vulnerable to long-term climate shocks (N. Devkota *et al.*, 2018). Addressing poverty through inclusive climate financing and targeted adaptation programs is therefore essential for building resilience among Nepal's most vulnerable urban populations.

Nepal's ethnic minorities and marginalized communities also face heightened vulnerability to natural hazards due to historical socio-economic disparities and cultural marginalization.

Aksha *et al.* (2019) highlight that indigenous and lower-caste groups often reside in the highest-risk zones, such as floodplains and landslide-prone slopes, largely because

of economic constraints and historical settlement patterns. Additionally, language barriers, cultural exclusion in disaster planning, and unequal access to emergency services further exacerbate these groups' risks, limiting their ability to adapt and recover from climate-related disasters (Aksha *et al.*, 2019). Addressing these cultural vulnerabilities requires inclusive adaptation strategies that integrate local knowledge, community participation, and equitable resource distribution.

4. OPPORTUNITIES

4.1 Climate-Resilient Infrastructure Development

Despite challenges, several cities in Nepal, including Ghorahi, Biratnagar, Sidhartha Nagar (Figure 8), and Nepalgunj, have adopted innovative climate-resilient infrastructure solutions, demonstrating the potential for adaptive urban development. One key opportunity has been improving urban waste management to enhance resilience and public health. For example, Ghorahi established a dedicated landfill site nearly two decades ago, which has proven to be a successful model for solid waste management. The city identified a strategic location for waste disposal and developed a systematic, sustainable collection process. The landfill accommodates Ghorahi's waste generation with an annual reuse system, minimizing land degradation while maximizing resource recovery (Bijay, 2011). This initiative underscores the importance of long-term planning and investment in urban infrastructure and offers a replicable model for other municipalities in Nepal.

Beyond waste management, Nepal has implemented climate-resilient projects that emphasize integrated planning and sustainable resource management. One such initiative is the Climate-Resilient Water Safety Plan (CR-WSP), deployed in ten water supply systems across the country to ensure safe, reliable water access in the face of climate variability (D.P. Poudel *et al.*, 2023; M. Poudel *et al.*, 2024). This program integrates risk assessments, early warning systems, and infrastructure upgrades to enhance water security and community resilience. Additionally, the Nuwakot Mid-Hill Climate-Resilient Development Project focuses on adaptive measures for soil erosion control and watershed management, reducing landslide risks, and improving agricultural sustainability in mountainous regions (A. Pandey *et al.*, 2021). These cases highlight the potential for locally driven, climate-resilient infrastructure models to address environmental challenges while supporting long-term urban and rural sustainability in Nepal.

The Low-Emission and Climate-Resilient Development Program is another significant initiative integrating federal, provincial, and local efforts to strengthen climate adaptation policies and infrastructure investment (Uprety & Chhetri, 2024). Similarly, the Climate-Resilient Agriculture Program in Udayapur District has introduced adaptive farming techniques, water-efficient irrigation, and climate-smart crop varieties to strengthen food security and environmental resilience for local farmers (Rai *et al.*, 2018).



Figure 8: New Drainage to Contain the Flooding in Sidhartha Nagar Municipality (ADB, 2016)

Even with limited financial resources, small-scale climate-resilient infrastructure projects in Nepal have shown that effective coordination among local governments, communities, and diverse stakeholders can lead to impactful adaptation. These projects often succeed due to strong local engagement, decentralized decision-making, and long-term commitment, ensuring that strategies are locally appropriate and community-driven. The success of such initiatives highlights the power of collaboration and sustained effort, proving that bottom-up approaches can effectively enhance climate resilience.

Equally important is the production and exchange of knowledge across different adaptation projects. Documenting and sharing best practices can help scale up these small initiatives into larger, more comprehensive resilience programs. Local successes can inform national and international adaptation strategies by fostering peer learning, cross-regional knowledge transfer, and institutional capacity-building. Replicating proven models on a broader scale through integrated policies, enhanced financing mechanisms, and cross-sectoral cooperation can significantly strengthen Nepal's urban (and rural) resilience to climate change, while also serving as a model for other vulnerable regions.

4.2 Participatory Governance

Participatory governance is crucial for strengthening climate adaptation strategies, especially in smaller cities where community engagement enhances the relevance and effectiveness of actions. Nepal's Local Adaptation Plans of Action (LAPAs) exemplify how participatory processes empower local governments and communities to take proactive adaptation measures. Designed to incorporate local knowledge and priorities, LAPAs enable bottom-up planning, ensuring that climate interventions are contextually relevant, inclusive, and widely supported (H.R. Ojha *et al.*, 2016).

These frameworks have proven effective in aligning scientific data with indigenous and experiential knowledge. Studies show that communities often possess valuable insights on climate risks, water management, and agriculture that can improve urban resilience strategies (Paudel *et al.*, 2013; Shah *et al.*, 2023). In Nepal, local governments that actively engage communities in climate action planning are better able to identify site-specific vulnerabilities and craft targeted interventions (Paudel *et al.*, 2013; Regmi & Bhandari, 2013). Additionally, participatory planning builds public trust and cooperation, which is crucial for the long-term sustainability of adaptation policies. Without community buy-in, many top-down climate initiatives risk failing due to a lack of local ownership and acceptance.

Another significant innovation in climate adaptation planning in Nepalese cities is the adoption of Geographic Information System (GIS)-based mapping for assessing climate risks and prioritizing adaptation investments. The Nepal Climate Change Support Programme (NCCSP) Phase 2 has effectively utilized GIS-based hazard mapping and vulnerability assessments to identify and target climate-sensitive areas at the municipal and community levels (Ministry of Forests and Environment, 2021). By leveraging spatial data and climate risk indices, local governments can visualize and understand the spatial distribution of vulnerabilities, prioritize interventions, and strategically allocate resources toward areas and communities most in need. This data-driven, visual approach facilitates informed decision-making, enhances transparency, and strengthens the engagement of local stakeholders in adaptive planning, ultimately improving the resilience of urban communities in the face of increasing climate-related hazards (Ministry of Forests and Environment, 2021).

A successful example of participatory governance in climate adaptation can be seen in Nepal's Terai region, where community-led institutions, such as Community Forest User Groups (CFUGs) and Water User Associations (WUAs), have played a pivotal role in sustainable land and water resource management. These local governance mechanisms facilitate equitable resource distribution, promote adaptive strategies for climate resilience, and ensure that adaptation efforts align with community needs. Thorn (2019) highlighted that CFUGs have successfully implemented afforestation programs, soil conservation projects, and erosion control measures, effectively mitigating climate risks while maintaining community involvement. Similarly, WUAs have been instrumental in the construction of small-scale irrigation infrastructure, flood control measures, and the establishment of water-sharing rules, ensuring that local populations have sustained access to water resources despite changing climate conditions (Thorn, 2019). These participatory initiatives foster collaboration between residents and local authorities, incorporating indigenous knowledge and lived experiences into climate adaptation planning, ultimately resulting in more effective, equitable, and sustainable adaptation outcomes.

In addition to this, despite being highly vulnerable to flooding, communities in Koshi Tappu have successfully implemented sustainable livelihood diversification strategies to adapt to climate risks. The study highlights efforts where households

have shifted from traditional rain-fed agriculture to flood-resistant crops such as sugarcane and bamboo, which are more resilient to water logging and soil erosion (Dulal *et al.*, 2010). Additionally, cooperative-based fish farming and ecotourism initiatives have emerged as alternative income sources, reducing economic dependence on high-risk agriculture. These initiatives have been partially supported by NGOs and local government programs, proving that integrating climate-sensitive livelihood strategies can enhance adaptive capacity and reduce long-term vulnerability.

However, even with successes of participatory governance in climate adaptation, challenges remain in ensuring consistent implementation, equitable resource allocation, and long-term institutional support. In Nepal, disparities in local capacity, funding availability, and political commitment can hinder the effectiveness of participatory approaches. Enhanced capacity-building and sustained support from higher levels of government are needed to guarantee that community-driven plans translate into concrete and equitable climate actions. Further, addressing institutional barriers, improving financial access, and scaling up proven adaptation models will be crucial in strengthening Nepal's response to climate change.

4.3 Protection and Promotion of Wetlands

Wetland conservation in Nepal has gained momentum through local government-led initiatives that integrate ecosystem restoration, water management, and community engagement. These efforts recognize that healthy wetlands provide valuable services for urban climate adaptation. For example, Pokhara's Lake Conservation and Development Authority has been working to restore and improve nine lakes in the Pokhara Valley, integrating wetland restoration with urban development planning. In Kapilvastu, the local government has incorporated wetland conservation into annual planning, focusing on removing invasive species and establishing community-led conservation committees. These efforts demonstrate a trend toward decentralized wetland governance, where local authorities, communities, and conservation groups collaborate to protect and rehabilitate wetlands.

According to Shah *et al.* (2023), Nepal's urban wetlands have the potential to achieve *Ramsar Wetland City* accreditation, which would provide international recognition and financial incentives for conservation. Cities such as Pokhara, Bharatpur, and Ghodaghodi already meet several accreditation criteria, positioning them as strong candidates for global recognition in wetland conservation. The model used in Ghorahi, which integrates community participation, flood mitigation, and agricultural sustainability, exemplifies a scalable approach to urban wetland conservation that could be replicated in other climate-vulnerable cities. Across Ghorahi's wards, new wetlands have been established to serve multiple functions, including flood control, groundwater recharge, and support for agriculture (Figure 9). By actively involving residents in the planning and upkeep of these wetlands, Ghorahi has instilled a strong sense of ownership and responsibility that helps ensure long-term sustainability. This local ownership and stewardship reinforce the role of wetlands in climate adaptation and sustainable urban planning. Moreover, integrating wetlands into local farming

systems has improved water availability, enhanced crop productivity, and strengthened food security (Sherpa, 2024).

Similar initiatives are emerging across Nepal as local governments increasingly prioritize climate-resilient infrastructure to address urban environmental challenges. In Biratnagar, implementing rainwater harvesting systems and developing green spaces has complemented efforts to enhance stormwater management and mitigate urban flooding (Ghimire & Chhetri, 2022). These projects align with a broader trend of integrating ecosystem-based adaptation strategies into urban planning, which addresses immediate environmental risks and supports long-term urban sustainability. By engaging communities and investing in nature-based solutions, smaller cities can design adaptive responses tailored to their unique climatic and socio-economic contexts, strengthening resilience against climate-induced disruptions.



Figure 9: Artificial Reservoir Constructed in Ghorahi Sub-Metropolitan City

Source: The Rising Nepal, 2023.

Furthermore, Shah *et al.* (2023) emphasize the critical role of wetlands in sustainable urban planning and in enhancing climate resilience. When effectively integrated into urban infrastructure, wetlands function as natural flood buffers, improve water quality, and provide multifunctional spaces for recreation and tourism. Strategic wetland conservation initiatives also contribute directly to the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 6 (Clean Water and Sanitation), reinforcing that urban wetland protection is a key component of climate-adaptive development.

4.4 Innovative Policies and Infrastructures

Resource-constrained cities in Nepal and similar regions face severe climate risks, requiring cost-effective, community-driven, and scalable adaptation strategies. Given their limited financial and technical resources, these cities must rely on participatory governance, innovative technology, and ecosystem-based adaptation to build resilience (Popovici *et al.*, 2024). One example is Ghorahi Sub-Metropolitan City,

which has implemented community-led artificial wetlands and water reservoirs to mitigate water scarcity, enhance biodiversity, and improve flood resilience. This initiative demonstrates how integrating local knowledge with municipal planning can lead to sustainable, low-cost solutions that serve ecological and socio-economic functions. Another innovative approach is the Climate-Resilient Agriculture Program in Udayapur District, where farmers adopt climate-smart agricultural techniques, such as drought-resistant crops and water-efficient irrigation, improving food security while reducing vulnerability to erratic rainfall patterns (Rai *et al.*, 2018).

Additionally, such efforts in effective disaster risk reduction are also extended. In resource-constrained urban settings, effective disaster mitigation depends on low-cost, community-driven strategies that integrate local knowledge, technology, and governance frameworks.

The Community-Based Flood Early Warning System (CBFEWS) implemented in Nepalgunj and the Karnali Basin is a notable success in Nepal's climate adaptation efforts. This initiative, supported by ICIMOD and Practical Action, has provided real-time flood alerts to vulnerable communities by integrating hydrological monitoring and mobile-based warning systems (Dulal *et al.*, 2010). The system has significantly reduced casualties and economic losses by allowing communities to evacuate before major flood events. As a low-cost, scalable model, CBFEWS has demonstrated the effectiveness of local knowledge and technology in enhancing climate resilience, serving as a replicable adaptation strategy for other flood-prone areas in Nepal (S.R. Bajracharya *et al.*, 2021; Dulal *et al.*, 2010).



Figure 10: Landslide and Flood Resilience Project in Dailekh and Surkhet, Respectively, With Bioengineering Techniques

Source: Apil KC.

A notable example of community-led disaster risk reduction (DRR) was implemented in Dullu, Dailekh, and Birendranagar, Surkhet, where one of the authors of this study was directly involved in the project. This initiative, supported by donor agencies,

focused on integrating bioengineering techniques to mitigate landslide and flood risks while enhancing local livelihoods. The project strategically utilized locally available vegetation for slope stabilization and riverbank reinforcement, ensuring the interventions were cost-effective and ecologically sustainable (Figure 10). More importantly, the initiative prioritized community ownership, as residents were directly engaged in the plantation process, ongoing maintenance, and resource management, ensuring long-term sustainability. By aligning disaster mitigation efforts with livelihood generation, the project reduced environmental vulnerabilities and strengthened socio-economic resilience in the region. This case demonstrates how integrating DRR with local economic activities can lead to sustainable and community-driven climate adaptation solutions, particularly in resource-limited regions.

Finally, integrating climate-sensitive land acquisition strategies, such as land banking for flood mitigation and green infrastructure, can create long-term adaptation benefits with limited resources (Puustinen *et al.*, 2025). In growing cities like in Nepal, integrating land banking into urban planning frameworks could enable municipalities to safeguard floodplains, develop green infrastructure, and support long-term adaptation efforts. For resource-constrained municipalities, collaborative governance involving local authorities, private sector actors, and community groups can significantly improve policy execution despite financial limitations (Puustinen *et al.*, 2025).

Innovative climate adaptation solutions must be designed with a deep understanding of resource constraints, ensuring that interventions are cost-effective, scalable, and practical for local implementation. By fostering community ownership, integrating indigenous knowledge, and prioritizing inclusivity, these solutions can become sustainable, socially equitable, and resilient to long-term environmental and socio-economic challenges.

5. CONCLUSION

Nepal's rapidly urbanizing cities face significant climate adaptation challenges due to unplanned urban expansion, limited institutional capacity, and inadequate infrastructure. These constraints disproportionately impact smaller and mid-sized urban centers, which often struggle with resource scarcity and lack the visibility required for effective climate action. Despite these challenges, innovative and participatory local adaptation practices offer promising opportunities. It is imperative for researchers to critically examine these cities, identifying context-specific vulnerabilities and leveraging local knowledge to develop sustainable adaptation strategies. In addition, strengthening climate data systems and risk assessment capabilities will ensure that adaptation projects are well-informed and effective even under extreme conditions. Securing sustainable financing mechanisms is also crucial, as many municipalities require external support to implement and maintain large-scale resilience initiatives. By leveraging innovation, encouraging multi-stakeholder collaboration, and incorporating local knowledge, Nepal's cities can shift from

reactive disaster response to proactive climate resilience, ensuring a secure and adaptive future for urban communities.

The experiences of Nepalese cities provide valuable lessons for urban areas worldwide, particularly in rapidly urbanizing, resource-constrained contexts facing intensifying climate threats. By prioritizing inclusive, community-driven approaches and adopting innovative, low-cost adaptation technologies, researchers and practitioners can establish scalable models for climate resilience. Integrating participatory governance and ecosystem-based adaptation into urban planning can strengthen adaptive capacities and socio-economic resilience in diverse settings. A strategic synthesis of these approaches can inform global urban adaptation practices, highlighting the importance of localized solutions and proactive, inclusive policymaking in fostering sustainable urban futures.

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Multi-Sectoral Opportunities in the Development of Food Green Cities for Urban Sustainability

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ABSTRACT: To safeguard themselves from health disorders, many urban residents have changed their eating habits, resulting in a rise in the market demand for healthy food. Many of these residents who cannot improve their diets cost effectively are destined to endure the stigma of illnesses encountered by older lifelong city residents. Sufficient amounts of healthy vegetables can be made available on the market but due to the absence of certification, the risk in urban vegetable is high. Moreover, the presence of heavy metals in cities and the lack of nutrients in food have increased the risk factor. Large scale sustainable food production in cities can drastically change the life of city dwellers by providing them with healthy diets and improve their environment. The United Nations Decade of Action on Nutrition along with the Sustainable Development Goals provides an opportunity for many cities to promote sustainability in food production. Some cities have already incorporated sustainable food systems in planning but despite that climate change in these cities are not quite at its tipping point, increasing their local sustainable food production can greatly contribute to reverse it. In fact, the effects of global warming affecting most of our cities can be mitigated by innovative agricultural practices. Food Green Cities can also reduce carbon footprint with good planning and layout of agricultural areas. This chapter presents the opportunities of creating a sustainable environment for the urban population by adopting a comprehensive literature review of case studies and reports. The SPECIES principles for the development of sustainable Food Cities can create many opportunities which have been identified in the social, environment, economic and other sectors.

Keywords: Sustainable Food Systems, Opportunities, Economic, Health, Agriculture, Environment, Technologies.

1. INTRODUCTION

In order to practice traditional agriculture, urban residents cannot move to rural areas for many reasons. Consequently, they have to engage in urban agriculture and face various challenges such as pollution, lack of sufficient nutrients, limited space, foul odours, rooftop waterproofing, certification issues, overcharging,

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governance conflicts, legal constraints, large investments, and high energy costs. In practicing sustainable urban food agriculture there is a lot of opportunities for them to face these challenges. It is the practice of multidimensional and multifunctional urban agriculture that brings multi-sectoral opportunities beyond food production. These opportunities have been neglected in the recent past mainly due to lack of sufficient market demand, planning and awareness. A lot of these opportunities can be obtained when the SPECIES principles are adopted to make urban farms in Food Green Cities (FGC) successful. The aim of this chapter is to elaborate the opportunities in the social, economic and environmental sectors among others to give better understanding of how to facilitate the development of sustainable food cities. After mentioning the materials and method used, a brief description of the principles for the development of FGC is given. This is followed by a full description of all the principles with relevant examples. The findings are then elaborated with recommendations before the conclusion.

2. MATERIALS AND METHODS

Review of research papers and case studies have been carried out during this research. Relevant case studies in today's date have been selected in order to align with the topic of research. Applying comprehensive literature review of existing action plans has helped in achieving the objectives. Adopted qualitative research techniques by reviewing ten qualitative interview transcripts, articles on successful sustainable urban agricultural business model in Mauritius and related to sustainable farming, food security, technology and sustainable food systems. This research study encompasses an analysis of SPECIES principles opportunities for development of Food Green Cities.

3. PRINCIPLES FOR DEVELOPMENT OF FOOD GREEN CITIES

The Seven SPECIES principles that can be adopted for the successful development of Sustainable Food Green Cities are:

1. **Social Sustainability:** This promotes better sustainable living conditions, quality of life and food safety.
2. **Policies for sustainable agriculture:** These are instrumental in managing the transition towards a sustainable food green city.
3. **Empowerment of farmers:** This is to engage them in the agricultural sector, providing them with the skills, knowledge, and resources necessary to thrive.
4. **Climate resilient agriculture:** This improves the resilience of agricultural systems to climate change.
5. **Innovation in agriculture:** This is the application of new ideas and technologies to farm production.
6. **Economic Food Sustainability:** This aims at achieving economic growth without harming the environment.

7. **Sustainable quality management:** This takes into account resource efficiency, environmental impact, quality safety, and quality cost to improve the overall effectiveness of urban agricultural production.

3.1 Social Sustainability

This is based on the concept that a decision or project promotes the betterment of society. It is true that the working conditions can greatly affect the lives of the city residents (Mariana *et al.*, 2022). Indoor or roof top urban farms can be equipped with lighting that can enable farmers to work at night or at flexible hours. In urban areas, banks and the wireless networks are easily accessible for digital payment that is less dangerous and time consuming. Since there are opportunities for urban residents to work at flexible hours, in shade and without soil, the people can be more interested to work and this can ease the recruitment process.

Social sustainable urban agriculture can be practised in community gardens such as schools and senior citizen homes to get the opportunity to offer students practical training and bring people together encouraging social interaction and cooperation.

For instance, Østergro is an urban farm located on a rooftop in Copenhagen, Denmark. In addition to growing a variety of vegetables and herbs, Østergro features a communal dining space where residents can enjoy meals made from the farm's produce. The rooftop farm hosts regular community dinners, workshops, and events, creating a vibrant social hub for the local community. Østergro exemplifies how urban agriculture can be combined with social activities to foster community engagement and sustainable living (Ostergro., 2025).

3.2 Policies for Sustainable Agriculture

Government should promote resource efficiency and conserve natural resources that can be achieved by for example removing subsidies on resources use by the private and public sectors. This can create an opportunity for removing subsidies on electricity, diesel, petrol, gas and irrigation water in cities for food production that lead to their wasteful use. The cost of using natural non-renewable resources on environment should be pointed out to consumers and city farmers in scaling up the sustainable agriculture.

Governments and regional entities have the opportunity to establish evidence-based policies, investment plans, programmes and governance mechanisms for promoting productive and sustainable agriculture.

The main policies that can be adopted are: (Sanket Suman., 2023).

1. **Reducing Poverty:** Case study the US Farm Bill, is a comprehensive piece of legislation that covers various aspects of agricultural policy, including subsidies, conservation programs, and food assistance. The Farm Bill supports American farmers, promotes sustainable practices, and ensures food security for low-income households.

2. **Removing Subsidies:** An agreement published at the end of COP26 climate summit called on all countries to accelerate the phasing-out of “inefficient” subsidies for fossil fuels—but no firm dates have been set. (BBC, 2021)
The International Energy Agency defines an “inefficient” subsidy as something that encourages wasteful consumption.
The potential challenges are: Political resistance as Fossil-fuel companies are powerful political groups and legitimate concerns about job losses in communities that have few alternative employment options.
Removing subsidies on coal, gas and oil would result in significantly higher costs for both business and private consumers. This can boost the renewable energy transition but transitioning to a fossil-free society is a huge challenge in many developing countries, and increased fuel prices risk hitting the most vulnerable the hardest. To support them, the subsidies can be redirected to provide low-cost agricultural loans such as to replace fossil fuel-based systems with electric alternative powered by harnessing solar energy, use of energy efficient equipment, built smart grids in cities and use of low carbon foot print materials.
3. **Market Based Approaches:** There are two types of trading programs currently used in the United States that uses markets mechanisms to address environmental problems; (EPA, 2024)
 - (a) Emission Reduction Credits (ERCs): Companies earn credits by reducing emissions below their specified rate;
 - (b) Capped Allowance Systems: These allowances are distributed among the individual polluters and the number of allowances held by each firm sets the limit on the amount of pollution they have the right to emit.
4. **Classifying and Expending Property Rights:** Property rights refer to rules that specify who may do what with rooftops, for how long and under what conditions. The right to derive benefit from the rooftop (e.g. through cultivation, which is a use right) and the right to exclude others from using the rooftop or otherwise interfering with it.
5. **Economic Incentives:** Fees, charges, and taxes are widely used incentives which generally place as per unit monetary charge (or fee or tax) on pollution emissions or waste to reduce the overall quantity. Subsidies including grants, low-interest loans, favorable tax treatment, and procurement mandates.
6. **Regulatory Policies:** It lays down technical standards and regulations and charges on air, water and land pollutants.
7. **Trade Policy:** Domestic trade policy stresses on the use of environmentally friendly processes for polluting industries by adopting cleaner technologies.
8. **Public Awareness:** Conducting of formal and informal education programmes relating to environment management and environment awareness programmes can go a long way in controlling environmental degradation and keeping the environment clean.

9. **Participation in Global Environmental Efforts:** Efforts should be made to make agreements about environmental protection. They include the Montreal Protocol in phasing out of ozone-depleting chemicals.

3.3 Empowerment of the Farmers

An opportunity exists to provide farmers with technical agricultural literacy and access to information on sustainable food agriculture. Successful empowerment of young people can be facilitated by an educated population. The youth can be made aware of the ground realities in old agriculture that are causing deterioration in food quality and hampering the progress of sustainable food production.

To empower young farmers, interventions at the community and individual levels are also required (UNDP, 2019). At the community level the young farmers have the opportunity to access resources such as land, credit, and technology for sustainable food production. Young farmers can be invited to participate in agricultural events to connect them with other farmers in the community to learn from their experience and benefit from On-farm opportunities.

Young farmer's can have the opportunity to understand their environmental rights and advance justice to protect the vulnerable groups from discrimination such as loss of land, lack of access to information and clean water.

Successful empowerment initiatives for young farmers in Africa are: (Agritech., 2024)

- (a) **Digital Agriculture in Rwanda with FAO:** Since 2017, the FAO has collaborated with Rwanda's government to promote digital agriculture and train young farmers. One of the initiative recipients is Daniel Nshimiyimana.

Daniel was trained in using apps such as "Cure and Feed your Livestock," "e-Nutrifood," "Weather and Crop Calendar," and "AgriMarketplace," This gave Daniel access to production techniques, weather forecasts, and direct market access.

In an interview with Yenkasa Facilitating Dialogue Africa, Daniel stated, "This technology gives me all the information I need in my farming. First, on production, how I can better produce, and secondly, how I can access the market freely without intermediaries who used to affect prices negatively. Lastly, technology helps build a strong network with my fellow farmers for peer education. I encourage every farmer to leverage these FAO applications."

These applications have empowered farmers to make informed decisions, enhancing productivity and profitability.

- (b) **Tech Young Farmers' Club in Nigeria by SAHE Foundation:** The Sustainable Agro and Hunger Eradication (SAHE) Foundation, alongside the National Association of Proprietors of Private Schools (NAPPS), launched the "Tech Young Farmers' Club" to teach hands-on agricultural education to secondary school students in Lagos, Nigeria. This initiative aims to modernise perceptions of agriculture and empower over 1,000 young participants with agricultural

technologies. According to the foundation, it represents “a commitment to empowering young individuals with the knowledge, skills, and resources they need to thrive in the agricultural industry.”

Through roundtable discussions and workshops, the project promotes sustainable agriculture, food security, and environmental stewardship.

3.4 Climate Resilient Agriculture

Agro ecological systems are examples of more resilient systems since they have a greater capacity to recover from drought, floods or hurricanes (Honor *et al.*, 2020). Furthermore, they foster stronger socio-economic resilience because by diversifying the range of crops grown and reducing dependence on external inputs, producers dilute economic risk.

There are opportunities to share sustainable agricultural knowledge and information in the relevant public sector institutions at national level. Possibilities for improvement of resilience in agriculture exist by enhancing communication between the actors in the food system and consciousness of ecological feedback, through e.g., increased reliance on local resources (Sundkvist, Milestad, Jansson 2005).

Modular greenhouses, electric farming, vertical farming and micro farms can adopt stand alone technologies that enhances climate resilience agriculture.

Examples of successful rooftop greenhouses in USA are, The Gotham Greens facility in Chicago’s Pullman neighbourhood features a 75,000-square-foot greenhouse, supplying fresh vegetables to local retailers year-round and Lufa Farms in Montreal manages four rooftop greenhouses covering 300,000 square feet. Greenhouses have structural reinforcement that supports growing medium-weight, waterproof membrane protection, proper drainage systems, wind barriers, and lightweight growing containers that can produce drought-resistant plants like herbs, tomatoes and leafy greens that thrive in container environments. (FarmstandApp., 2025)

3.5 Innovation in Agriculture

Cities are already equipped with fast internet connectivity and it will be easy to use technological progress in Artificial Intelligence, Drones, Agri-Biotech, Internet of Things, Robotics, Big data and analytics, Controlled environment agriculture, Regenerative agriculture, Precision agriculture and Connectivity technology [Research blog., 2023] to transform our agriculture into sustainable agriculture.

Improvement in production techniques by using higher-yielding genetically modified seeds, new methods for improving soil fertility or more efficient irrigation technologies are examples of “process innovation” in agricultural farming. Downstream industries creates new and improved products, such as healthier foods, or new chemical or pharmaceutical products are “Product innovations” that can really change the output of our agricultural sector. Throughout the supply chain “Marketing and organisational innovations” are also increasingly important.

Opportunities in high-value crops, downstream processing and livestock are great. Morocco for instance, cultivated high-value crops such as tomatoes and olives cultivation as the most effective way to address rural poverty but same can be done in cities also.

Despite technology's potential to transform agriculture, many farmers, especially in developing regions, struggle to access it. The high costs of advanced equipment and digital tools can exclude small-scale farmers from these innovations. Affordable Technology Solutions: Collaborative efforts between governments and NGOs can provide subsidies or cooperative purchasing options to make technology more accessible. Training Programs: Educating farmers on effective technology use can maximize its advantages and foster greater adoption.

The rise of precision agriculture relies on collecting extensive data to enhance farming efficiency. However, many farmers lack the necessary skills or resources to analyze this data, which results in the underutilization of valuable insights. User-Friendly Platforms: Creating intuitive software for data analysis can empower farmers to make informed decisions. Community Data Sharing: Encouraging farmers to collaborate and share data can enhance collective knowledge and improve overall farm management. (Cropway., 2024)

3.6 Economic Food Sustainability

For agriculture and its food system to be sustainable then economic viability is a necessary condition and to begin with, profitability is a good place. Evaluating the likely profitability of potentially more sustainable practices can start with budgeting. But economic viability is about more than profitability.

To be economically sustainable, a farm does not have to make profit every year. In fact, competent farmers know that they will not be able to cover their operating costs all the time, and plan accordingly.

To ensure the economic sustainability of their operations, effective farmers adopt a wide range of rational private sector-based risk management practices. Examples include maintaining low debt to asset ratios, diversifying the farm's resources among livestock and crop enterprises, and using market-based risk management strategies.

Farmers can have the opportunity to get payments to produce public goods such as water quality, biodiversity, animal health and welfare and climate change mitigation, alongside food production. Sustainable food incentive is aimed at farmers, paying for actions that relate to farming activities.

Recycling is among one of the best economic sustainability examples. For instance, Kamikatsu, Japan, embarked on a journey towards a zero-waste goal, they managed to recycle approximately 81% of their waste in 2016 and serves as a model for any community aiming to decrease its landfill waste.

Micro-farming, also referred to as urban farming, involves cultivating crops on residential or commercial properties covering less than five acres. For instance,

Italian startup NovaFarm offers vertical indoor farming solutions with products like Microfarm. Micorfarm caters to the large-scale needs of restaurants, bars, and hotels. This stimulates local economic development while benefiting the environment.

The use of alternative energy is among the best economic sustainable development examples in today's world. Renewable energy sources, such as wind, solar, and hydropower, provide a cleaner, more sustainable, and cost-effective approach to fulfilling our energy requirements. (Olivia Bolt., 2023)].

3.7 Sustainable Quality Management

It offers career opportunities for residents of Food Green Cities who are qualified to work in quality assurance, supply chain and food production. Their goal will be to improve quality, customer satisfaction, and productivity without compromising cost, health, safety or environment. ISO 22000 establishes a comprehensive framework for managing food safety. For example, the successful healthy beverage startup, Smoodies, headquartered in Bengaluru has implemented ISO 22000 to upgrade its processes. (Case study, 2025).

Examples of quality management practices are better documentation and record-keeping practices that ensure traceability throughout the entire supply chain so that any potential contamination or adulteration is identified quickly and efficiently.

Enhanced food safety practices including proper cleaning, use of protective clothing when necessary, separating raw from cooked foods, following correct temperature control during storage and transportation as well as adhering to personal hygiene standards helps in preventing contamination, product deterioration, cross-contamination, or any other occurrence that could potentially affect a company's reputation and its customer's health.

Practices for more efficient use of resources by following guidelines, businesses can guarantee the highest level of hygiene in production areas while also reducing waste and increasing efficiency.

By planning practices to establish objectives and processes necessary to deliver safe food it enables food manufacturers to ensure that their products meet the required standards of quality including quantity of minerals in food and safety by establishing a set of protocols for operations, personnel, facilities, and processes.

Planned processes and controls can be implemented to ensure consistency in every batch produced by controlling each step from raw material intake down to final packaging.

Proper monitoring, maintenance of equipment and measuring processes against policies, objectives, and requirements and taking actions to improve performance, as necessary makes sure that the same level of quality is maintained throughout the entire process—from sourcing ingredients up to distribution methods used—thus allowing companies to produce safe food products with good taste at competitive prices (Tutorialspoint, 2023).

4. FINDINGS/RESULTS.

Development of Food Green Cities may involve different sectors namely Health, Environment, Social, Economic, Labour, Information Technology, Education, Energy, Tourism and Infrastructure. In fact, concerted efforts from stakeholders in these different sectors may avail of multisectoral opportunities that can increase public sector efficiency and effectiveness.

4.1 Health Sector

By providing opportunities for physical and mental well-being, FGC can help stakeholders in the health sector to encourage such activities. FGC can play a central role in the health sector in providing healthy foods to curb chronic diseases among citizens.

4.1.1 Findings

Sustainable Food Businesses can explore feasible opportunities to create partnerships with health care organizations. For example, sustainability is central to partnership between Sodexo the global leader in sustainable food and UK's largest healthcare, Nufflied. (Sodexo, 2025) Relevant data is shared between Sodexo and Nufflied to better understand health outcomes. Government agencies have also the opportunity to perform research and evaluation on the impact of sustainable food stores located in health care settings on food security, diet quality, and health outcomes. [Brittney *et al.*, 2021] The Singapore Food Agency (SFA) is a statutory board under the Ministry of Sustainability and the Environment that oversees food safety and security in Singapore (Singapore, 2025). It manages food safety and security risks through research and development.

Health care providers have the opportunity to assist individuals in improving their diabetes control and food security in the setting up self-management or food prescription programs incorporating sustainable food consumption habits. How such programs may contribute to changes in health outcomes and its impact on HbA1c levels can be assessed. It is best to implement successful models of programs that work best for patients and understand the barriers to overcome. A study by Friedman school of Nutrition Science and policy researchers shows that produce prescription programs for patients could save Billions in Health Care Costs. (Joseph, 2023)

There are opportunities for healthy food producers to co-locate produce distributions within a health care setting and also make referrals to local sustainable food suppliers. Hospital foodservices have the potential to positively contribute to the local food system and planetary healthcare. Understanding the factors contributing to the success of "exemplar hospitals" with environmentally sustainable foodservices gives an opportunity to re-imagine food services and guide strategic planning. (Stephanie *et al.*, 2021)

4.1.2 Recommendation

Food insecurity screenings can be conducted in healthcare institutions giving the opportunity to refer them to sustainable food producers and distributors. It may consist mainly of asking people questions like do they have increased anxiety and stress about the cost of food, whether they are consistently eating the same, few, low-cost foods and eating a limited variety of foods. The challenges that can be faced when asking these questions are patient discomfort, lack of training, and stigma. Patients and providers can help ease these challenges by effective communication between them.

Reform in health systems will help in moving away from sick care to preventive and nutrition-based care. Challenges such as insufficient public health infrastructure, restricted healthcare resources, or discrepancies in healthcare access exist. These could be addressed by improving the health infrastructure, increase healthcare resources and provide better access to healthcare.

Organizations sustainable food voucher sponsor programs will help in achieving United Nations' Sustainable Development Goal 2 (SDG 2), Zero hunger. But it has to face challenges such as natural disaster, corruption and balanced meals among others. With improved road infrastructure, food distributors should act in the interest of their city and distribute diets recommended by nutritionist.

4.2 Environment Sector

Responsible to improve the environment, pollution and wastes can be easily reduced in FGC. Environmental protection and proper management of natural resources in the environmental sector can stop malpractices and boost sustainable food production in cities.

4.2.1 Findings

Great opportunities for reduced waste production and composting exist. Implementation of Circular solutions (like food upcycling), smart packaging and cooling can help address food loss and waste along the food supply chain from the farm to the home. An example of circular economy in the food industry is the Rubies in the Rubble which is a UK-based company that makes jams, relishes, and chutneys from surplus fruits and vegetables that would otherwise be thrown away due to aesthetic imperfections. There are certain food safety concerns, such as the risk of contaminants, antimicrobial resistance and physical hazards.

Strengthening the ability of local health departments to detect, respond to, and report antimicrobial-resistant infections is one of the preventive steps.

The rapid technological change can help city factories to become sustainable by producing biodegradable packaging that can preserve the quality of sustainable foods. Examples of sustainable food packaging options are: Dissolvable or biodegradable packaging. Paper bubble wrap alternative which can be recycled after use. Biodegradable air pillows made from recycled plastic. Hybrid meal delivery boxes.

There are also opportunities to apply modern high-tech farming to create closed-loop energy systems between different types of agriculture (e.g. between fish farming and crop production) (Tuijl *et al.*, 2018). For example, the integration solar PV panel can make closed-loop energy systems in urban agriculture more sustainable.

4.2.2 Recommendations

The proper management of our natural resources can be enforced. By creating green spaces, promoting urban farming, supporting local conservation efforts, enhancing urban water bodies, adopting sustainable practices, and connecting with nature, city dwellers can make a meaningful contribution to preserving nature in cities (Yama., 2025).

However, cities may be too compact to provide sufficient and well-functioning green space. Due to densification measures there can be loss of public and private urban green spaces resulting in insufficient green spaces. There is a risk for quality loss of existing green space and for provision of green space with low quality and risk for low priority of green space planning in the context of exploitation. To tackle these problems the participation of stakeholders and the public is important to preserve green spaces, enhance quality of existing green spaces, and provide green spaces on sites redeveloped and greening difficult sites lacking green space.

A community-by-community approach can be implemented for sustainable food production to mitigate 1) Deforestation, 2) Carbon emissions, 3) Unsustainable reliance on fossil fuels and Oceanic. For example, by engaging city residents, schools and organizations to participate in forest preservation activities such as tree planting, use of energy-efficient equipment and investment in renewable energy.

By buying products from urban farms that provides fresh produce, we can support them whilst improving air quality and manages storm water runoff.

4.3 Social Sector

It encompasses community cohesion which implies better social interaction among citizens. Stakeholders in this sector are involved in targeting the most vulnerable groups to supplement them with food produced in cities.

4.3.1 Findings

Wasting food raises social question and is very poorly measured right now, and most value chains are not equipped to understand the extent of waste that is occurring in their supply chain or at consumer levels. However, this is a topic that brings social opportunities. For example, in order to measure quantity of food waste from households by questionnaires, city dweller can record their food waste over days or weeks in a diary. And even physical waste surveys can be carried out by extracting food wastes from disposal units and weighed.

A Community Sustainable Food Study Group to assess and direct the communities' efforts can be created. City dwellers' can volunteer at farms or community gardens,

that can help them in becoming more successful in starting their own garden without arable land or get involved on city college campus. In addition, World-Wide Opportunities on Organic Farms (WWOOF) offers a unique opportunity to deepen connection to sustainable farming by linking its visitors to organic farmers and promote educational exchange.

City organisations have the opportunities of creating shared-value and propose practical initiatives to sustainable food producers they rely on. City workers have opportunities to drive action, from a professional perspective. For instance, they can aim at influencing the spending habits of the organization they work for (catered events, cafeteria options), work for food manufacturers and retailers to help accelerate their transitions to more sustainable and regenerative models; participate in sustainable food advocacy groups or organizations. [Oliver Camp 2020].

4.3.2 Recommendations

Address the issue of hunger in cities by promoting hunger program. For example in the zero hunger program in Brazil, local governments launched popular restaurants that served balanced and nutritious food at low prices as well as prioritizing the purchase of locally produced food. (UN news., 2017). The challenges of addressing hunger are mainly climate crisis and shocks, currently farming practices and orientation are not sustainable and increase in consumption. Resolve the hunger problem by paying attention to the most vulnerable to climate crisis, prioritizing sustainable farming practices and increasing sustainable food production. Moreover, social relation has to be created between scientists, policy makers and society for developing policies to foster sustainable food development in cities.

Support community gardens such as school and senior citizen homes gardens.

Challenges such as theft and vandalism and lack of structure can be tackled by proper fencing with lighting and following proper guidelines (Jacob, 2024). A good example of community gardening is the case of Samyuktha Kannan, a resident of Chennai, Tamil Nadu India who started a community garden in her locality after witnessing its success abroad (Muthukumar, 2021).

Improve the progress of the setting up School Nutrition Gardens (also called Kitchen Gardens) in schools by following for example the Ministry of Human Resource Development (MHRD) guidelines in India. This can address malnutrition & micronutrient deficiencies by improving the consumption of freshly grown vegetable if same is issued in other countries [Deirdre Appel., 2019]

4.4 Economic Sector

FGC falls in the primary sector of the economy by generating income through agricultural practices. It focuses on increasing income by controlling subsidies, taxes and loans to promote sustainable food production.

4.4.1 Findings

As the city industries are the main polluters, green taxes may be imposed on them to gain revenue. Green taxes may include: “Pollution charges (emission tax/waste taxes), marketable permits, depositor fund system, input taxes/product charges, differential tax rates and user administrative charges. However, these taxes may lead to economic problems such as a decrease in firms’ profit due to high taxes leading to insufficient investment for job creation. Finally, green taxes if not balanced properly can have a negative impact on the economy due to low profit, it can also affect the society due to unemployment and the environment due to not fully solving the environmental degradation problem

Better methods of production using Climate-Resilient Agriculture (CRA) technologies and practices provide an opportunity to meet the challenges of climate change as well as economic growth and development of the agricultural sector. There are investment opportunities for establishing financial schemes to help small scale farmers to expand or to restart their business in the aftermath of extreme weather events and pandemics. Especially, poor countries with high levels of food insecurity can minimize risk and costs associated with food price hikes especially in bad weather conditions or pandemics.

Countries that have a sufficient natural resource base can be self-sufficient if Farm businesses focus on profitable opportunities for improving its efficiency.

Research suggests that a plant-based diet not only has an emission intensity that is around 90% lower than that of a current average diet, but that it also has the potential to reduce the number of premature deaths among adults by around 11 million. It may be inevitable for City dwellers to adopt a more plant-based diet for a sustainable city. Therefore, there is strong growth potential for alternative animal-protein products and it is estimated that the market for alternative meat and dairy can grow. New economic opportunities need to be created for small and mid-sized city farmers who by practicing modern agriculture like vertical farming can provide 80% of urban food demand while reducing the imports on food [Credit Suisse., 2021].

Successful strategies from around the world, such as financing ecosystems mapping and conservation to meet scientific targets for healthy biomes permanency as well as subsidizing sustainable land and sea farming can be implemented to ensure economic food sustainability.

Opportunities to provide incentives are usually given in the form of variable fees to resource users for the quantity of wastes, water and land use. They can be given rebates if less waste is generated than the standards laid down by the Govt.

4.4.2 Recommendations

Government can support sustainable food producing businesses by subsidizing their consumables and by giving fiscal incentives to start ups. The challenges are the

design of these subsidies to benefit large agribusinesses as well as small farmers. So, it is important to consider the social and economic impacts of agricultural subsidies, as well as their environmental effects and also the implementation of agricultural subsidies should be consistent with the World Trade Organization (WTO) rules.

All stakeholders should be familiarised with green taxation policies so as to make the tax reforms socially acceptable.

Complementary policies will have to be implemented in order to reduce the burden of green tax on the private sector to remain profitable. [Haitham., 2020]

Provide strong financial support for universities, education programs, and research & development is an important part of economic sustainability as well.

Moreover, food loss is not measured presently, and, this is a topic that brings great economic opportunities. By comparing products entering a store (inputs) with products sold (outputs) and subtracting outputs from inputs, an estimate of food loss and waste can be made.

4.5 Labour Sector

Responsible to set the working conditions to ensure better productivity of urban agricultural workers. Faces issues of decent work standards, inequality and unemployment in cities

4.5.1 Findings

There are opportunities to offer green and decent jobs in new productive markets. Moreover, this will give vital opportunities to increase productivity in those parts of the world that really need it most. With higher labour productivity this then lowers the cost (and hence price) of food relative to agricultural worker incomes, which raises agricultural workers' budget surpluses after food expenditures and hence increases their real incomes, and stimulates demand for non-food goods and services. However, to maintain the productivity is one of the major challenges that could be mitigated by focusing on results.

4.5.2 Recommendations

Employee can be allowed flexible working hours in sustainable urban farms to increase productivity and ease recruitment processes. If required, flexible working conditions should come into force and employee rights to ask for flexible time can be made possible for urban farms.

For example, Nestlé the largest food company in the world has successfully implemented flexible working policies helping to boost the overall productivity of the business (Nestlé, 2020). It has been found by Farm Progress that if a farmer is looking for talent, he needs to think about extending employees benefits to include flexibility. [Johnson., 2021]. Another study by Tyler Farm shows that by implementing flexible work hours on the farm, it allows employees to work when they are most productive and motivated (Tyler., 2024).

Create new jobs in namely 1) Research and other agricultural practices 2) Media and Communications, 3) Advocacy, 4) Restaurants and Food Services, 5) Law and Policy, 6) Public Health, 7) Teaching, 8) Entrepreneurship.

4.6 Agricultural Sector

Supports policies and regulations to promote and facilitate urban agriculture. It can be responsible to facilitate access to rooftops and permits to businesses practicing sustainable urban agriculture.

4.6.1 Findings

Opportunities exist for the creation of regulatory authorities to decide on the methods that policies can target the problems in sustainable agriculture. However, the challenge is that farmers should be well versed with the regulations and it should be fair to all food producers so as not to misled consumers. Clear guidelines could be given to farmers on the prevailing regulations and unfair restrictions can be eliminated. For example, registration permits can control the number of businesses who are really practicing sustainable agriculture. Strategic management support can also be provided by these bodies to help start-ups succeed in their businesses.

Sustainable organisations can also implement a Sustainable Quality Management System that can control the quality of their outputs and ensure customer satisfaction.

Innovative agricultural techniques can use plant breeding techniques to increase the vitamin and mineral content of staple foods and genetic engineering technology can offer opportunities to transfer genes across species.

4.6.2 Recommendations

Implementation of established standards and norms for ensuring quality of sustainable food produced can be encouraged. This can ease the monitoring of the product quality on the market by government agencies.

ISO 22000 establishes a comprehensive framework for managing food safety. For example, many major food producers and retailers have embraced ISO 22000 certification. Nestlé Waters, a global leader in bottled water, implemented ISO 22000 to strengthen its food safety management system. This resulted in improved performance and better alignment with international regulations. Other notable companies with ISO 22000 certification include Danone, Coca-Cola, and Mars. These multinational corporations have integrated the standard into their operations across various countries. (O'Hare, 2024)

Create regulatory authorities that can impact on standards for food production, labelling and distribution practices.

4.7 Information Technology (IT) Sector

It addresses the unique challenges of city environments in developing technologies and internet-based applications that can improve the efficiency of urban farmers.

Promotes access to IT infrastructure to create a conducive environment for the growth of IT in agriculture.

4.7.1 Findings

Cities worldwide are embracing Vertical Farming due to lack of space. Information technology plays an important role in vertical farming to monitor and optimize plant growth. It makes use of sensors that are installed in the farm to collect data on nutrient levels, light intensity, temperature and humidity among others. The data is fed to a central control system that is connected to computers that can retrieve all the data. IT applications on the computer can analyze the collected data and automatically adjust fertilization and irrigation among others to maintain the optimal growth of different crops (Jugdish, 2023). Many benefits such as increased yield, reduced resource usage and improve quality can be obtained. There are opportunities for IT professionals to develop IT applications that can help farmers to become efficient.

4.7.2 Recommendations

Encourage the creation of IT packages like for example the Trimble Ag Software and Ag leader applies IoT (Internet of Things), GPS and AI to analyze weather, crop growth, and soil conditions. Mobile applications can be created like for example IoT-enabled irrigation apps that can measure the soil's water content and environmental conditions through sensors and provide the crops with ideal quantum of water.

Sensitize urban vertical farmers on the benefits of using IT in vertical farming to achieve efficiency. Insufficient IT infrastructure, high cost and lack of knowledge are some of the challenges. Mobile applications on their phones can be used to access agricultural information and financial services. Farmers can learn gradually by starting to use these applications and share their knowledge with other farmers.

4.8 Education Sector

Promotes capacity building in urban agriculture to empower farmers and stakeholders. Provides skills for improved agricultural practices including modern farming techniques.

4.8.1 Findings

The youth and neighbours need training and there is an opportunity to develop a food education centre to train them. Training of extension staff is also important so that they can provide right advice and guidance to those practicing sustainable agriculture and having the ambition to develop sustainable food systems. Both on-job training and classroom-based training will greatly help the city farmers to enhance their skills on innovative techniques to build sustainable food systems. Although there may be some training centres already, they should focus on emerging technologies for cultivation that can transform the existing practices in agriculture to

modern and sustainable agriculture. For example, the gardening blog Green Packs offers hydroponics education programs for individuals interested in exploring the world of hydroponic farming. (Gallagher, 2025)

Global collaboration in scientific research has grown considerably over recent decades, opening up new opportunities for combining the most advanced scientific capabilities with detailed local knowledge in key areas of sustainable development.

4.8.2 Recommendations

Specialist laboratories in the field of agriculture can determine for different farming setup, the optimum water quality, species of vegetables and fish to grow together in the aquaponics system, the appropriate density of the fish, the right filter quality, and other similar parameters. (Facknath, 2018)

Universities or research centres can get into partnership with the public and private sectors to work on projects that will provide the necessary data to help sustainable city farmers to establish a bigger, field level aquaponics unit.

4.9 Energy Sector

This sector is mainly concerned with the significant greenhouse gas emissions caused by the use of costly non-renewable energy resources in food production. It enables sustainable food production by increasing renewable energy in the energy mix to make cost savings.

4.9.1 Findings

Harnessing solar energy requires a lot of space that can be acquired from rooftops of city buildings. Opportunities to develop photovoltaic plants to generate electricity from solar energy exist as to be completely sustainable, city farmers have to use electrical power generated from renewable sources. In densely populated urban areas, space is a coveted commodity. Solar panels offer a solution to this problem by maximizing the use of available space. They serve dual purposes—they are not only a source of renewable energy but also provide a sturdy supporting structure for vertical farming. This innovative approach allows us to cultivate more food in the same footprint, thereby promoting an efficient use of space. For example, Sky Greens (Singapore) is a company that uses little solar energy from Solar panels installed on the farm's roof to maintain its vertical farming operations [Tau., 2025].

4.9.2 Recommendations

To harness renewable energy sources for production of electricity in Sustainable Food Green Cities in order to achieve Net Zero objectives.

The challenges include the initial installation costs, regulatory hurdles, and the need for skilled maintenance. However, with the right strategies in place and robust support from rooftop solar panels suppliers, these challenges can be surmounted.

4.10 Tourism Sector

In cities the tourism sector encompasses all businesses and activities related to food and attractions among others that can significantly boost food production in cities. It can promote businesses in partnership with food producers prioritizing sustainable practices.

4.10.1 Findings

Green Tourism is emerging and is providing the opportunity to simulate local production that can retain tourism earnings as well as improve the distribution of economics benefits of tourism to city farmers. Sustainable agriculture can provide the tourism industry with sustainable food and can also become a background for tourist attraction in cities (Diriba *et al.*, 2018). Urban farms can provide insights into sustainable food production techniques and farm to table experiences.

For example, Singapore's Edible Garden City provides an excellent example of the economic potential of urban agriculture tourism. This social enterprise designs, builds, and maintains food gardens in the space-constrained city-state. Alongside its core urban farming activities, Edible Garden City offers a range of tourism experiences, including guided tours, workshops, and team-building activities for corporate groups. (Dreamwork, 2024)

4.10.2 Recommendations

Provide nature attractions within farms in cities that can allow city farmers to have direct contact with tourist and improve sale of their products. The tourism sector should promote attraction site within farms and the farmers can get incentives when the tourists visit their site. Tourists can have guided visits to urban farms, including explanations of different farming techniques and sustainability practices. They can also learn skills like planting, composting, or hydroponics and stay overnight, allowing them to immerse themselves in the urban farming lifestyle.

Challenges in urban agriculture tourism is striking a balance between tourism activities and the core function of food production. Therefore, design visitor experiences should be carefully designed so as to minimize negative impacts on food production while still providing engaging and educational experiences. Seasonal variations and weather conditions can pose challenges for tourism operations, which typically aim for year-round appeal but strategies can be developed to manage these fluctuations, such as offering indoor activities during inclement weather or focusing on different aspects of urban farming during off-peak growing seasons.

4.11 Infrastructure Sector

This sector is responsible for planning, coordinating and monitoring the construction of roads, buildings, houses and green spaces in cities. Stakeholders such as Consultants in the construction industry, Planners, Designers, Engineers and Permit issuers can significantly influence projects.

4.11.1 Findings

Development of infrastructure and land can be strategically designed so as to enable food production in cities and ensure urban sustainability. The needs for food production can be easily integrated in the infrastructure at the design stage itself. For example, the designers can incorporate green roof tops and vertical gardens complete with all amenities in new buildings that can be used to grow crops. There is an opportunity to minimize cost by good planning for sustainable urban food production at early stages of construction.

4.11.2 Recommendations

City consultants and planners in construction should focus on sustainability and integrate green infrastructure for food production in new city buildings at early design stages. Building-integrated agriculture (BIA) can enhance food security in urban areas but to be effective, it must overcome important challenges. Finding farming spaces within the city can prove challenging due to zoning laws, technical feasibility and competition for other revenue-generating uses. New planning strategies will have to facilitate the access to buildings for BIA projects.

The technical knowledge connected to the food production provided by agronomists and practitioners is crucial to develop future BIA projects.

BIA projects today face relevant challenges to become completely circular and sustainable. Nonetheless, technological innovation, as well as infrastructure planning strategies will help overcome these challenges. (D'Ostuni., 2022)

6. CONCLUSIONS

In conclusion, urban agriculture is multidimensional and multifunctional. It is also considered to be multidisciplinary because it draws upon a wide range of fields and therefore creates many opportunities in different sectors of the economy. Unlike rural areas, cities are facing major challenges to practice agriculture but there are opportunities in the development of Sustainable Food Green Cities for city dwellers to combat them. Multisectoral opportunities exists in different sectors namely social, economic, health, IT, energy, tourism, labour, education, environment, agricultural and infrastructure. By adopting the seven principles SPECIES in the development of sustainable Food Green Cities, these opportunities can be easily created successfully.

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Urban Forestry in Selected Nepali and US Cities: Assessment, Analysis, and Recommendations

Ambika P. Adhikari¹ and Keshav Bhattarai²

ABSTRACT: Urban forest delivers several benefits to urban area residents. The benefits include shade, dust control, noise mitigation, water retention, ecological services, pedestrian comfort, aesthetic improvements, and economic benefit to the community including the provision of food. Nepali urban areas face several environmental and infrastructure-related problems that include air and noise pollution, frequent street flooding, and unclean road and sidewalks. Further, a vast majority of pedestrian in cities face discomforting, unpleasant, unhygienic, and unsafe conditions. Urban forests can help alleviate many of these problems at a low cost as trees provide shade to the pedestrians, absorb dust and decrease noise, and can help reduce the surface water run-off. Further, urban trees help improve the aesthetics, raise property value, and provide therapeutic comfort to the residents.

Urban forestry is often an under-appreciated topic in Nepal's urban planning and development process. Recently, some municipalities have realized the value and benefits of urban forestry and have begun to contemplate how to improve the state of urban forests. However, much work is left to do in creating effective urban forestry plans and implement those to help mitigate some of the problems described above. In contrast, urban forestry practice in the US cities is relatively well-developed. Most US cities now have urban forestry master plans designed to improve urban shade, aesthetics, biodiversity, and to capture environmental benefits.

This paper summarizes the benefits of urban forests, reviews examples from the selected US cities, and the state of urban forestry practices in Nepal, particularly the Kathmandu and Pokhara Valleys, Bharatpur, Birgunj, and Biratnagar Metropolitan Cities, and Dharan, Hetauda, and Nepalgunj Sub metropolitan cities. It proposes policy recommendations and steps to develop urban forestry master plans for Nepali cities. The paper also reviews examples of urban forestry practices in selected US cities and states as well as Nepali municipalities. Urban planners and policy makers may benefit from the recommendations and urban forestry planning ideas outlined in the paper.

Keywords: Urban Forestry, Nepal, US, Ecological Services, Canopy Cover, Shade.

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1. BACKGROUND AND INTRODUCTION

The term “Urban Forestry” was first used in 1965 by a graduate student for a research paper title at the University of Toronto. In the last six decades, the practice of urban forestry has become a common element in cities in North America and several other regions.

At the first Canadian Urban Forests Conference in 1993, Frederick J. Deneke defined urban forestry as “the sustained planning, planting, protection, maintenance, and care of trees, forests, green space and related resources in and around cities and communities for economic, environmental, social, and public health benefits to people” (Cayford 1993).

According to G. Kuchelmeister (1998), “Urban forestry is considered as planning, management, and conservation of trees, forests and related vegetation to create or add value to the local community in an urban area”. C.C. Konijnendijk and T.B. Randrup, in *Encyclopedia of Forest Sciences*, (2004) state that “Urban forestry is an integrated concept, defined as the art, science, and technology of managing trees and forest resources in and around community ecosystems for the psychological, sociological, aesthetic economic, and environmental benefits trees provide society”.

Urban forests include parks, street trees on sidewalks and medians, public and private gardens, greenways, riparian trees, and various other woodlots. Urban forestry deals with the study of all these areas and their management for the environmental, economic, and social benefits for the city’s residents (Wood and Esaian, 2020). As cities face increasing air and noise pollution, extreme heat events including due to urban heat islands, and flooding, urban greenery can be an effective means of ameliorating these impacts. Environmental, social, psychological and economic benefits of urban forests are now well-recognized by planners and policy makers (Cichowicz and Bochenek, 2024). In the past three decades, urban forestry has been gaining importance as the urban population is growing globally and cities face mounting environmental challenges. Urban areas often experience increased air and noise pollution, heat island effects, and flooding. Trees can provide numerous benefits in air purification, carbon sequestration, temperature regulation, noise reduction, stormwater management, and they support wildlife. In addition, trees and large plants provide aesthetic improvements and psychological amenities for the urban residents, who often experience high levels of stress in their daily lives (O’Brien *et al.*, 2022).

Because of these positive environmental impacts of trees, recent focus has been on urban forestry through tree planting, green infrastructure development, community engagement, and policy implementation to improve the system of management and maintenance of trees. Urban foresters regularly collaborate with urban planners, landscape architects, environmental scientists, arborists, residents, and community organizations to promote the health and sustainability of the urban fabric with a goal of improving the urban environment and providing various services to the residents.

Despite its many benefits, urban forestry faces several challenges, particularly related to the management and integration of natural area forests into city planning. A key issue is the lack of representation and data for natural areas in city plans, which may lead to their underutilization in sustainability and climate goals. The distinction between natural area forests and designed green spaces is often overlooked, complicating management and policy decisions. Natural area forests, though critical for biodiversity and ecosystem services, require different management practices compared to street and yard trees. However, national-level data on urban forest management is sparse, and there is little understanding of the collective challenges faced by cities across the U.S., and even more so in Nepal. This gap in data and awareness hampers effective green space planning and policymaking (Livesley *et al.*, 2016; Nilon *et al.*, 2017; Pregitzer *et al.*, 2019).

Urban forestry in the US faces challenges such as limited funding, low public awareness, and the pressures of urban expansion, which contribute to issues like costly damage from invasive tree roots affecting sewage and water systems and increased destruction from tornadoes. Similarly, in Nepal, rapid urbanization, weak urban planning, and a lack of expertise and resources for sustainable forest management lead to significant problems, including tree damage to buildings and obstruction of sewage and water systems. To address these issues, it is recommended to invest in research to better understand and manage tree root systems, conduct public awareness campaigns to increase support and funding, and integrate urban forestry into city planning to mitigate the impacts of rapid urban growth and environmental damage.

To address the above issues, this paper is structured as follows: a) role of urban forests within urban environment; b) methodology; c) analysis of urban greenery in selected areas in the U. S., especially, in the states of Arizona and Missouri, and in Nepal's major metropolitan areas, d) discussion; and e) conclusion and recommendations.

2. ROLE OF URBAN FORESTS WITHIN URBAN ENVIRONMENT

Urban tree planting offers significant environmental and social benefits for cities. Trees sequester greenhouse gases, reduce air pollution, and cool urban environments (Pataki *et al.*, 2021; Shashua-Bar and Hoffman, 2000). In addition to their environmental functions, trees enhance the aesthetic appeal of cityscapes (Arnold, 1980) and improve air quality by absorbing pollutants (Nowak *et al.*, 2006, 2018). Furthermore, they help mitigate stormwater runoff, thereby reducing flood risks (Bartens *et al.*, 2009). The shading provided by trees lowers energy consumption in buildings, reducing the need for air conditioning (Akbari *et al.*, 1997; Akbari, 2002; Donovan and Butry, 2009; Hsieh *et al.*, 2018). By supporting biodiversity and maintaining ecological balance, trees contribute to urban ecosystems (Burghardt *et al.*, 2009). They also add economic value to urban areas (Figge and Hahn, 2004) and offer mental health benefits by alleviating psychological fatigue (Houlden *et al.*, 2018).

This positive perception of trees has led to widespread initiatives for urban tree planting, even in areas with limited space (McDonald *et al.*, 2016). The ability of trees to sequester carbon and purify the atmosphere by filtering pollutants has been well documented (Tallis *et al.*, 2011; McPherson *et al.*, 2005). However, urban tree planting requires careful planning regarding costs and species selection to maximize benefits (Oldfield *et al.*, 2013). Despite these benefits, urban trees also present challenges. For example, air pollutants can accumulate under tree canopies when wind speeds are low, hindering air movement and pollutant dispersion (Salmond *et al.*, 2013). Additionally, some trees release pollen that can trigger respiratory issues such as asthma (Lovasi *et al.*, 2013). Urban trees typically capture only a small percentage of a city's total carbon emissions, mitigating less than three percent of emissions (Lindén *et al.*, 2020).

Globally, terrestrial land constitutes a third of the Earth's surface (FAO and UNEP, 2020), while cities occupy less than one percent (Zhou *et al.*, 2015; Liu *et al.*, 2018; Nowak and Greenfield, 2018). Consequently, the ecosystem services provided by urban trees are most effective on a local scale, particularly in neighborhood patches or urban forests. Through evapotranspiration, shading, and solar radiation interception, trees help cool the environment (Zhao *et al.*, 2018). In U.S. cities with abundant trees, temperatures can be up to 3° C lower than in treeless areas, though this cooling effect varies based on land cover and urban density (Jung *et al.*, 2021). The cooling effect of a 100% tree canopy with heights between 60 to 90 meters is estimated to be about 2.9°C compared to treeless areas (Green, 2023; Ziter *et al.*, 2019).

Given the limited space and competing demands in urban areas, tree canopies are crucial for enhancing social, economic, and environmental sustainability. Strategic placement of trees addresses urban challenges and offers critical ecosystem services, such as carbon sequestration. The effectiveness of trees in reducing CO₂ levels and mitigating climate change is influenced by canopy distribution, demographic shifts, and the interaction between tree growth and soil processes (Pallathadka *et al.*, 2023). Even small-scale tree planting initiatives can significantly improve air quality and promote human health. Therefore, urban forestry requires long-term strategies, careful site design, and continuous monitoring to optimize its role in fostering urban resilience and prosperity.

To maximize the benefits of urban forestry, it is essential to consider the needs of all communities, particularly the marginalized ones that are often overlooked in planning for sustainability programs. Effective urban forestry initiatives must overcome challenges such as limited funding, lack of technical knowledge, and political resistance. Tailoring these strategies to the specific environmental and social contexts of each area can enhance green spaces and contribute to a more inclusive and sustainable urban environment (Pallathadka *et al.*, 2023). Urban forestry also plays a vital role in mitigating the urban heat island effect by reducing surface temperatures and providing cooling shade, making cities more livable and resilient.

Urban forestry is now a well-established practice in many North American cities, such as Winnipeg, Toronto, Vancouver, Calgary, Washington, D.C., San Francisco, Honolulu, Chicago, Portland, Seattle, Phoenix, Tempe, and Denver. In these and several other cities, urban forestry is often deeply integrated into municipal landscape requirements, design reviews, policy documents, and zoning regulations. For instance, in Arizona, urban forests in major cities provide benefits far beyond aesthetics, particularly when analyzed at the micro level. These green spaces improve air quality, manage stormwater, conserve energy, and provide essential shade in Arizona's hot and dry climate. Research reveals that the financial, environmental, and social returns of urban tree planting far exceed the costs of planting and upkeep, promoting sustainability and enhancing public health. Tree planting is portrayed as a strategic investment that yields substantial returns, not only through direct financial gains for property owners and local governments but also by contributing to the broader economic vitality of communities (Dawyer *et al.*, 1992; Pataki *et al.*, 2021).

Urban environments in Missouri, like many cities worldwide, face tough growing conditions due to soil compaction, contamination, limited space, and air pollution. Trees thrive in deep, well-draining soils that retain sufficient moisture. Tree selection for urban environments should consider light needs, tolerance to urban heat stresses, and the specific characteristics of urban spaces. For example, planting trees with larger canopies on the south and west sides of buildings can reduce indoor cooling costs by up to 10%. Missouri's hot summers can slow tree growth and cause leaf browning, making careful tree placement and maintenance essential. Strategically placing trees to provide afternoon shade can help mitigate these challenges. Despite all these challenges, it has been proved that trees are vital for improving air quality, reducing heat, supporting biodiversity, and increasing infrastructure resilience in urban environments. Urban forestry in the cities in the state of Missouri (Figure 3a), especially, the Kansas City (Figure 3b) and the City of St. Louis (Figure 3c) integrates environmental stewardship, aesthetic enhancement, and practical urban planning. Urban planners, urban foresters and policymakers carefully select tree species and plant them in the right places to beautify cityscapes, add value to properties, and address local environmental challenges. Proper tree type selection and placement is crucial to avoid future problems related to poor site conditions, and the intended urban forest services. The importance of urban tree planting in Nepal has been long realized. No matter which part of the world is, community engagement in urban forestry is crucial for promoting economic growth, conserving cultural landscapes, and integrating sustainable practices into urban planning.

This chapter underscores the importance of trees in urban environments for enhancing air quality, reducing heat, supporting biodiversity, and increasing infrastructure resilience. It highlights the need for community engagement in urban forestry to promote economic growth, conserve cultural landscapes, and integrate sustainable practices into urban planning.

3. OBJECTIVE AND SCOPE

This chapter introduces urban forestry, especially for urban professionals, policy makers, and city residents. It provides examples of urban forestry practices in some selected locations in the US and Nepal and offers recommendations for urban forestry practice. Specifically, the paper discusses how urban forests can achieve the following objectives.

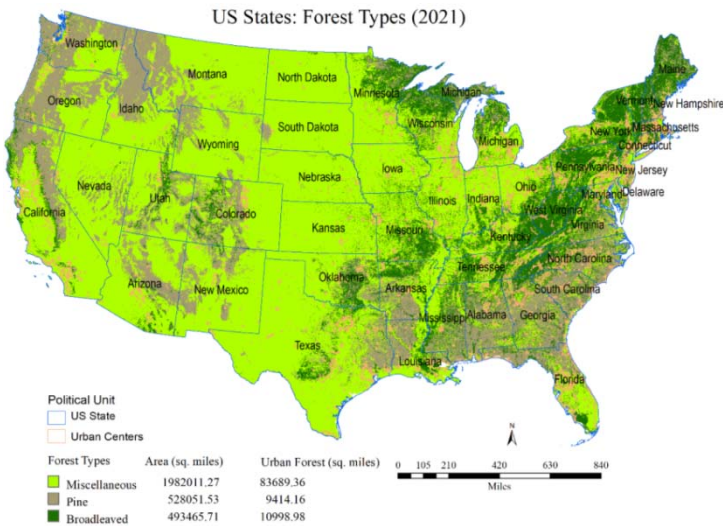
- Improve air quality, reduce urban heat island effects, enhance biodiversity, provide wildlife habitats, and promote public health and well-being by creating green spaces for recreation, reducing noise pollution, and encouraging physical activity for the residents.
- Strengthen infrastructure and resilience by helping manage stormwater, reducing flood risks, sequestering carbon, and providing shade.
- Foster community engagement and education by involving residents in tree planting and maintenance and by educating the public on the benefits and care of urban forestry.
- Support economic development by enhancing property values, attracting businesses, and creating jobs in urban forestry and related sectors.
- Conserve cultural and historical landscapes by protecting significant trees and integrating traditional knowledge into urban forestry practices.
- Promote sustainable urban development by integrating urban forestry into planning policies and prioritizing native and climate-resilient tree species.

4. METHODOLOGY

We utilized processed land use data from the Environmental System Research Institute (ESRI) in Redlands, California, for the U.S., and from the International Center for Integrated Mountain Development (ICIMOD) and ESRI based Sentinel-2 data for Nepal. Several vector datasets were generated by the authors using ArcGIS (ArcMap 10.8.2) and ArcGIS Pro 3.2, based on ESRI base maps. We also incorporated various socioeconomic and demographic information from multiple websites, as cited in the references. Our data for the U.S. is at a 250-meter \times 250-meter resolution (Figure 1 a-c), with the tree cover data extracted from the U.S. National Land Cover Database (USNLCD). For the state levels in Arizona, Missouri, and selected cities within those states, we used Sentinel-2 10 m Land Use/Land Cover Timeseries Downloader (arcgis.com). For Nepal and its major cities, we used both ICIMOD processed data and ESRI-based Sentinel data at a 10-meter \times 10-meter resolution, accessible through the Sentinel-2 10 m Land Use/Land Cover Timeseries Downloader (arcgis.com). We compared the classified data from ICIMOD (30-meter \times 30-meter resolution) with the classified Sentinel 10-meter \times 10-meter data available on the ESRI website. To improve accuracy, we merged ICIMOD's 30-meter \times 30-meter data with the classified Sentinel 10-meter \times 10-meter data to address instances where urban areas were not consistently visible in either dataset. By combining these datasets, we successfully delineated urban and vegetated areas in and around urban regions.

For the US, we first mapped the vegetation cover at macro-scale, and then focused on the states of Arizona and Missouri to provide representative samples of vegetation coverage at the state levels and their selected cities' levels. Since our focus was on the urban areas of the US, we excerpted land use data for major cities within the states from the classified 10-meter \times 10-meter sentinel data. For example, for the State of Arizona (Figure 2a), we excerpted land use data for the cities of Phoenix (Figure 2b) and Tucson (Figure 2c), and for Missouri (Figure 3a) we extracted land use data for the cities of Kansas City (Figure 3b) and St. Louis (Figure 3c) using urban shape file. And for Nepal (Figure 4a), we excerpted urban land use data resulted from the merging of 30-meter \times 30-meter ICIMOD classified data, and 10-meter \times 10-meter Sentinel-2 classified data. This was followed by the extraction of land use data for the cities located in the Kathmandu Valley (Figure 4a, d & e), and Pokhara Valley (4c). Likewise, we also extracted land use data for the metropolitan cities of Bharatpur (Figure 4f), Biratnagar (Figure 4g), and Birgunj (Figure 4h). Similarly, we also excerpted land use data for the cities of Nepalgunj (Figure 4i), Dharan (Figure 4j), and Hetauda (Figure 4k) as representative samples. We have covered the major populated urban and geographic areas in Nepal.

We looked at the change in urban level vegetation coverage for the US for the year of 2011 and 2021(Figure 1b & c) to see if there have been any changes in tree canopy cover in urban areas. We observed no significant changes on urban tree stand cover between 2011 and 2021. Thus, we decided to map the state level forest coverage for one time point to look at the urban greenery for the states of Arizona (Figure 2a-c) and Missouri (Figure 3a-c) in the US using the 10-meter \times 10-meter classified data from Sentinel-2 10 m Land Use/Land Cover Timeseries Downloader (Mature Support) (arcgis.com) and mapped the states and major cities' landcovers.



(a)

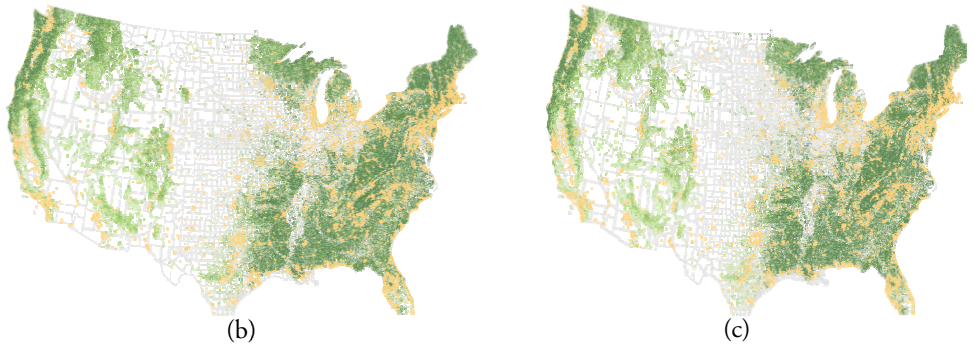
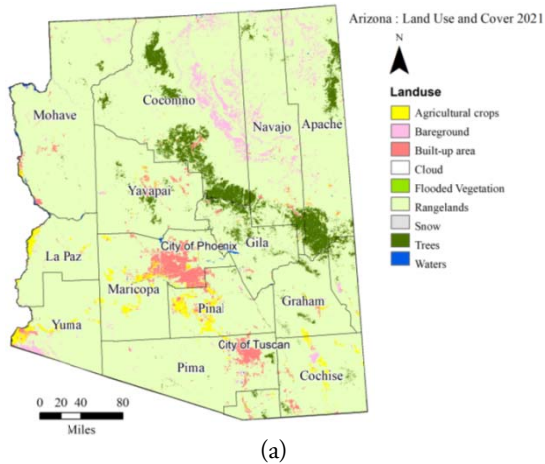
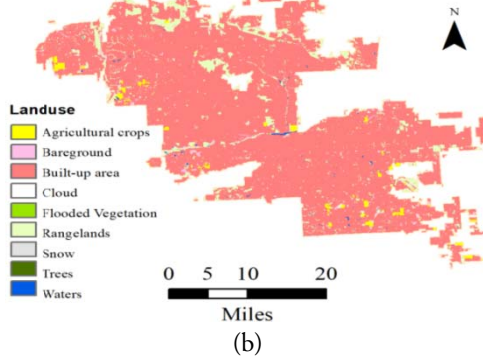


Figure 1: Forest Tree Cover. Yellow Represents Urban Areas, and Grayish Line Represents Boundaries of Various Counties: a). Forest Trees Cover in the US Grouped Under conifer, broadleaved, and Miscellaneous; b) individual tree cover in 2011; and c) individual cover in 2021.



City of Phoenix : Land Use and Cover 2021





(c)



(d)

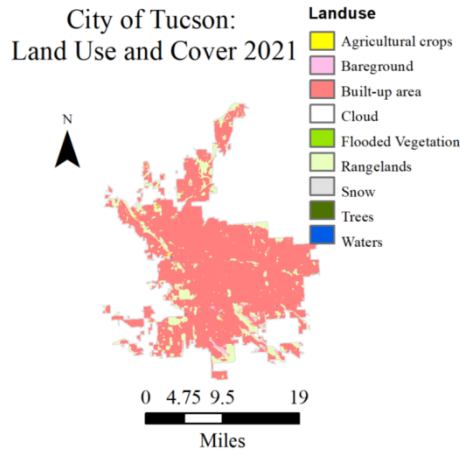
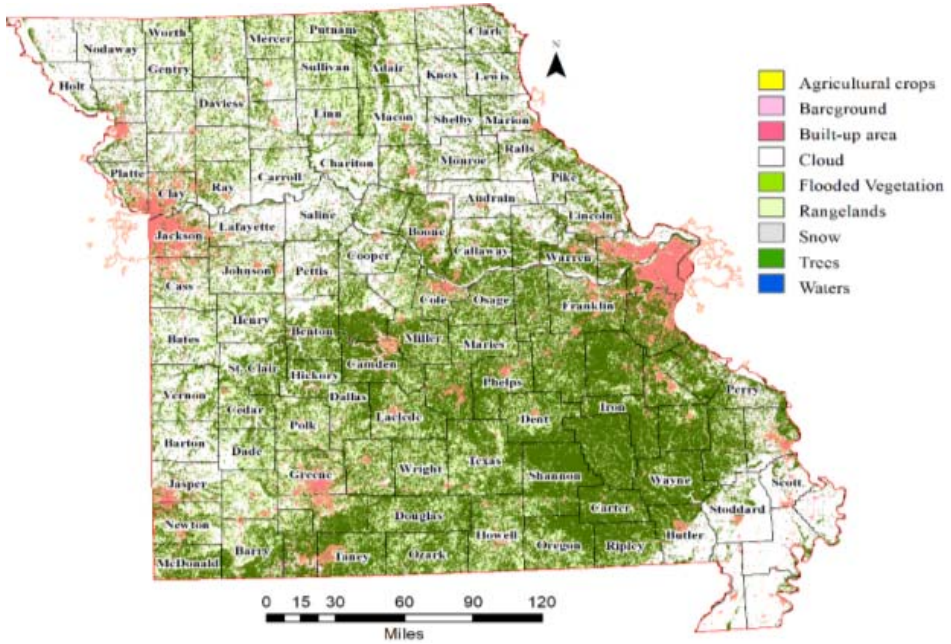
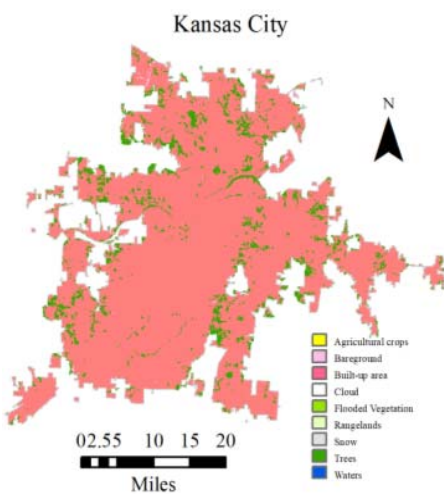


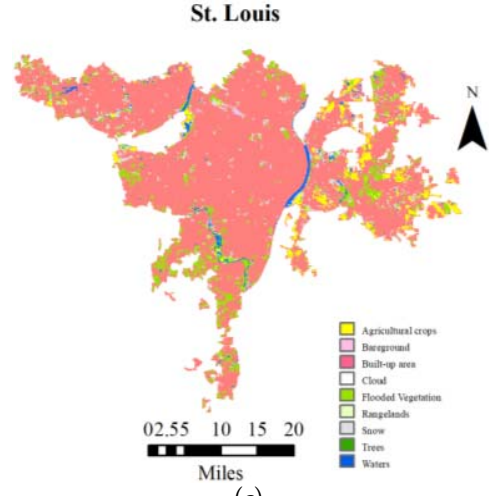
Figure 2: Urban forestry in the State of Arizona: a) Land cover in the State of Arizona; b) Land use in the City of Phoenix, c) Sidewalk trees in downtown Tempe. Photo by Ambika P. Adhikari, d) trees in residential area on sidewalks and front yards, Metro Phoenix (Gilbert), AZ, USA. Photo by Ambika P. Adhikari. and e) Land use in City of Tucson.



(a)



(b)



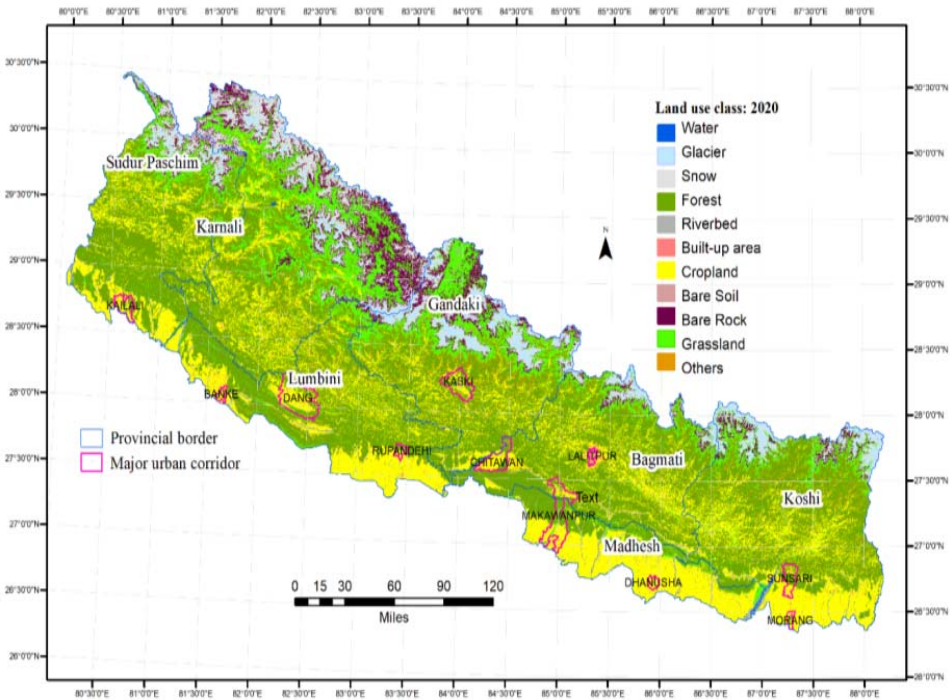
(c)

Figure 3: Urban Forestry in the State of Missouri: a) Land Cover in the State of Missouri; b) Land use in the City of Kansas City, c) City of St. Louis

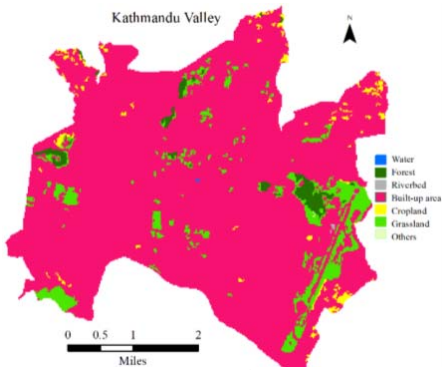
In addition to the examples of urban forestry in the United States, we also looked into the urban forestry situations- in Nepal's major metropolitan cities (Figure 4). To make the review consistent, we used Landsat data of 30-meter \times 30-meter for the entire state of Nepal (Figure 4a). We merged 30-meter \times 30-meter resolution data

with Sentinel-2 10-meter \times 10-meter data and excerpted land use information for the Kathmandu Valley (Figure 4b-d), Pokhara Valley (Figure 4e), different cities of Nepal (Figs. 4f-k). Though we have land use data for Nepal from the years 2000 to 2020, to be consistent in data uses for the U. S. and Nepal, we used data for a single time point. For example, for the US, it is for 2021 and for Nepal it is for 2020. For Nepal, we used data for a single time point without comparing between 2011 and 2021 like in the US, because of two reasons: a) Nepal wide-scale urban expansion only occurred after 2017 after the promulgation of Nepal’s new constitution for the Federal State of Nepal; and b) urban tree plantation as a campaign did not start in Nepal from environmental concern like in the US, but tree plantation in Nepal has been a factor of land availability and cultural preferences. Generally, if land is less expensive and affordable, then only tree plantation is done on such lands.

We chose only 2020 year as a representative sample to review forestry cover in Nepal because for this year, data was accessible from ICIMOD and ESRI. We excerpted the land use and cover for only a few selected urban regions, for example, the Kathmandu Valley (Figure 4 b-d) and the Pokhara Valley (Figure 4e). Then we also compared tree cover in cities located in different ecological regions (Figure 4 f-k).



(a)



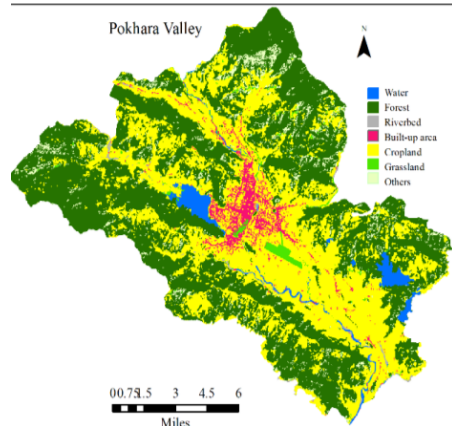
(b)



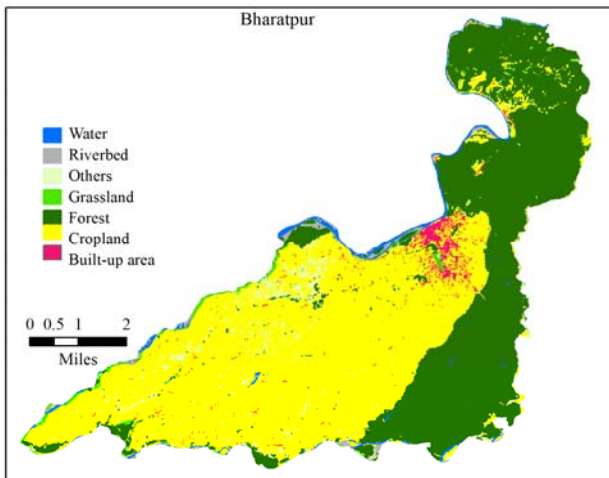
(c)



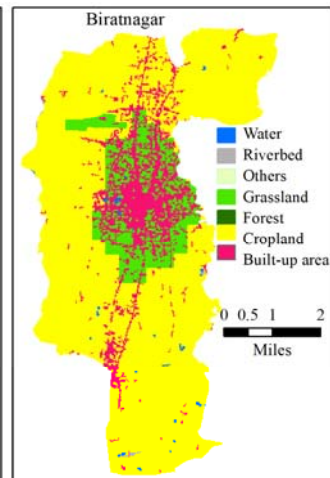
(d)



(e)



(f)



(g)

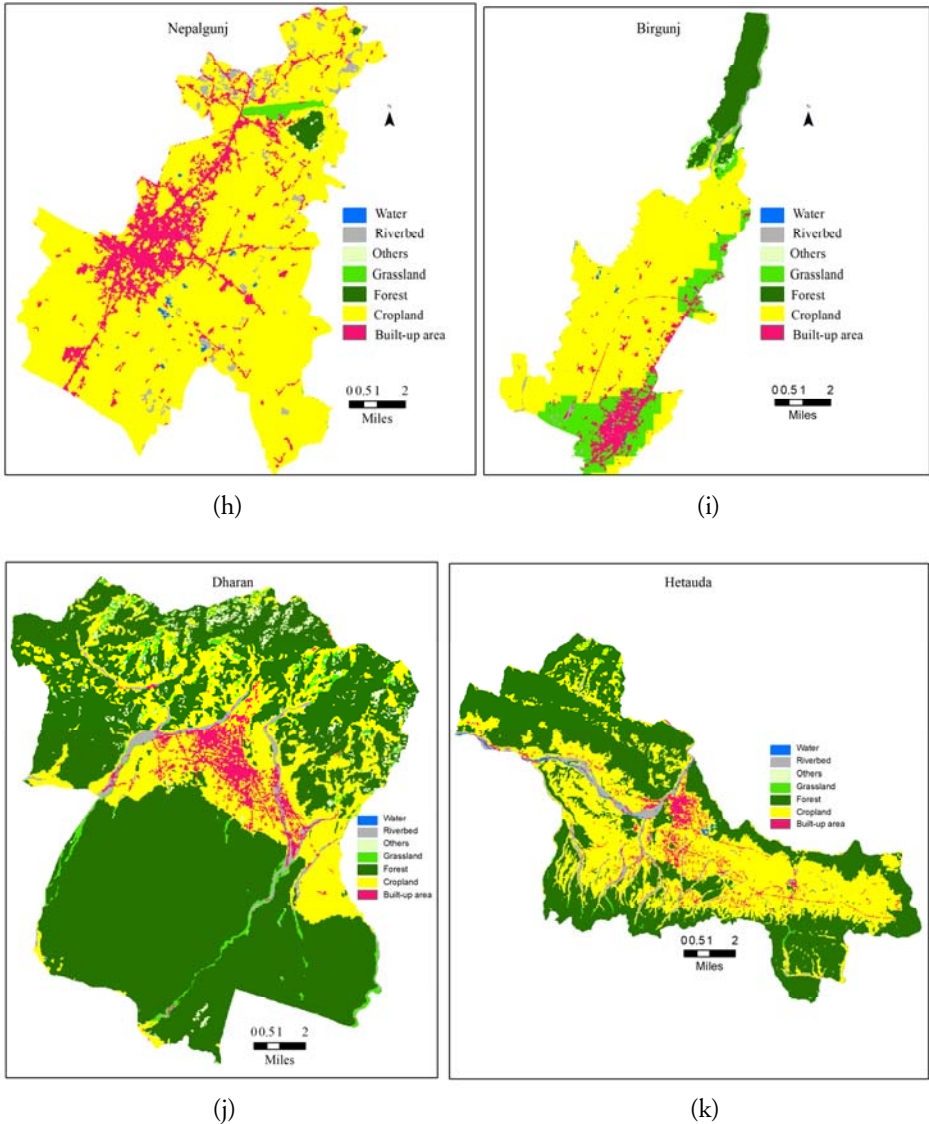


Figure 4: Urban Forestry in the Nepal: a) Land cover in the Federal Republic of Nepal; b) Land use in the Kathmandu Valley, c & d) Trees in urban streets in Kathmandu. Photo by Krishna P. Acharya, e) Land use in Pokhara Valley, f) Land use in Bharatpur, g) Land use in Biratnagar, h) Land use in Nepalgunj, i) Land use in Birgunj, j) Land use in Dharan, and k) Land use in Hetauda.

4.1 Selecting Appropriate Trees for Urban Areas

Selecting tree species that can endure specific urban conditions is essential for the success of urban forestry programs. In the State of Missouri, notable species that

perform well in cities include baldcypress (*Taxodium distichum*), river birch (*Betula nigra*), black gum (*Nyssa sylvatica*), Kentucky coffee tree (*Gymnocladus dioica*), and American elm (*Ulmus americana*). These trees can grow in limited root space and amidst high levels of pollution. For street planting, species like American beech (*Fagus grandifolia*), thornless honey locust (*Gleditsia triacanthos*), little leaf linden (*Tilia cordata*), and Northern red oak (*Quercus rubra*) are suitable as they also offer practical benefits like shading streets and cooling buildings, thereby significantly lowering energy costs. Although visually stunning, Japanese flowering cherries (*Prunus serrulate*) have a shorter lifespan due to vulnerability to pests and diseases, and the tree health generally declines after 20 years. Despite these challenges, their varied shapes and colorful blossoms make them popular for enhancing urban aesthetics and property values (Ma *et al.*, 2020; Sjoman *et al.*; 2018; Davey Resource Group, Inc., 2018; USDA, 2013; Missouri Department of Conservation, 2009).

Ironwood, or hophornbeam (*Carpinus betulus*), is an exemplary species for selected locations of urban areas in Missouri and Kansas. It is strong, tolerant of dry and rocky soils, and has attractive papery fruits. However, choosing a good location for Ironwood trees to avoid near human activity areas is important. These trees have sharp thorns, they grow slowly, and the branches spread horizontally as multi-trunks impacting close human encounters. Hophornbeam enhances both private gardens and public spaces as it matures from a stately pyramidal shape to a gracefully rounded form. Similarly, the 'Ivory Silk' lilac tree (*Chionanthus retusus*), with its large, fragrant white flowers, thrives in full sun and requires regular watering during droughts, making it a good accent tree in urban landscapes. Magnolia trees (*Magnolia grandiflora*), particularly the saucer and sweet bay varieties, thrive in deep, acidic soils with good moisture retention and have few pest problems, making them relatively low maintenance trees while providing year-round beauty with their striking flowers and foliage (Davey Resource Group, Inc., 2018; USDA, 2013; Missouri Department of Conservation, 2009).

To create a resilient and thriving urban forest, a wide variety of species should be considered, including European alder (*Alnus glutinosa*), green ash (*Fraxinus pennsylvanica* Marsh), white ash (*Fraxinus americana*), American and European beech (*Fagus sylvatica*), flowering crabapple, dogwood, ginkgo, and various oak species like bur, saw tooth, and swamp white oak. The biodiversity of plantings ensures that urban forests can withstand various environmental challenges and diseases while providing essential environmental services like air purification, carbon sequestration, and mitigation of the urban heat island effect. In certain areas, it is important to also plant some tree varieties that grow very tall. Aleppo Pine (*Pinus halepensis*), Indian Rosewood (*Dalbergia* spp.), and certain species of eucalyptus can fit these specifications. Such tall trees are important to provide habitat for birds of prey, and for maintaining a healthy bird and wild animal ecosystems in urban areas (Davey Resource Group, Inc., 2018; USDA, 2013; Missouri Department of Conservation, 2009).

Urban forestry is still at a primitive stage in Nepal, and there is a growing recognition of its importance for enhancing aesthetic quality, ecological maintenance, and environmental services in urban areas. However, the challenges of urbanization, including competition for space and poor soil quality, necessitate tailored approaches, such as Urban Community Forestry (UCF), to effectively manage trees in densely populated environments. Despite some initiatives and research, urban forestry in Nepal has yet to gain significant attention from policymakers and requires further focus and development to meet future urban challenges (Lamichhane and Thapa, 2012).

Overall, urban forestry requires careful selection and placement of tree species to address the unique challenges of urban environments. By choosing trees suited to local conditions and ensuring they receive the necessary care and space, urban foresters can create green spaces that enhance the quality of life, environmental health, and aesthetic appeal of these urban areas. Properly selected and placed trees not only enhance property values and appearances but also prevent future problems related to poor site and species choices. It is important to avoid trees that are invasive, and those that demand high water use in areas that experience low rainfall.

5. COMPARATIVE URBAN FORESTRY PRACTICE IN NORTH AMERICA AND NEPAL

As a part of its effort to enhance greenery, mitigate extreme heat, and increase shade across the city, it adopted its first Urban Forestry Master Plan in 2017 (City of Tempe, 2017) (Table 1). The main objectives of the plan are to support a collaborative creation of an urban forest that provides a 25 percent tree canopy by 2040 (Table 1). Further, the plan seeks to enhance walkability and bikeability by distributing shade trees across the city, specifically in the areas where they are scarce. In addition, it intends to create an urban forest that is healthy and biodiverse, and that increases tree canopy on public properties.

Table 1: Urban Forestry data in City of Tempe, AZ, USA

<i>Parameter</i>	<i>Value</i>
Population in 2022	186,000
Municipal planning area	40 sq. mi. (64 sq. km)
Total number of city-managed trees in 2017	19,450
Top five tree species	Palo Verde (<i>Parkinsonia microphylla</i>), White Carob (<i>Algarrobo blanco</i>), Desert Willow (<i>Chilopsis linearis</i>), Chinese Elm (<i>Ulmus parvifolia</i>), Indian Rosewood (<i>Dalbergia sissoo</i>)
Urban tree canopy coverage in 2017	13.4%
Total monetary value of urban trees for the residents	US\$ 1.4 m

<i>Parameter</i>	<i>Value</i>
Target tree canopy coverage by 2040	25%
Value of each city-managed tree for benefits in energy, stormwater, pollution, and aesthetic improvements	US\$72/yr.

Source: Adapted from City of Tempe, Urban Forestry Master Plan, 2017.

The City of Phoenix created its Trees and Shade Master Plan in 2010 (City of Phoenix, 2010) with the goals of raising public awareness about urban forestry, increase urban forests, and enhance the sustainability of the city’s infrastructure including reduction of urban heat islands.

Table 2 highlights some of the parameters related to urban Forestry in Phoenix, AZ, USA.

Table 2: Urban Forestry in Phoenix, AZ, USA with Some Important Parameters

<i>Parameter</i>	<i>Value</i>
Population in 2022	1.644 m
Municipal area (2022)	520 sq. mi. (833 sq. km)
Tree canopy coverage (2010)	11–13%
Target tree canopy coverage by 2030	25%
Per-capita/yr. expense—tree planting (2010)	\$3.48
Master Plan goals	Raise awareness; preserve, protect, increase; sustainable maintenance

Source: Adapted from City of Phoenix, Trees and Shade Master Plan, 2010.

Nepal’s National Law (Muluki Ain, 1963) prohibited cutting down trees, including in urban areas. Historically during the reigns of Jayasthiti Malla (1382–1395) and Ram Shah (1606–1633), cutting trees was punishable by imprisonment. Nepal’s recent constitution (2015) guarantees the right for all citizens to enjoy clean environment. Forestry law (2014) includes provisions for promoting urban forestry. The Local Government Act (2017) requires the promotion and expansion of urban forestry.

Many cities in Nepal practice urban forestry. For example, the metropolitan city of Kathmandu has planted and maintained large trees along major arterial roads such as Kanti Path, Darbar Marg and around Tundikhel (Figure 4 c&d). The urban image of Hetauda often includes the rows of poplar trees planted along both sides of the main road. Tree-filled streets images are often used to promote the city as a good place to live and establish business.

6. APPROACHES IN MEETING THE STATED OBJECTIVES

The chapter outlines six main objectives. The following paragraphs provide details how these objectives will be met.

Objective 1: *Improve air quality, reduce urban heat island effects, enhance biodiversity, provide wildlife habitats, and promote public health and well-being by providing green spaces for recreation, reducing noise pollution, and encouraging physical activity.*

Urban forestry is a highly effective strategy for mitigating urban heat islands due to the trees' cooling mechanisms through shading and evapotranspiration, which can lower ambient temperatures compared to nearby areas with no tree coverage. Strategic placement of trees, especially around buildings and pavements, maximizes their cooling benefits. Beyond temperature reduction, trees also contribute to energy savings, improved air quality, enhanced stormwater management, extended pavement longevity, and overall quality of life. Despite the costs of planting and maintenance, the economic and environmental benefits of trees significantly outweigh the expenses, making urban forestry a cost-effective and multifaceted solution for urban heat mitigation.

Objective 2: *Strengthen infrastructure and resilience by managing stormwater, reducing flood risks, sequestering carbon, and providing shade.*

Urban forests, which include trees on both public and private land, contribute to stormwater management by intercepting rainfall, enhancing infiltration, and promoting deeper percolation through root systems. These processes help regulate runoff volumes, mitigate flooding, and manage soil moisture over time, highlighting the importance of strengthening urban infrastructure with green elements like trees to enhance resilience against stormwater challenges (Berland *et al.*, 2017). Cities play a major role in contributing to, and exacerbating the effects of, global warming as they replace natural surfaces with heat-absorbing materials, that consume large amounts of energy, and produce greenhouse gas emissions. As urban areas grow and populations rise, changes in urban morphology—including layout, structure, and form—create significant challenges for the urban thermal environment, worsening heat-related health problems. Understanding how urban morphology influences local heat generation and dissipation is essential for optimizing urban design, and reducing negative impacts of urbanization on urban ecosystems. Advances in remote sensing provide new opportunities to study these interactions and develop effective strategies for mitigating the increasing urban temperatures. This chapter suggests interdisciplinary studies to deepen our understanding of urban morphology and to guide improvements in urban heat environments. Some tools for such studies include spatiotemporal observations, climate zone mapping, land surface temperature observations, urban heat island modeling, and reviewing the impacts of urbanization on heat environments.

Objective 3: *Foster community engagement and education by involving residents in tree planting and maintenance and by educating the public on the benefits and care of urban forestry.*

Engaging residents in tree planting and maintenance while educating them on the benefits and care of urban forestry enhances community well-being, promotes environmental stewardship, and improves urban ecosystems. Public education and participation play a pivotal role in the success of urban forestry initiatives and the greening of urban areas. Educating the public about the benefits of urban green infrastructure, such as urban tree planting initiatives, is essential for fostering community involvement and support. Awareness programs can highlight how trees mitigate the adverse environmental impacts of urbanization, enhance human well-being, and improve community livability and quality of life (Benedict & McMahon, 2006; McAndrews & Marshall, 2018). By understanding the multifunctional benefits of urban trees, including shading, and stormwater interception, and their role in human stress reduction, and encouraging physical activity (Escobedo *et al.*, 2019; McPherson *et al.*, 1997; Seamans, 2013; Doroski *et al.*, 2020; Eisenman *et al.*, 2021; Nguyen *et al.*, 2017; Young, 2011; Young & McPherson, 2013), residents are more likely to participate in and support tree planting initiatives. This participation is crucial, as expenditures on street trees are a significant part of municipal tree management budgets in the U.S. (Hauer & Petersen, 2016). Ultimately, public education and participation empowers residents to actively contribute to creating healthy, vibrant, and sustainable urban environments, ensuring the long-term success of urban forestry efforts (Beatley, 2012; Wheeler & Beatley, 2014).

Objective 4: *Support economic development by enhancing property values, attracting businesses, and creating jobs in urban forestry and related sectors.*

Investing in urban forestry enhances property values, attracts businesses, and creates jobs, thereby supporting economic development. This sector not only beautifies cities but also stimulates local economies and fosters urban sustainability.

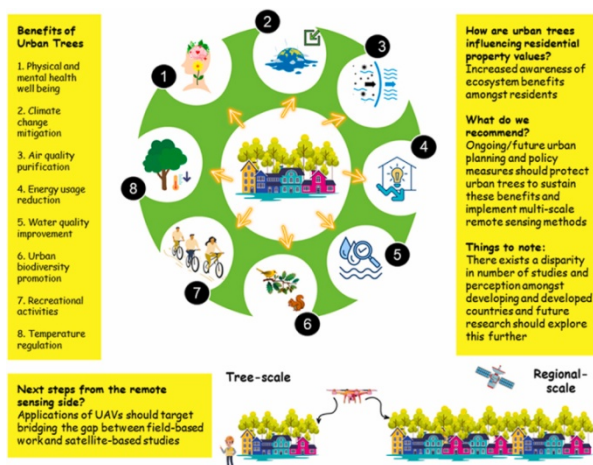


Figure 5: Role of Urban Forestry in Property Valuation

Source: Adapted from Ewane et al. (2023).

Note: UAV means Unmanned Aerial Vehicles, sometimes known as drones.

Urban forestry encompasses a range of green spaces within urban areas, including peri-urban forests, city parks, pocket parks, street trees, and other tree-covered areas like riverbanks and vacant lands. These urban forests offer significant benefits such as pollution control, water quality regulation, carbon sequestration, noise reduction, and recreation, which enhance human well-being and contribute to multiple sustainability-related goals. Studies indicate that urban forests positively impact residential property values through these ecosystem services (Ewane *et al.*, 2023). Factors such as forest conditions, proximity to green spaces, and neighborhood attributes also influence this relationship. In developing countries, the effect of trees on property values seems to be more pronounced for homeowners than renters. However, poorly managed urban forests can become a nuisance to neighborhoods. Effective urban planning and policy reforms are essential to leverage the benefits of urban forests while avoiding issues like gentrification and displacement of low-income residents. Advanced methods like remote sensing and GIS complement field surveys to better understand and quantify the economic value of urban forests on property values (Ewane *et al.*, 2023).

Objective 5: *Conserve cultural and historical landscapes by protecting significant trees and integrating traditional knowledge into urban forestry practices.*

Urban forestry helps in conserving cultural and historical landscapes through the protection of significant trees and biodiversity and integration of traditional knowledge in urban forestry practices. Traditional ecological knowledge, rooted in millennia of observation by indigenous peoples, offers profound insights into ecosystem dynamics, contrasting with Western scientific ecological knowledge. While traditional knowledge encompasses cultural practices and beliefs, its terminology has faced criticism for potentially implying a static knowledge system. Despite these debates, more current scientific knowledge has gained recognition in scientific literature since the late 1980s, demonstrating its value in ecological management and conservation efforts. Integrating new knowledge into federal land management has been found to be crucial for protecting ecocultural resources and supporting indigenous communities, and ensuring sustainable practices amidst global environmental challenges (Souther *et al.*; 2023).

Objective 6: *Promote sustainable urban development by integrating urban forestry into planning policies and prioritizing native and climate-resilient tree species.*

To achieve sustainable urban development, it is crucial to integrate urban forestry into planning policies and prioritize the planting of native, locally adapted, biodiverse, and climate-resilient tree species. In doing so, urban forestry can play a critical role in cities to sustain ecological services, promote biodiversity conservation, and contribute to human well-being. Urban forests are depicted as crucial for sustainable urban development, providing benefits like stormwater management, climate regulation, cultural ecosystem services, and enhancement of urban dwellers' quality of life. However, planners should also note the challenges urban forests face about the need for effective management so that the forests can maintain their ecosystem and socioeconomic functions (Aleha *et al.*, 2024).

7. BENEFITS AND CHALLENGES RELATED TO URBAN FORESTRY IN UNITED STATES

7.1 Benefits of Urban Forestry

Urban forestry provides benefits to the local urban environment, its economy, and aesthetics character. As we have seen, the major impacts of urban forestry are to improve air quality, reduce ambient noise levels, regulate ambient temperature, enhance pedestrian environment, improve storm drainage, support traffic and visibility situations, and enhance the urban aesthetics, which can improve real estate value.

As an example, the City of Phoenix Shade and Tree Master Plan (2010) includes the following as environmental and ecological benefits from urban forest. Urban forestry improves public health, provides dust and noise control, provides shade, temperature moderation, improved storm drainage condition, protects land, enhances urban aesthetics, provides ecological services, and provides therapeutic environment. Further, urban forest acts as cultural asset, improves quality of urban life, provides research and education opportunities, and creates and maintains urban and neighborhood identity. Trees help reduce greenhouse gases combating climate change and improving air and water quality. The reduce urban heat island effects that are often caused by paving areas in the cities, reduce urban energy consumption, and provide for wildlife habitat.

The economic benefits of urban forest include an increase in property values supporting economic stability. Trees enhance the business appeal of the local areas, and extend the life of pavements and other infrastructure by protecting them from continuous sun and weather exposure. Trees in urban areas help in various equity related goals such as improving human health, and creating walkable streets for all.

It can be seen that urban forest plays a vital role in addressing pressing global challenges such as climate change and biodiversity loss. By strategically managing and expanding urban tree canopy cover, cities can help mitigate the urban heat island effect in the area, reduce energy consumption, improve air and water quality, and enhance the resilience of communities to deal with extreme weather events. Figure 6 shows some of the benefits of inner, nearby, and faraway forest from the city.



Figure 6: Forest's Benefits for the Cities

Source: Cities4Forests (No date), <https://publications.wri.org/better-forests-better-cities/executive-summary#better-forests-make-for-better-cities> (Accessed on 04/01/2024)

7.2 Challenges Related to Urban Forestry

Urban forestry also can create challenges related to planning, engineering, maintenance, diseases, and traffic-related issues. These challenges include conflict with underground and above ground infrastructure, irrigation for trees, regular cleaning the fallen leaves, debris, and maintenance of urban landscape. In addition, trees can obstruct the visibility triangles needed for safe vehicular turning, and the visibility of commercial and institutional signage from strategic points and to the drivers. Problems can also occur when certain species of trees catch disease, and if wrong tree species including invasive species of trees are planted. Similarly, clearing dead trees and plants, and landscape trash costs money and needs to be properly planned. Figure 7 shows how different size of trees are recommended for different locations in an urban setting.

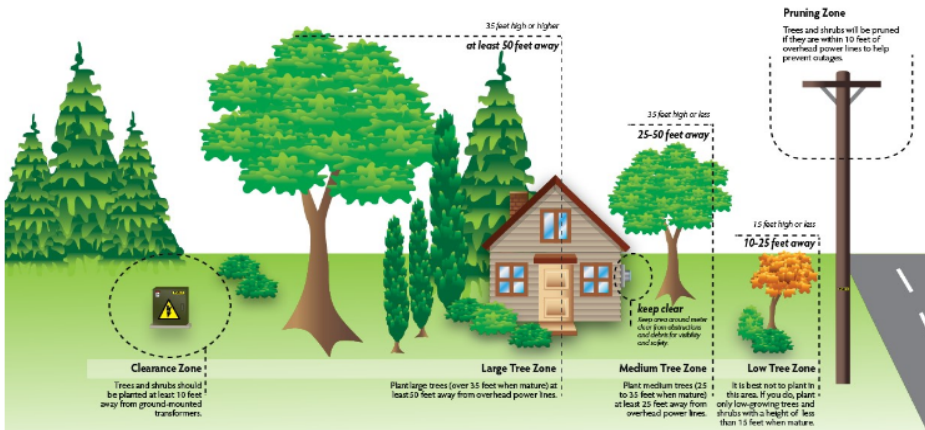


Figure 7: Recommended Size of Trees According to Locations in an Urban Context

Source: Trees and Utilities, North Carolina Urban Forest Council website (accessed on 04/01/2024).

8. ANALYSIS OF URBAN FORESTRY PRACTICE IN NEPAL

The Federal Republic of Nepal is divided into seven provinces, namely 1. Koshi, 2. Madhesh, 3. Bagmati, 4. Gandaki, 5. Lumbini, 6. Karnali, and 7. Sudur Paschim (Figure 8). These provinces are divided into different local political units such as Rural Municipalities, Municipalities, Sub-metropolitan (Upa-mahanagarpalika) City, and Metropolitan (Mahanagarpalika) Cities. They are spatially distributed in different geographic regions (Figure 8). Altogether, there are 753 such local governance units in the country.

The focus of this chapter is on the land use of Nagarpalika, Upa-mahanagarpalika, and Mahanagarpalika to highlight how much tree cover exists in each local political unit. Table 3 presents the land use in hectare for the year 2020. Each of the three level political units namely Nagarpalika, Upa-mahanagarpalika, and Mahanagarpalika has some level of tree cover (Table 3).

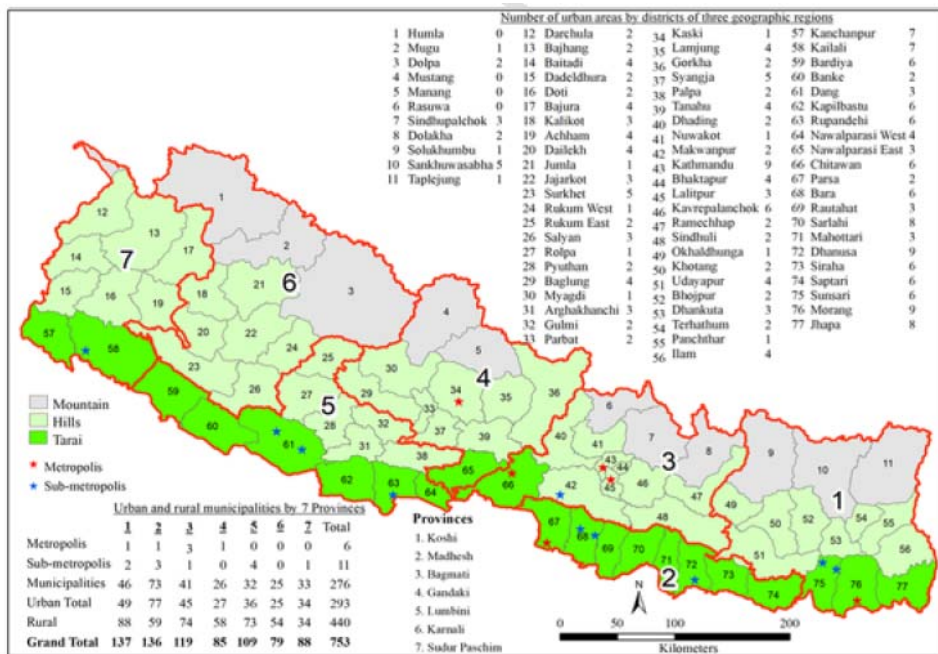


Figure 8: Spatial Distribution of Different Political Units in Nepal by Three Geographic Regions by 77 Administrative Districts in Seven Provinces of Nepal. Adapted from Bhattarai *et al.* (2023).

Table 3: Land Use Distribution in Seven Provinces of Nepal by Nagarpalika, Upa-Mahanagarpalika, and Mahanagarpalika in 2020

Political Unit	Land Use Class	Area in Hectare (Ha) in various provinces within the territory of urban declared areas, within the territory Nagarpalika, Up Nagarpalika (Sub-metropolitan areas), and Maba-Nagarpalika (Metropolitan areas) in 2020						
		Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	SudurPaschim
Urban classified area	Forest	446468	216009	300784	258414	349726	281664	338238
	Shrubland	147864	36420	91588	78920	55847	275535	18083
	Cropland	158909	333701	59315	30890	193709	1502	101159
	Built-up	66064	65115	90849	30145	56855	11053	29641
	Water	7409	7809	4117	5060	4046	5057	5242
	Total	826714	659054	546653	403429	660183	574811	492363
Nagarpalika	Forest	431362	194929	269538	234296	300630	281663	328678
	Shrubland	145553	35572	89020	71954	48612	275534	17953
	Cropland	151071	302063	39502	28899	154204	1501	90498
	Built-up	55517	55015	68148	19097	43239	11053	24921
	Water	7253	7544	2738	3727	4054	5057	4758
	Total	790756	595123	468946	357973	550739	574808	466808

Political Unit	Land Use Class	Area in Hectare (Ha) in various provinces within the territory of urban declared areas, within the territory Nagarpalika, Up Nagarpalika (Sub-metropolitan areas), and Maha-Nagarpalika (Metropolitan areas) in 2020						
		Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	SudurPaschim
Sub-metropolitan Urban classified area	Forest	15095	19438	14464	0	49096	0	9561
	Shrubland	2292	749	1541	0	7235	0	545
	Cropland	4017	23700	4496	0	39497	0	10661
	Built-up	6850	6695	5203	0	13614	0	4720
	Water	137	239	258	0	293	0	484
	Total	28391	50821	25962	0	109735	0	25971
Metropolitan	Forest	12	1642	16783	24118	0	0	0
	Shrubland	198	100	1025	6966	0	0	0
	Cropland	3827	7938	15317	1991	0	0	0
	Built-up	3697	3406	17498	11048	0	0	0
	Water	20	27	1122	1334	0	0	0
	Total	7754	13113	51745	45457	0	0	0

Source: Analysis of remotely sensed image (Sentinel 10 × 10 square meters) 2020; Bhattarai & Conway (2021).

Information and data related to urban forestry in all the cities of Nepal is hard to find. Most studies in this topic have centered on the towns of the Kathmandu Valley. Based on various sources, the common and scientific names of major urban trees found in the cities of the Kathmandu valley are listed on the Table 4.

Table 4: General Recommended Species for Urban Plantation in Nepal

Common Name	Scientific Name
Lemon-scented Gum	Eucalyptus or Corymbia citriodora
Jacaranda	Jacaranda mimosifolia
Fir	Pinus picea
Oleander	Nerium oleander
Bar	Ficus benghalensis
Bamboo	Bambusa vulgaris
Orchid tree	Bauhinia variegata
Poplar	Populus ciliata
Pipal	Ficus religiosa
Bottle Brush	Melaleuca viminalis
Willow	Salix babylonica
Raj Sallo	Cupressus torulosa
Kaiyo ful	Grevillea robusta
Monkey puzzle	Araucaria araucana

9. CONCLUSIONS

Urban forest can be highly effective for providing several ecological and economic services to cities. For example, forests can mitigate urban heat islands due to their cooling mechanisms of shading and evapotranspiration, which can lower urban temperatures by an average of 2.9°F compared to nearby areas with no tree coverage. Strategic placement of trees, especially around buildings and pavements, maximizes their cooling benefits. Beyond temperature reduction, trees also contribute to energy savings, improved air quality, enhanced stormwater management, extended pavement longevity, and overall quality of life. Although there is costs of planting and maintenance for urban forestry, and that urban forests can also sometimes conflict with the urban infrastructure, the economic and environmental benefits significantly outweigh the costs, making urban forestry a cost-effective and efficient solution for urban heat mitigation and other environmental services.

Future research should focus on refining methodologies to assess the comprehensive benefits of urban trees, their long-term impacts on climate adaptation, socio-economic dynamics, and ecosystem resilience, and the scalability of these initiatives across various urban contexts for effective policy and management strategies.

10. RECOMMENDATIONS FOR NEPAL

Although a few studies have been done to survey and assess the urban forestry situation in the Nepali cities, regular monitoring of urban vegetation changes will help improve urban forestry situation in Nepal. Towards a better urban forestry practice in Nepal, planners and urban foresters should create a comprehensive inventory of urban trees in different ecological regions of Nepal, and create a data base of what kind of trees are best suited for what areas of the city. For example, the trees recommended for the road medians are better as having a single trunk, and having the canopy at a sufficient height so as not to obstruct the visual fields for drivers. Similarly, the more suitable trees on sidewalks are those that have no thorns, have a good shade canopy at a medium height, can reduce noise, control dust, and can thrive when the area around the tree trunk is paved. Similarly, suitable trees for public parks should be chosen for their canopy, aesthetics appeal and flowering ability. Trees in the front yards of homes should not fully obstruct the views, and should have a variety of flowers, while remaining relatively moderate or small in size when they attain full growth. Trees for the yards in public and commercial buildings are selected for their beauty, shade capacity, relatively larger scale size, non-obstruction for signage, and for their ability to attain maturity in a short time. In all cases, maintenance of biodiversity and appropriateness for water consumption by tree are essential.

A study of the best practice of urban forestry in selected US cities can provide an excellent reference for improving urban forestry practice in Nepal.

Based on the authors' experience in urban planning and urban landscape studies, and based on the best practice example of urban forestry in selected US cities, the authors are providing recommendations related to what kind of urban trees are appropriate in different urban situations and locations (Table 5).

Table 5: Author's Recommendation Matrixes for Selecting Types of Trees for Different Functions and Locations in an Urban Area

<i>Location in the Urban Context</i>	<i>Recommended Shape, Characteristics, and Physical Features of Trees</i>	<i>Examples of the Major Function of the Tree</i>
Sidewalk of local and collector streets	Good shade canopy, single trunk structure	Shade, aesthetics, environmental services
Sidewalks of arterial streets, urban highways, ring roads	Large and tall trees with sturdy branches	To provide habitat for birds of prey, easy maintenance, sturdy branches
Median on the right of way	Single trunk medium height trees	Provide aesthetics, allow visual fields, and mitigate heat gain
Public parks	Large, medium and small trees with flowers, and dense canopy capacity	Varieties of trees for biodiversity, shade, flowers, therapeutic value
Water retention areas	Trees that do well in wetlands, large and tall trees, edible fruit bearing trees	Erosion control, provide aesthetics, storm water control
Front yard of public, commercial, office, and institutional buildings	Trees selected for aesthetics, shape, large to medium size, with seasonal flowers	Aesthetics, shade, education, monumental scale
Interior of public, commercial, office, and institutional buildings	Smaller patio trees that can flourish under shade, edible fruit trees, small and medium size trees with thick canopy that flower	Fruits, shade, aesthetics
Front yard of residential multi-family high rise and mid-rise buildings	Medium size slimmer trees that bear edible fruits, and flower in different colors	Aesthetics, environmental services, sound and dust control
Front yard of single-family residential buildings	Small size trees for edible fruits, and seasonal flowering	Aesthetics improvement, sound and dust control
Backyard of single-family buildings	Fruit bearing small and medium size trees	Support agriculture and rainwater absorption, sound and noise control
Interior common spaces in multi-family buildings	Fruit bearing small and medium size trees	Support urban agriculture, improve aesthetics, provide shade
Surface parking areas	Single trunk trees that are more vertical, having good shade canopy at the top, that flower in seasons	Shade, reduction of heat island effect, minimal conflict with parked vehicles

All Nepali cities should gradually create and adopt urban forestry master plans that can be updated regularly. As cities can vary significantly in their needs based on where they are located, local governments can create distinct templates for urban forestry master plans for cities in the mountains, hills, and Tarai regions. The plans should create a list of recommended, and prohibited trees for urban areas in different ecological regions. They should also assess urban forestry practices, and lessons learned in the SAARC countries, and elsewhere. The plan should include creating, and hiring a full or part time urban forester position for major cities. Sometimes, urban planners can also look after the task of urban forestry if they have appropriate training, education, and interest. Importantly, cities should incorporate urban forestry requirements in local zoning ordinances and regulations. Further, municipalities should train and educate planners, architects, and engineers in urban forestry. Cities should mandate landscaping plans for all building permit and master plan applications, create maintenance plan for urban trees, and develop planting standards to be compatible with the underground and overground infrastructure. Additionally, they should promote nurseries in and around urban areas, and breed the best composite trees for urban locations in different ecological regions.

Provincial and local governments should coordinate with national, and provincial forestry departments to support urban forestry initiatives. They should also collaborate with relevant institutions and organizations, e.g., universities and non-profits to advance urban forestry agenda.

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APPENDIX I

Recommended and Not-recommended Tree Species for the Cities in the Mountain Region of Nepal

Recommended and not recommended tree species for Nepali cities in the mountain region.

<i>Recommended Trees</i>	<i>Not Recommended Trees</i>
Ashoka (<i>Saraca asoca</i>)	Birch (<i>Betula alnoides</i>)
Amala (<i>Phyllanthus emblica</i>)	Silk tree mimosa (<i>Albizia julibrissin</i>)
Jacaranda (<i>Jacaranda mimosifolia</i>)	Swami (<i>Ficus benjamina</i>)
Willow (<i>Salix babylonica</i>)	Bar (<i>Ficus religiosa</i>)
Champa (<i>Magnolia champaca</i>)	Silky Oak (<i>Grevillea robusta</i>)
Black Juniper (<i>Juniperus indica</i>)	Jamun (<i>Syzygium cumini</i>)
Neem (<i>Azadirachta indica</i>)	

Source: Adapted from Bohara, M., Nepali Times. 12-09-2021, and authors’ analysis and recommendations.

APPENDIX II

Some Images for Urban Forestry in the US, Canada, and Nepal

All photos for US and Canada are by Ambika P. Adhikari

All photos for Nepal are by Krishna P. Acharya



City of Tempe, AZ, USA. Trees on the City Hall and Surrounding



Urban Trees and Landscaping at the Optima Residential Project, Scottsdale, AZ, USA



Urban Trees and Landscaping at the Optima Residential Project, Scottsdale, AZ, USA



Shade Trees in a Mixed Use Development, Kierland Commons, Phoenix, AZ, USA



Trees on Central Avenue, Phoenix, AZ, USA



Trees at the University of Hawaii at Manoa campus, HI, USA



Tree Lines on Canal Side Walkways. Honolulu, HI, USA



Trees on Both Sides of the Sidewalk in Honolulu, HI, USA



Urban Forestry in the Middle of the City. Toronto, Canada



Urban Trees in Toronto, Canada



Trees around Royal Ontario Museum, Toronto, Canada



Trees at Residential Development, Guelph, ON, Canada



Urban sidewalk Trees in Kathmandu, Nepal



A Large Sidewalk Tree in Kathmandu, Nepal



Tree Saplings on Sidewalk, Kathmandu, Nepal

Sustainable Food Systems in Urban and Peri-urban Areas in the Global South, with Special Reference to Heifer International's Experience

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ABSTRACT: Rapid urbanization in the Global South has led to the depletion of agricultural land, creating food security challenges. Urban and peri-urban agriculture (UPA) is now recognized as an essential strategy for addressing urban food needs, though it is supplemental rather than a wholesome solution to food security. In this chapter, we discuss the current status, common challenges and opportunities of UPA, through the documented experiences of countries in the Global South- Asia including experiences from Indonesia, Malaysia and urban agriculture (UA) model in China; Latin America including a Cuban and Brazilian experience; and Africa including a model emerging in sub-Saharan experience of urban food production, followed by the first-hand information on the related experiences from the Heifer International, an Arkansas based global humanitarian charity, narrating the following aspects: 1) Food system connecting rural and urban communities, 2) Examples of impactful initiatives, 3) Food security and nutrition, 4) Climate and environment, 5) Marginal land use, and 6) Income. The policy implications drawn from these experiences include: 1) Integrating UPA into urban planning, 2) Providing financial and technical support, 3) Encouraging and Enabling community participation, 4) Enhancing market access, and 5) Promoting sustainable practices.

Keywords: *Urban and Peri-Urban Agriculture (UPA), Food Security, Urban Food Systems, Agricultural Land Depletion, Sustainable Practices, Living Income (LI), Local Led Development, Heifer model.*

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1. INTRODUCTION

Rapid urbanization in the Global South has led to the depletion of agricultural land, creating food security challenges. The Food and Agriculture Organization (FAO) and the World Food Program recognize urban agriculture (UA)/urban and peri-urban agriculture (UPA) as an essential strategy for addressing urban food needs. According to Hoornweg and Paul (2008), UPA is defined as “an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city, or a metropolis, which grows and raises, processes, and distributes a diversity of agricultural products, using largely human, land, and water resources found in and around that urban area. Agriculture has been widely depreciated by urban planning and city management, despite it being always a part of city landscapes. However, local policy options for city farming as an environmentally sustainable land use are emerging initiative in diverse settings in countries such as Mozambique and Brazil (Brebberia, *et al.*, 2002).

In this chapter, we discuss the current status, common challenges and opportunities of UPA in the Global South that covers the countries as shown in the map (Figure 1). We provide a review of selected studies on UPA and UA from three key regions: Asia, Latin America, and Africa. Additionally, we present the experiences of Heifer International, an Arkansas-based humanitarian charity, as a case study of small-scale UPA farming in developing countries. UPA and UA play a crucial role in the Global South for multiple reasons: 1) **Food security**: Ensuring fresh food availability in rapidly urbanizing areas, 2) **Household income**: Providing additional sources of revenue for urban and peri-urban dwellers, 3) **Marginal land/space use**: Utilizing underused or degraded urban spaces for agriculture, 4) **Health benefits**: Improving nutrition and dietary diversity, 5) **Environmental sustainability**: Enhancing urban ecosystems and reducing food transportation costs. Finally, we conclude with policy implications and future directions for sustainable urban food systems.



Figure 1: The Map of the World Showing the Countries Included in the Global South (2024)

2. HOUSEHOLD PARTICIPATION IN UPA ACROSS THE GLOBAL SOUTH

Among 13 sampled countries from the African, Asian, and Latin American regions across the Global South. Zezza and Tasciotti (2010) reported that the percentage participation of the population in UPA (measured in various years) has been prominent in Vietnam (69%), Nicaragua (68%), and Nepal (57%) as shown in Figure 2. Furthermore, Nepal had the highest percentage (36%) of urban population engaged in raising livestock (Zezza and Tasciotti, 2010).

Warren *et al.* (2015) investigated through a systematic literature review the association with urban agriculture with various factors of food systems, such as food security, dietary diversity, and nutritional status in the Global South settings of developing and transitional countries. Most studies reviewed found that urban family and community engagement in urban agriculture (UA) was positively linked to dietary diversity and, in many cases, to increased food consumption. Results for food security and nutritional status were mixed, though some studies showed improvements, including reductions in child stunting. While motivations for practicing UA varied across the Global South—and weren't always focused on food security, access to a diverse diet was a consistent and compelling driver. Overall, UA was widely associated with better dietary diversity, which in turn supported improved food security and child nutrition. Warren *et al.* (2015) were wary of the fact that the interpretations of these reported associations do not lend themselves to the assignment of causation due to poor quality and weak designs of the studies.

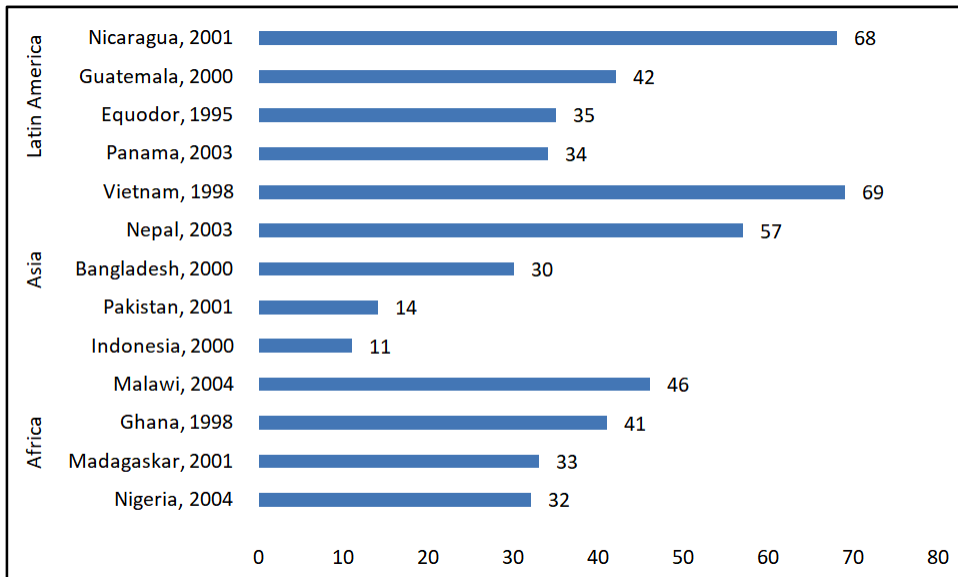


Figure 2: Percentage Participation of the Population of Sample Countries from the Global South in Urban Agriculture as Measured in Various Years (Zezza and Tasciotti, 2010)

3. EXPERIENCES FROM THE GLOBAL SOUTH

3.1 Asia

Urban agriculture is increasingly seen as a strategy to enhance food security and reduce living costs in Asia. It is crucial to estimate and acknowledge the tangible contribution of urban agriculture to the food security situation in an urban population (Rezai *et al.*, 2016; Chandra and Deihl, 2019) so that food policy framework can be formulated to ensure sustainable, sufficient and safe food to feed the population for healthy living (Bhandari *et al.*, 2020).

In Malaysia, with the urban population (UA) expected to be 75% by 2020, urban residents are increasingly facing challenges in meeting living costs, particularly due to rising cost of food production. In order to ensure an adequate supply of safe and quality food to feed the country's population, urban agriculture is viewed as a way forward in the livelihood strategies for urban households. For that reason, the government is considering UA to contribute to food security as well as a whole, and the supply of an adequate nutritional diet becomes crucial. With the purpose to estimate the potential contribution of UA to food security, Rezai *et al.* (2016) conducted a study exploring the effectiveness of urban agriculture in providing food security to the urban dwellers, and reducing their food bills substantially. The results of the study showed that the food availability and accessibility, nutritionally adequate diet and cost effective food supplies were the components of food security that were significantly associated with urban agriculture, while educational level, age, income and household size were significant as influencing factors.

The study by Chandra and Diehl (2019) in Jakarta (Indonesia), where urban agriculture occupies approximately 21% of total green space area, demonstrated that understanding the characteristics of form and function of urban agriculture is useful and timely in determining the level and type of reformation needed by the farmers. Moreover, this case study, which is meant to describe one specific typology of undefined urban agriculture in Jakarta, provides evidence that one solution cannot fit all situations. Understanding of the various typology characteristics of urban agriculture, combined with more comprehensive agriculture maps, can aid future development planning and policies, and lead to systematic metrics for categorizing urban agriculture that enable more targeted and comprehensive strategies toward urban food security across diverse contexts.

Zhu *et al.* (2024) reviewed nature-based solutions (NBS) adopted for urban agriculture in China, which is gaining importance as a strategy to improve food security for city dwellers. In response to rapid urbanization over recent decades, three distinct types of urban agriculture have emerged in China: small-scale, capital-intensive, and tourism-oriented, involving growing, processing, and distributing plants and animals within urban and suburban areas (Figure 4). Each type offers specific advantages and faces unique challenges, with their growth influenced by local socio-economic conditions and supportive government policies. China's urban agriculture

system provides numerous benefits, such as strengthening community bonds and promoting physical health.

Further, Zhu *et al.* (2024) reviewed the importance of urban green space, the role of supportive government policy and cultural benefits of city's green infrastructure, as China has expanded urban green spaces through the Sponge City Program (SCP), which utilizes Green Infrastructure such as rain gardens, urban parks, and forests—to address urban water resource challenges and environmental concerns; the Chinese government has played a key role in fostering peri-urban agro-tourism farms, enhancing the visual appeal of city outskirts while providing urban residents with greater access to natural spaces; and from a cultural perspective, Chinese cities with extensive green infrastructure offer greater opportunities for fitness and well-being by counteracting declines in physical activity and dietary deficiencies. Furthermore, the Chinese model of urban agriculture has demonstrated that urban agriculture not only supports eco-environmental improvements but also provides cultural benefits, while vegetation in urban areas helps reduce noise and odor, enhances aesthetic appeal, and mitigates light pollution. Finally, Zhu *et al.* (2024) made four specific recommendations to promote urban agriculture for healthier cities with a robust agriculture system in China, namely, integration of urban agriculture into cities, solutions for land and resource use, government support and actions, and planning and regulations.

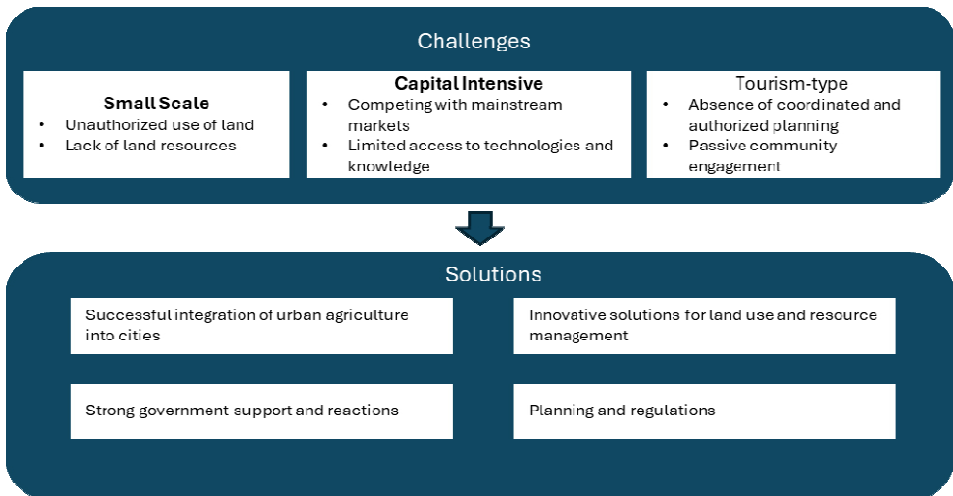


Figure 3: Graphical Summary of Nature-Based Solutions for Urban Agriculture in China (Zhu *et al.*, 2024)

3.2 Latin America

A literature review conducted by Bohrt (1993) summarized the following characteristics of urban agriculture (UA) in Latin America:

- The family, school or community/group vegetable gardens that consisted of greenhouses, microclimatic tunnels (organic beds) and open-air plots (solar gardens) were the most widespread production system in Latin American cities.
- Vegetable produce (tomatoes, squash, broad beans, lettuce, onions, radishes, etc.); forest production (for reforestation and ornamental purposes) including flowers and medicinal plants; and some fruits were main produces.
- The backyard farming with the breeding/raising of small livestock (pigs, chickens, hens, rabbits, etc.), fed mainly with household level vegetable production residues, were fairly well developed and widely adopted.
- The outputs from most household vegetable gardens were small, fulfilling the family's self-consumption, but afforded diversification and a supplement to the basic diet and facilitated an increase in family income and create self-employment, putting vacant urban lands to use.
- Food transportation costs were reduced, food quality is improved, and family energy/caloric supplies are increased.
- Attempts to scale up the UA to the communal vegetable gardens to grow products for marketing and generate income for the organization and its family members, had faced with a series of difficulties: high production costs, lack of resources to gain access to markets (transportation, storage, refrigeration, etc.); poor management, low productivity (due to soil exhaustion, lack of water and seed), scarce technical counselling.

In Cuba, following the collapse of the socialist bloc in 1989, an emerging grassroots movement rapidly turned urban agriculture as a significant source of fresh produce for the urban and suburban population, with a large number of urban gardens surfacing in Havana and other major cities. These gardens helped stabilize the supply of fresh produce to urban centers in response to the crisis brought about by the loss of trade. This led to the development of an urban agriculture system in the country comprising 8,000 gardens generating significant amounts of agricultural produce, flowers, eggs, and meat. The system has been managed along the lines of agro ecological principles, eliminating the need for synthetic chemical pesticides and fertilizers that were imported previously, and featured diversification, recycling, and the use of local resources. The types of gardens developed in Cuba include intensive gardens, Organopónicos and suburban farms that were mixed with the state and private ownership, popular gardens, generally private gardens in state or private land, which were the largest in numbers, enterprise and factory owned gardens, state owned hydroponics, and household owned gardens. The main crops grown in these varieties of urban and peri-urban farms were tomato, bean, bell pepper, cucumber, radish, celery, chard, beets and cabbage. In addition to increased food security, urban gardens have also helped to empower many individuals and communities, with renewed solidarity and purpose within neighborhoods, sustaining morale during the ongoing economic crisis (Altieri *et al.*, 1998).

Madaleno (2002) described some experiences from Brazil, where with 80% of the population residing in urban areas, vertical housing has become common in major

cities. Despite this, Brazilians maintain a deep-rooted belief in the healing powers of nature and medicinal herbs, along with a preference for spicy cuisine influenced by Portuguese, Italian, and other European, African, and Amerindian traditions. This cultural heritage has fostered a strong tradition of home food cultivation and small-scale livestock raising, with many cities showcasing green public spaces and flourishing private gardens. In 1997, the Agriculture Department of São Paulo State launched the *Feed Prudente* project, a municipal initiative aimed at promoting community food production among low-income families in peripheral neighborhoods. The program sought to encourage cooperation among underemployed, elderly, and economically vulnerable individuals, providing them with jobs, income, and improved nutrition. Initially designed to support 200 participants, it focused on horticulture rather than livestock, which was banned within city limits. Key crops included cassava, sweet potatoes, beans, pumpkins, chicory, spices, medicinal herbs, and maize. Public land was leased for cultivation, and the municipality offered free legal assistance to those interested in farming idle private plots. However, the program faced significant challenges, including poorly maintained inner-city and peripheral areas overrun with rats and mosquitoes. Limited municipal funding and personnel shortages further hampered efforts to sustain and expand the initiative, leading to frequent complaints from participants.

In more recent times, UA has been generally considered a potential solution across Latin American countries for urban food security, with strong interest in its benefits, including improved diets, green spaces, local economies, and reduced CO₂ emissions (Nadal *et al.*, 2018). At the same time, rapid population growth leading to urban expansion with particularly social housing posed as an impediment to green culture as revealed by a study by Nadal *et al.* (2018) on UA perceptions in Mérida, Mexico, which indicated limited housing space and urban planning that lacks open areas as key barriers, despite Yucatán's agricultural history. While rooftops could still be utilized for UA, stakeholders emphasize the need for government support through policies and incentives to address housing problems.

3.3 Africa

Like in most countries around the world, the countries in the African continent have recognized the importance of UPA, which could have the potential to tackle household food insecurity, by increasing urban food production and to improve employment status by encouraging productive participation in urban development (Korir *et al.*, 2015), while higher food insecurity situation and higher rate of stunting in children were reported in peri-urban area compared to urban and rural areas in a West African country Burkina Faso (Chagomoka *et al.*, 2017). Cofie *et al.* (2003) posited that UPA has a significant share in the food supply of many cities in sub-Saharan Africa (SSA) in fulfilling urban diets, with exotic or perishable vegetables, fresh milk and poultry products. However, the authors emphasize that this food supply would be basically supplemental, rather than the complete solution to food security in the UPA. In the macro-economic context, the contribution of

urban agriculture to the Gross Domestic Product could be small, but the importance for certain commodities, such as cabbage or milk, might be substantial especially considering up- and downstream activities, through which individual households in the UPA have earned profits from the sales of UPA produce in addition to improvement in household nutritious diets (Cofie *et al.*, 2003).

3.3.1 *An Emerging Model of Urban Food Production in Sub-Saharan Africa*

Professor Christopher Gore's research highlights a model emerging for urban food production in sub-Saharan Africa that is driven primarily by local actors such as citizen groups, city bureaucrats, and municipal politicians, rather than top-down national or international policies (Gore, 2018). His fieldwork in Kenya, Uganda, and Tanzania reveals that urban agriculture is a vital source of food, income, and environmental resilience, despite often being overlooked or even resisted by national governments.

The emerging sub-Saharan model of urban food production can be characterized by the following key elements:

- **Local-Led Policy Development:** In cities like Nairobi, Kampala, and Dar es Salaam, municipal governments and grassroots organizations have been instrumental in legitimizing and promoting urban farming. Nairobi, for example, has become a leader in urban agriculture policies, inspiring both national and international policy shifts.
- Further to this study by Gore (2018), Heifer International, a US based development charity organization has also been embracing Locally Led Development (LLD) approach. The LLD emphasizes empowering local communities to carve out their own paths to progress, and enabling them to walk through it. Heifer trusts in the communities' ability to know what's best for them, and in return, they trust Heifer to help build their confidence in their own judgment, abilities, and collective strength. Heifer believes LLD becomes Sustainable Locally Led Development (SLLD) when communities are enabled to strengthen their social, economic and environmental resilience, such that gains made through locally led development are sustainable over the long term. Heifer is relatively early in a learning process about the full dynamics of SLLD and how to fully implement it.
- **Urban Agriculture as a Food Security Solution:** Despite the perception that farming does not belong to cities, urban agriculture provides a significant proportion of fresh produce, including leafy greens, benefiting people across all income levels. It also serves as a buffer against food price volatility and crises. It is important to note here that the UA/UPA are more efficient in reducing post-harvest losses
- **Environmental and Economic Benefits:** Urban farming contributes to climate resilience by improving water retention, reducing soil erosion, and creating green spaces. It also generates employment, particularly for women and youth.

- **The Role of City-Based Coalitions:** Urban agriculture policies emerge through collaboration between citizens, local governments, and civil society organizations, rather than being imposed by national or international entities. This decentralized approach, which also aligns well with Heifer experience, ensures that policies are tailored to local needs and realities, preferably under local leadership.
- **Global Recognition and Knowledge Sharing:** African cities are increasingly engaging in international discussions and exchange agreements on urban agriculture, as seen in Nairobi and Toronto (TMU, 2019). These exchanges help cities refine their approaches and gain recognition for their innovations in food system sustainability.

Overall, the findings of Gore (2018) as well as experience of Heifer International (2024) suggest that urban and peri-urban food production thrives when local actors take the lead, challenging traditional governance models and offering a blueprint for other cities looking to integrate agriculture into urban planning.

4. HEIFER MODEL AS A CASE STUDY ACROSS COUNTRIES IN GLOBAL SOUTH

Heifer International has played a significant role in supporting smallholder urban and peri-urban farmers across the Global South. By providing livestock, training, and resources, Heifer has empowered families to engage in sustainable agriculture, enhance food security, and improve economic resilience. Case studies from Heifer-supported projects illustrate the effectiveness of micro-livestock programs, cooperative farming models, and agro ecological practices in urban and peri-urban settings.

4.1 Food Systems Connecting Rural, Peri-urban and Urban Communities

Heifer International, in collaboration with local partners worldwide, works closely with smallholder farmers particularly women farmers alongside their households and their communities. Together, they develop strategies that enable these farmers to engage productively, profitably, and sustainably in food systems. These systems are vital for a collective capacity to provide nourishment, support livelihoods, and protect the environment, ensuring that all individuals can thrive not just survive—today and in the future.

A fundamental aspect of this initiative is changing mindset from pessimism to optimism through “Personal Transformation”. Project participants develop their sense of self by building self-efficacy. They improve their communication skills by being willing to voice their ideas and thoughts. Participants experience a fundamental state of leadership and increase both their civic and community engagement. With the personal transformation strategy in place, Heifer is able to take the pulse of their impact not just on economic well-being, but also on human development and growth.

The second aspect is enhancing smallholder farmers’ access to formal markets. By enabling them to compete on a level playing field, farmers can improve their

livelihoods and invest in their families and farms. This often involves organizing into cooperatives and other collective enterprises, which empower them to negotiate better deals, fair access to essential inputs, increase their market power, and share knowledge and resources among members, adopting a sustainable system of “Passing on the Gift” to other members and new members.

Heifer International’s experience has demonstrated that the sustainable success of these collective endeavors hinges on the presence of strong social capital within farming communities. This is especially crucial in rural and peri-urban areas where food is produced and supplied to urban markets, particularly in large cities.

4.2 Examples of Innovative Agricultural Practices

Several initiatives illustrate how Heifer is making a difference in communities across 19 countries in Asia, the Americas, and Africa:

4.2.1 Poultry Project of National Pride in Cambodia

This project aims to enhance and modernize Cambodia’s poultry industry by developing cooperative networks that integrate into broader market systems. The program provides smallholder members of cooperatives with the necessary tools to produce enough chickens to meet domestic demand, particularly in major cities like Phnom Penh and Siem Reap. By making the indigenous poultry value chain accessible, farmers can secure fair market prices for their products.

4.2.2 Coffee and Cacao Program in Latin America

Spanning four countries in the Latin America - Guatemala, Honduras, Ecuador and Mexico, a regional initiative focuses on improving coffee production and marketing, capitalizing on its high global market potential. Coffee is more than just a beverage; it is a global phenomenon that shapes cultures and traditions. It serves as a common thread that connects people and fosters social interactions, with demand rapidly growing in megacities worldwide. Connecting the demand for coffee with rural and peri-urban farmers who produce it is essential for meeting this global demand. Heifer communities in Central America and Africa are playing a crucial role by producing high-quality coffee for major market players.

4.2.3 Supply of Goats to Urban Areas in Nepal

In Nepal, the annual meat consumption reaches approximately 609,000 tons, with goats accounting for 20% of the total. This translates to a significant contribution to the country’s dietary needs, particularly during festive seasons.

The average meat consumption per person in Nepal has risen to 21 kg annually. A notable spike in demand occurs during the Dashain festival, a major cultural celebration in Nepal, when around 4 million goats are consumed nationwide. This festival is a critical period for goat sales, especially in urban areas, where goats are brought from outside the valley and kept on holding until sold live.

In 2023, the Kathmandu Valley experienced robust sales of live goats, with approximately 50,000 goats sold during the festival season. This surge highlights the growing demand for goat meat in Nepal's most densely populated metropolitan area.

To address this demand effectively, Heifer International has played a pivotal role in facilitating production and sales of goats during the festival. The organization has established hundreds of cooperatives aimed at enhancing the supply chain and ensuring that urban areas, particularly Kathmandu, receive adequate goat supplies. These cooperatives not only support local farmers but also help meet the increasing demand for goat meat in urban markets.

4.2.4 *Women's Cooperatives in Urban and Peri-urban Food Supply Chain in Nepal*

Cooperatives play a pivotal role in supply chains of agriculture and livestock products in urban and peri-urban food systems. Heifer's focus on women empowerment and their active participation in economic activities has resulted in women farmer led cooperatives especially in Nepal, India, Bangladesh and Cambodia.

There are many testimonials from the women farmer-led cooperatives established through Heifer International in Nepal. So far, Heifer has facilitated the establishment of more than 400 cooperatives with over 400,000 smallholder farm families as members throughout Nepal. These cooperatives are helping farmers to produce good quality agricultural and livestock products for supply to the urban population. The supply of goats to urban areas in Nepal, particularly during festive seasons, is a crucial aspect of the country's meat consumption landscape. The cooperatives streamline the supply chain; the goal of meeting the growing demand in metropolitan areas is becoming increasingly achievable.

Some illustrative examples of these cooperatives with their business performance supplying various agricultural commodities (milk, and other dairy products, live goats, turmeric and vegetables) to urban and peri-urban markets throughout Nepal are given below in Table 1. There is a growing demand in the local urban markets for these commodities that are produced and marketed by women-led cooperatives.

Table 1: Commodities Marketed and Revenues Generated by the Four Women-Led Cooperatives with Support from Heifer International from July 2023 to June 2024

<i>Cooperatives</i>	<i>Commodities</i>	<i>Revenue (US\$)</i>
Chakrawarti Social Entrepreneur Women's Cooperative, Tanahu, Nepal	Milk and dairy products	89,599
Shantikunja Social Entrepreneur Women's Cooperative, Chitwan, Nepal	Milk and dairy products	148,199
Laganshil Social Entrepreneur Women's Cooperative, Nepal	Live goat	45,496
Safal Social Entrepreneur Women Cooperative, Nepal	Turmeric	4,267

4.2.5 *Women's Cooperative in Nepal Connects Farmers to the Global Market* (Source: Heifer Nepal, Annual Report, 2024)

Historically, the Nepalese farmers' dependence on the Indian market for ginger often faced market instability, resulting in significant waste of their produce. In an effort to address this challenge, one of the Heifer supported women's cooperatives has succeeded to access global spice market- a major leap in diversifying Nepal's ginger market.

Galdha Social Entrepreneur Women's Cooperative (SEWC) at Nisdi, Palpa, exported 4,460 kg of processed ginger to Europe in May of 2024, following a successful trial export of 850 kg in 2023. Organic certification and export to Germany was facilitated by *aQysta Nepal*, a local marketing startup. Heifer Nepal supported this cooperative by subsidizing equipment for ginger washing, drying, grinding and packaging, in addition to technical assistance in production, processing, packaging as well as market promotion. The cooperative, comprising 272 women, has set ambitious goal to export 20,000 kg of fresh ginger and 10,000 kg of dried ginger in 2025.

Entering the European market has opened new opportunities, reducing reliance on India and offering market stability. Although challenges like market fluctuations and lack of tools have slowed progress, recent investments in processing facilities and coordinated efforts by the local government and Heifer Nepal aim to boost production, improve quality & market access, and enhance the livelihoods of farmers.

4.2.6 *Urban Food Production and Education: Heifer Urban Model Farm and Aquaponics at the Heifer International Headquarters, USA*



Figure 4: Heifer Urban Farm, Little Rock, Arkansas, USA, 2020
(Photo credit: Heifer International)

Heifer International has successfully experimented with the urban food security model by establishing an urban farm in the heart of Little Rock, the state capital city of Arkansas in the United States, where its world headquarters is located. The Heifer Urban Farm was a three-acre, multi-purpose garden located behind the Heifer headquarters (Figure 4). Created as part of its vision to actively engage in the local community, the Urban Farm has grown from a small community garden into an operation that was serving several Arkansas food networks. In addition to horticulture and aquaponics, the farm also maintained alpacas, chickens, goats, pigs, and composting demonstration, while learning about how animals are helping families overcome hunger and poverty.

In the same location, Heifer partnered with HATponics, a local private firm, to establish a renewable energy-operated aquaponic farm for growing fish and vegetables. This sustainable urban farmstead was using fish waste to fertilize the vegetables, like cabbage, lettuce, spinach, grown inside. The algae produced in the floating vegetable pens were feeding the fish. The solar panel provided the energy needed to the aquaponic farm. The installation of the portable farm unit provided an aquaponic farmer system that was fully off-grid. The integrated vertical farm system was installed as a demonstration unit to showcase effective food production systems and tools for globally stressed populations, especially the urban population. The farm was producing fish and vegetables in an aquaponics system streamlined for production in an urban setting. It was a 40-foot-wide greenhouse system that was a containerized portable farm. The farm was solar- and wind-powered and fully off-grid to provide a power model for developing nations. The aquaponics unit located within the greenhouse consisted of multiple deep water culture beds, a bucket-based operation, and a vertically integrated micro-green system to provide a full-sized demonstration model for Heifer's program worldwide.



Figure 5: Inside View of the Renewable Energy Operated Aquaponics Farm, Little Rock, Arkansas, USA, 2020 (Photo credit: Heifer International)

Through these initiatives, Heifer International is not only empowering smallholder farmers but also contributing to sustainable food systems that benefit communities in rural and urban areas, especially in the Global South.

4.3 Food Security, Nutrition and Health

Nearly half of the world's population particularly those living in poverty, relies on agricultural livelihoods to support their families. To achieve global sustainable development goals (SDGs) and nourish an ever-growing population, it is crucial to support farmers in sustainably enhancing their production and building resilient food systems for urban and peri-urban populations.

Heifer International collaborates with smallholder farmers and a diverse range of partners to create farms and food systems that not only feed families but also generate economic opportunities while minimizing environmental stress. The organization emphasizes climate-conscious production methods and inclusive market access, ensuring that agricultural practices are both sustainable and equitable.

To empower farmers, Heifer International provides comprehensive technical training aimed at increasing crop yields and improving livestock productivity. This training is essential in meeting the rising demand for manpower to produce healthy foods for the market. Additionally, farmers are encouraged to establish kitchen gardens and diversify their production. This initiative not only addresses the dietary needs of their households but also responds to the high demand for fresh produce in urban areas, where local production is often limited.

By fostering these practices, Heifer International helps smallholder farmers enhance their livelihoods while contributing to a more sustainable and resilient global food system.

4.4 Climate Change and Environment

Smallholder farmers play a crucial role in developing a sustainable food system that benefits both people and the planet. As the world grapples with the complex challenge of producing more nutritious food with minimal ecological impact—amidst increasingly challenging growing conditions—engaging these farmers is an important strategy. Partnership with smallholder farmers, their communities, and a diverse array of stakeholders enables them to transform food systems. This collaboration aims to enhance the resilience of farming households, boost sustainable food production, and ensure the health of ecosystems. Central to this approach is the integration of the One Health concept, which seeks to harmonize human, animal, and environmental health within food systems.

To combat the effects of climate change, it is essential to promote climate-smart agricultural practices that empower farmers to adapt and thrive. These practices not only enhance biodiversity but also improve the livelihoods of farming communities. By implementing environmental strategies throughout the entire food system, Heifer

International identifies innovative ways to establish resilient and safe connections between producers and consumers in the urban areas.

Focus on improving equitable access to renewable energy solutions for smallholder communities, such as solar-powered irrigation systems providing essential water resources during droughts, while solar refrigeration ensures the safe storage of products during transportation to markets. Through these initiatives, communities are effectively addressing the needs of urban populations seeking healthy and nutritious food produced through environmentally friendly methods.

Smallholder farmers are not just vital to food production; they are essential to building resilient, sustainable food systems that prioritize health and environmental stewardship.

4.5 Marginal Land Use

The marginal lands surrounding communities in rural, peri-urban, and urban areas—often deemed unsuitable for traditional agriculture—have been effectively utilized by Heifer International communities worldwide. For example, Heifer supported smallholder goat farmers in Nepal have successfully planted over 16,000 hectares of unproductive, degraded, and underutilized waste lands, including public lands accessed through leases, the borders of irrigation canals, and the edges of roads and trails. Additionally, they are utilizing terraces and bunds on their farmland to cultivate fodder and forage crops. Community-managed nurseries play a crucial role in this initiative, serving as primary sources for seedlings and saplings. These farmers also collaborate with local government agriculture and forestry departments to access additional resources.

This approach not only ensures a consistent supply of nutritious livestock feed throughout the year but also facilitates stall feeding, which in turn supports the growth of livestock for nutritious animal source food. Promotion of enhanced fodder and forage production as part of a larger movement aimed at sustainable agricultural practices is a priority. A key method advocated is the “cut and carry” system for goat feeding, which allows farmers to efficiently manage their livestock’s nutritional needs.

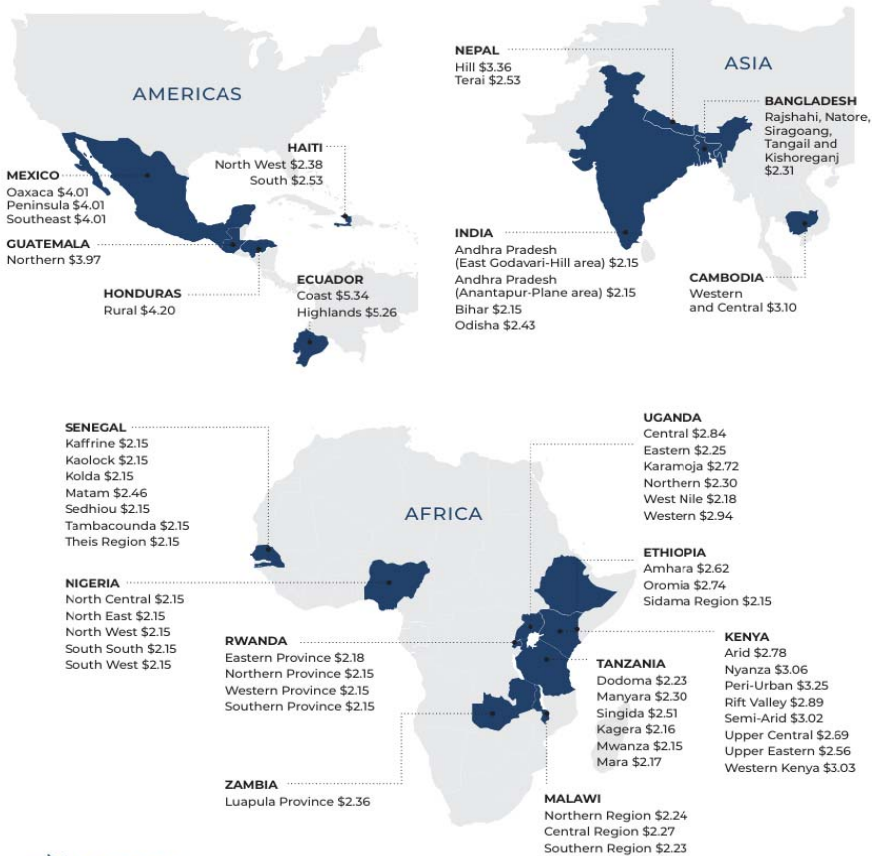
This positive trend has been gaining momentum in all countries in Asia, Africa and Latin America where Heifer International operates, reflecting a growing commitment to sustainable agricultural practices and food security.

4.6 Living Income and Migration

Heifer International works with communities around the world as they strengthen economies and build secure livelihoods that guarantee a living income (LI) for farmers. The LI is based on the Anker methodology (Anker and Anker, 2017) and builds on the work of academics, international NGOs, and the Living Income Community of Practice to achieve agreed-upon standards. The living wage income calculation has been customized to capture the unique household needs in the local context.

Household needs are captured across four categories: low-cost and nutritious diet, decent housing, other basic needs, and unexpected costs. Living income is the amount of money every person in a household needs per day to live a dignified life. A nutritious diet includes 11 food groups that provide sufficient calories and macro and micronutrients. Decent housing includes basic shelter, an adequate amount of space, and other housing criteria deemed necessary to live a dignified life. Other basic needs encompass education, healthcare, transportation, clothing, communication, and cultural events. Unexpected costs account for a minimal level of savings that families need to withstand shocks and unanticipated expenses.

Heifer International has calculated the living income benchmarks for communities where it works in 18 countries around the world, mostly in the Global South (Figure 6). This allowed Heifer to focus on transformational change at the household level for increasing farmers' income through agriculture and other businesses that cater to the dietary/food requirements of the urban/peri-urban population.



UPDATED JUNE 2024. ALL AMOUNTS IN USD.

Figure 6: Living Income Benchmarks of Heifer International in Communities Where it Works in Countries of Global South

Heifer advocates that consumers pay fair price to locally produced food by highlighting its health benefits as compared to industrial agriculture products. This will not only contribute toward a healthy population but also ensure living wage income for dignified living conditions for smallholder farmers.

Heifer's Living Income strategy, together with increased access to production inputs, technology, and a fair price market is likely to have positive impact in reducing out-migration. An unpublished report of 'Heifer International Nepal 2024 Annual Outcome Monitoring Survey' revealed that a total of 4,736 returnee migrant youths had microagro-enterprise start-up with Heifer's technical support. Another unpublished data obtained from Heifer International Nepal revealed that its recently completed partnership project with Tansen Municipality generated 1163 youth employment on agro-enterprise (target 1200) of which 41% were returnee migrants. The data also suggested that the average annual income of these entrepreneurs was USD 3,985 equivalent in local currency (Kafle, K, 2025). The returnee migrant youths have reported that this income will discourage the outmigration of youth.

5. POLICY IMPLICATIONS AND FUTURE DIRECTIONS

To enhance the sustainability of UA/UPA in the Global South, policymakers are suggested to focus on the following aspects:

1. **Integrate UA/UPA into urban planning:** Designate agricultural zones to prevent uncontrolled urban sprawl.
2. **Provide financial and technical support:** Facilitate access to credit, infrastructure, technology, and skill training tailored to the context at the local level.
3. **Encourage community participation including women and youth:** Encourage, empower and enable cooperative initiatives and knowledge-sharing networks to chart their own path tailored to their unique local context, and to execute their plan, monitor, evaluate and re-plan.
4. **Enhance market access:** Develop supply chains that connect urban farmers to local consumers as well as marketing through regional, national and global networks.
5. **Promote sustainable practices:** Implement agroecological approaches to minimize detrimental environmental impacts.

6. CONCLUSIONS

Urban and peri-urban agriculture is a vital component of food security and nutrition in the Global South. In addition, urban agriculture supports eco-environmental improvements and also provides economic, social and cultural benefits, while vegetation in urban areas helps reduce noise and odor, enhances aesthetic appeal, and mitigates environmental pollution. While challenges such as land use competition, market access, and policy gaps persist, successful case studies from Asia (including the experiences from Indonesia, Malaysia, and China), Latin America (including the Cuban and Brazilian experiences), and Africa (including the sub-Saharan African

model of urban food production) demonstrate its potential and promises. The experiences of Heifer International highlight the importance of targeted support for smallholder urban and peri-urban farmers, its multifaceted impact on UA/PUA food systems and its potential for scaling up. Moving forward, a holistic system approach integrating empowerment of local communities to lead the change process, their access to agriculture inputs markets and technologies, and financial investment together with enabling policy infrastructure will be essential to achieving sustainable urban food systems.

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The Changing Nature of Public Open Spaces in the Kathmandu Valley: What does it Mean for Social Sustainability of New Growth Areas?

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ABSTRACT: Urban change is a worldwide phenomenon with widespread consequences on the city's physical form and social life. The changing urban patterns of contemporary cities have transformed how public open spaces are developed and used in new growth areas. Kathmandu Valley is not exempt from the forces driving such transformation. Following the political change of 1951, the valley has witnessed rapid urban growth and change, with the new neighbourhoods demonstrating a sharp contrast with their historic counterparts in both physical and social settings. One major outcome of this transformation is the loss of public open spaces and the apparent consequences on social life. This chapter examines the changing nature of public open spaces and its implications for sustainable urban development through the lens of social sustainability. The chapter is based on the data collected from direct observations of public open spaces and the review of secondary sources. It argues that the current unsatisfactory provision and use of public open spaces has had an adverse impact on building sustainable communities in new neighbourhoods due to the lack of opportunities for social networking and exchange among residents. Consequently, social sustainability has emerged as a major challenge of contemporary urban development as the quality of life and well-being have been compromised, with a decline in the public realm and a poorly developed sense of community. Achieving social sustainability in new neighbourhoods requires incorporating elements of physical and socio-cultural significance, including open spaces, to support public life and activities. Future urban development plans for the Kathmandu Valley should attempt to establish public open space as a critical social amenity in the new growth areas.

Keywords: Urban Change, New Growth Areas, New Neighbourhoods, Public Open Spaces, Social Sustainability, Kathmandu Valley.

1. INTRODUCTION

Urban change is a worldwide phenomenon with widespread consequences on urban form and life across different geographical regions. Over the last century,

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contemporary cities have seen a significant transformation of urban environments, as evidenced by the rise of urban sprawl and the expansion of automobile-oriented development. Scholars argue that the changing urban development pattern has influenced how public open spaces are developed and used in new growth areas (Tibbalds, 2001; Madanipour, 2010). This transformation of urban form and public open spaces has now become a common experience taking place in most of the major metropolitan centres around the globe, raising concerns about the development of sustainable urban environments.

The Kathmandu Valley, Nepal's cultural, economic and political centre, has not been exempt from the forces driving urban transformation. Following the political change of 1951, the valley was exposed to globalisation as the nation entered a new era of modernisation and development (Aryal, 2016; Basyal & Khanal, 2001; Shah & Pant, 2005). This change, however, also generated migration from other parts of the country, exerting significant pressure on urban growth and prompting the course of contemporary urban development (Chitrakar *et al.*, 2016). This resulted in a rapid transformation of the valley's urban landscape, with city cores expanding to take the emerging form of sprawl (Chitrakar *et al.*, 2017a) (see Figure 1). Urban change became visible as the new growth areas began to demonstrate a sharp contrast with their historic counterparts in terms of physical settings (Adhikari, 1998). Today, the Kathmandu Valley, with around three million inhabitants (NSO, 2021), has turned into an uncontrolled metropolitan sprawl from a planned and compact settlement in the past (World Bank, 2001; Shah & Pant, 2005).

The contemporary urban development of the Kathmandu Valley presents several problems in the planning and design of the new growth areas (Adhikari, 1998; Thapa, Murayama and Ale, 2008; Chitrakar *et al.*, 2016; Chitrakar, 2023). Some of these problems are evident in the non-conducive physical environment of the new neighbourhoods, which hardly enhances the quality of life and well-being of the residents (Chitrakar, 2016a). However, one major issue that has been raised by most scholars is the loss of public open spaces and its consequences on the nature of the public realm. Observations show that very little public open spaces exist in the valley's new neighbourhoods, resulting in poor provision of communal meeting areas (Adhikari, 1998). Although the loss of public open space is a relatively new problem, it has had a profound impact on social life. Residents in new neighbourhoods frequently struggle to find places where they can meet and connect with neighbours; children do not find places to play; and without spaces for social gathering, the neighbourhoods lack a sense of community (Shrestha, 2001; Chitrakar, 2016b).

Currently, two distinct forms of public open spaces exist in the Kathmandu Valley (Sharma, 2006; Chitrakar & Shrestha, 2020) (Figure 1). On the one hand, the valley's traditional towns boast a fine provision of public open spaces with their outstanding ability to accommodate social life and activities (Tiwari, 1989; Chitrakar, 2006; Chitrakar *et al.*, 2014). Most notably, public open space remains the heart of urban neighbourhoods and is widely in use (Chitrakar, 2006; Shokoohy, 1994). However, on the other hand, the lack of proper urban development coupled with

the problems of urban change has significantly transformed the course of open space development and utilisation in the new growth areas (Chitrakar *et al.*, 2016). This changing nature of public open spaces demands critical investigation as studies indicate that it has major implications for sustainable urban development (Abu-Ghazzeh, 1999; Dempsey, 2009).



Figure 1: A comparison between traditional and contemporary urban open spaces in the Kathmandu Valley: a) Traditional neighbourhood open space in Kathmandu and b) public open space in the Gongabu Residential Area (new growth area)

Source: Bhandari & Okada (2009).

The sustainability of an urban area is largely dependent on the quality of the built environment and its capacity to meet the current and future needs of the inhabitants. While such needs can be both physical and social, the notion of urban sustainability now embraces social dimensions within the framework of a broader environmental context (Dempsey *et al.*, 2011). Against this background, this chapter examines the current provision and use of public open spaces in the new growth areas of the Kathmandu Valley and its potential consequences on the development of sustainable urban communities. The main objective of the chapter is to discuss the implications of the changing nature of public open spaces for sustainable urban development through the lens of social sustainability.

2. PUBLIC OPEN SPACES IN THE TRADITIONAL TOWNS

Kathmandu Valley has a rich history of urbanisation and exhibits a distinct pattern of urban settlement (Chitrakar, 2023). Its traditional towns as they appear today were mostly built during the *Malla*² period from the 13th to the 18th century by the *Newars*³ (Figure 2). These towns display a definitive urban character of compact and

² The Malla kings developed the Kathmandu Valley towns as a major trade and administrative centre and also contributed to its rich social fabric and highly developed cultural patterns.

³ The Newars are indigenous people of the Kathmandu Valley, who are solely responsible for its outstanding development in the medieval period.

dense settlements. They comprise marvellous urban spaces that are distributed over the entire town and organised in a unique and innovative way (Chitrakar, 2006; Shrestha *et al.*, 1986). Tiwari (1989, p. 95) suggests that these towns have “a distinct set of [urban] squares with a clear hierarchy of social [and] cultural activity” that include the *Durbar* (palace) square, the market square, the residential neighbourhood square and the private residential square. In every principal *Malla* town, there is only one *Durbar* square, whereas other square types are numerous and are central features of urban neighbourhoods (Figure 3). Each neighbourhood is centred around more or less spacious public squares (Gutschow & Kolver, 1975), and follows two basic approaches of spatial configuration: a) space formed at a street intersection—the street square; and b) the enclosed space of a courtyard surrounded by residences for extended families.

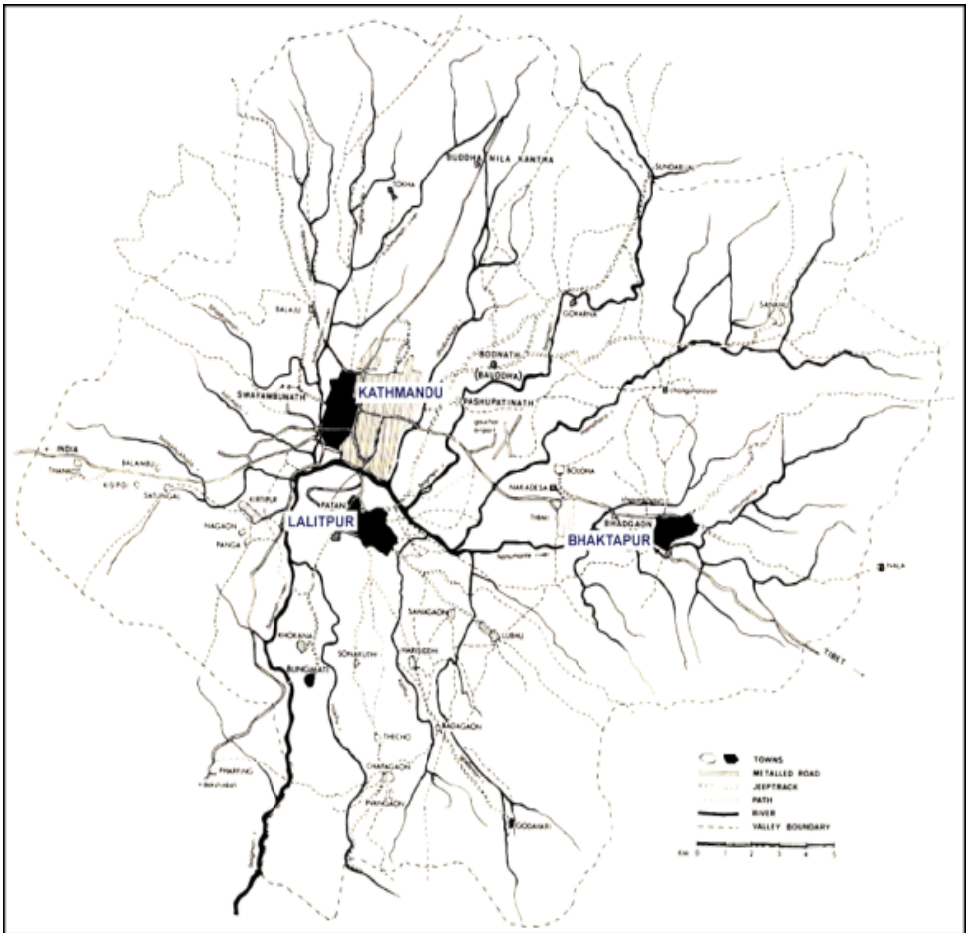


Figure 2: Map of the Kathmandu Valley Showing Three Principal *Malla* Towns

Source: Hosken (1974).

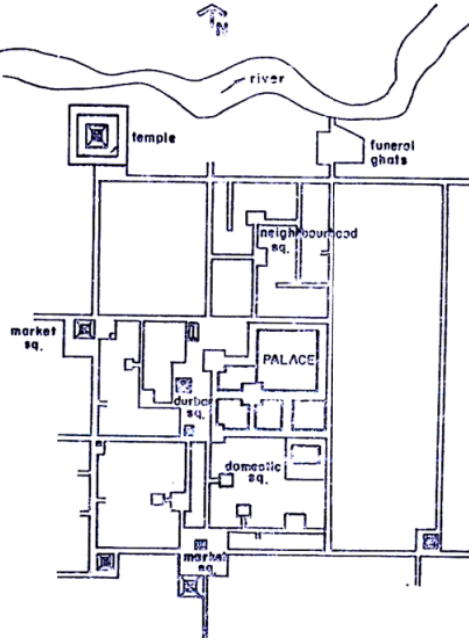


Figure 3: A diagrammatic Layout of a Typical *Malla* Town Showing a Hierarchy of Urban Open Spaces

Source: Tiwari (1989).

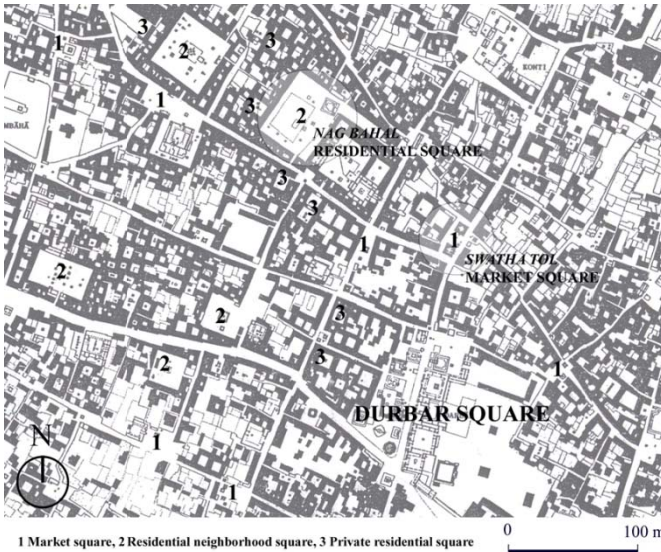


Figure 4: An Urban Pattern of Patan City Showing the Hierarchy and Distribution of Urban Squares

Source: Chitrakar (2006).

The market square is a public open space formed at the intersections of several streets that culminate in it. Most street squares reflect a nodal point of a town and make highly informal urban space settings with no symmetry found in the physical layout (Chitrakar 2006; Tiwari 1989). While the shape and size of such squares greatly vary, each open space exhibits a distinct design in terms of spatial layout and enclosure. The residential neighbourhood and private residential squares form public open spaces organised around a courtyard. A combination of these squares often forms a series of interconnected courtyards embedded within urban blocks (Figure 4).

In traditional neighbourhoods, public open spaces account for approximately 12% of the total housing area (Adhikari, 1998). These open spaces include a variety of elements of urban interest that serve both functional and aesthetic purposes. Chitrakar (2006) identifies several such elements that include temples and shrines, *pati* (public rest house), wells, *dhara* (stone water spouts), *stupa* and *chaitya* (Buddhist shrines) and *dabali* (an elevated platform for a range of socio-cultural uses). These urban elements are not only used widely by residents on a daily basis, but their strategic placement has also resulted in the formation of a picturesque urban setting with the potential to enhance the open space utilisation (Chitrakar, 2006).

Traditionally, the *Newars* lived in extended families, and displayed considerable ease among neighbours since they believed in the communal living philosophy (Tiwari, 1989). They show a gregarious pattern of urban living with their houses grouped around a central and common open space of residential neighbourhoods (Pant & Funo, 2007). Their lives have always revolved around social networking and exchange in the public realm, which has led to extensive use of public open spaces in everyday life and during festivals and social gatherings. In such neighbourhoods, children play and grow up together in open squares (Shokoohy, 1994); adults or elderly people can be found chatting with neighbours while sitting on a plinth of a nearby *pati*. The streets and squares acquire a new ambience during feasts and festivals, with intense activities taking place related to the socio-cultural and religious use of public open spaces.

3. CONTEMPORARY URBAN GROWTH AND CHANGE IN THE VALLEY

The end of *Rana* rule and the reinstatement of democracy in 1951 established the context for contemporary urban development in the Kathmandu Valley. This change has not only created opportunities for new urban development activities, but it has also brought several physical and socio-economic consequences (Basyal & Khanal, 2001; Chitrakar, 2017a). Two key factors that have contributed to the urban growth and change of the valley are the development of physical infrastructure and a surge in migration and population.

3.1 Development of Physical Infrastructure

The political change was backed up by several development initiatives that were considered fundamental to the progress of the nation. Some of these initiatives

include the development of physical infrastructure, such as the construction of the Tribhuvan Highway in 1956 and other major highways by the end of the sixties (Sharma, 1989; Subba, 2003). By 1975, the present Ring Road encircling the two major towns of the valley, Kathmandu and Lalitpur, was built, providing a linkage between the city core and the hinterland. This facilitated the movement of people and goods within the valley and between the valley and other major areas of the country, including the Terai region. With this, the Kathmandu Valley, which remained a confined area for centuries, gradually started to establish contact with the rest of the nation. Consequently, its urban landscape began to transform dramatically, particularly, since the 1960s. (Thapa *et al.*, 2008). The urban transformation accelerated during the 1970s and 80s (ICIMOD *et al.*, 2007) due to the rapid expansion of city cores and the emergence of urban sprawl that was made possible by greater mobility between geographical locations.

3.2 Migration and Population Growth

Nepal is one of the least urbanised countries in the world where urbanisation is a recent phenomenon (Karki, 2004; Sharma, 2003). Yet, the Kathmandu Valley is one of the fastest growing urban regions in South Asia (Muzzini & Aparicio, 2013). In the last 60 years, the urban population of the valley has increased more than fivefold. The valley currently consists of around 30% of the total urban population of the country (ICIMOD *et al.*, 2007; Poudel, 2012; Muzzini & Aparicio, 2013). Migration, which emerged as a distinctive 'urban phenomenon' in the post-*Rana* era, has significantly contributed to the growth of the urban population of the valley. In 2001, 42% of the population living in the valley were migrants (Thapa *et al.*, 2008). The migrating population has increased substantially in the last few decades with several consequences. Studies have found that the growth of a migrating and transient population has led to the changing socio-economic profile and increasing heterogeneity of residents in the new growth areas (Chitrakar, 2016a). Subedi (2010) found that Kathmandu city is the most complex in terms of ethnic composition, which is an outcome of both domestic and international migration. With the rise of multiculturalism, a diverse ethnic environment is becoming an inevitable phenomenon in the valley's new neighbourhoods (Pradhan, 2007; Toffin, 2010). Shah and Pant (2005, p. 9) observe that in the changing social environment, "old ties and beliefs are under severe stress, while the migrant communities of recent decades have yet to evolve into communities".

3.3 Contemporary Urban Scenario

Kathmandu Valley Environment Outlook (2007, p. 54) mentions "uncontrolled urban sprawl" and "unplanned land subdivision" as two major issues, among others, related to the contemporary urban development of the Kathmandu Valley. Although several policy and planning approaches were taken to regulate the urban development process from the early phase, the authorities have largely failed to deliver a positive outcome (Chitrakar *et al.*, 2016). The contemporary urban

scenario demonstrates the uncontrolled and haphazard growth of urban sprawl in the new growth areas often labelled as “anarchic urbanisation” by some scholars (see Toffin, 2010, p. 151) (Figure 5 and 6). Adhikari (1998) argues that virtually all Nepalese new towns or urban expansions of recent origin have evolved unplanned, with the Kathmandu Valley as no exception. In the valley, a large fraction of land development has taken place informally through the efforts of private land brokers (Karki, 1991). Subba (2003, p. 119) makes a similar observation and argues that “informal land development processes have emerged as the dominant sector in the production of space in the valley”. According to Shrestha (2010), it is estimated that approximately 90% of houses are still constructed informally, following the traditional practice of owner-built housing development. These shortcomings with contemporary urban development are directly reflected in the development of the new growth areas, with poor provision of basic infrastructure. There is a severe shortage of community facilities, including open spaces and green areas and other public amenities in the new neighbourhoods of the Kathmandu Valley (Adhikari, 1998; Chitrakar, *et al.*, 2014). Shrestha (2001, p. 17) observes that “unlike [the] old neighbourhoods of Kathmandu, the new neighbourhoods are merely a group of houses”, without any character of a cohesive community.



Figure 5: An Aerial View of the New Baneshwor Area in Kathmandu

Source: Google Earth (2024).



Figure 6: Urban Environment of the New Baneshwor Area

4. THE CHANGING NATURE OF PUBLIC OPEN SPACES

The existing regulations to control the urban development process in the Kathmandu Valley are weak and lack an effective mechanism (Chitrakar, 2023). The Building By-laws (KVTDC, 2007) have some guidelines for planned residential development (taking place through a Land Pooling scheme and private housing development), mainly focusing on access roads, open space requirements and the geometry of residential plots. Yet, these are inadequate and hence, found to be less effective in regulating the development process. One major shortcoming with the current By-laws is that there are no comprehensive guidelines available for the development of public open spaces in the new growth areas. Some regulatory provisions in the By-laws are limited to the area requirement of open space only and applicable to the planned residential developments (Shrestha, 2010). Hence, no public open space standards exist for residential development spontaneously taking place, following the informal process of urban land development. The consequences are seen in the new growth areas in which the provision of physical infrastructure, such as open spaces has become less important, and is left largely to the developer's decision without any appropriate intervention from the authorities (Chitrakar, 2023).

Over the past few decades, there has been a growing trend in the development of new neighbourhoods without satisfactory allocation of public spaces and social amenities. Evidence suggests that the development of public open spaces has remained poor both in the planned and unplanned new neighbourhoods (Chitrakar, 2015). Shrestha (2001, pp. 17–18) found that there is “a total lack of shared open spaces for social interaction or playground for children” in most new neighbourhoods

of the Kathmandu Valley. These observations match with the data published by the Ministry of Urban Development in the National Urban Development Strategy (NUDS). The NUDS highlights a “bleak picture” of the current status of open spaces in the two major municipalities of the Kathmandu Valley, Kathmandu and Lalitpur, with their proportion being only 0.48% and 0.06% respectively (MoUD, 2017, p. 3).

While the unplanned new neighbourhoods of the Kathmandu Valley have practically no open spaces, there are noticeable problems with public open spaces in the planned new neighbourhoods, including the gated communities (Chitrakar, 2015) (Figure 7). Shrestha (2005) observes that the planning and design of open spaces in the planned new neighbourhoods are not satisfactory, as their shape and location are inappropriate, and there is a lack of facilities such as a playground or sitting areas to render them users unfriendly. Furthermore, the amount of open spaces, which ranges from 2.5 to 5% of the total developed land area is far less than what is needed to fulfil the needs of the residents, including different age groups (Shrestha, 2005). Public open spaces without basic amenities or elements of interest do not contribute to active or passive engagement with the space. The open spaces are, thus, less inviting, and in appropriate for use during adverse weather conditions. Unfortunately, it is clear that public open spaces are no longer the central elements of the new neighbourhoods. If public open spaces are designed and developed well and the physical setting is conducive to life and activity, it can dramatically increase socialisation by combining necessary, optional and social activities on a common platform (Gehl, 1987). However, this platform is very much missing in the new growth areas of the valley in the present changing context.

The use of public open spaces is changing with the changing provision. Studies have found that accessibility is one of the major issues with the use of the existing public open spaces in the new neighbourhoods of the Kathmandu Valley (Shrestha, 2005; Chitrakar *et al.*, 2022). An urban open space needs to be accessible to the users, both physically and visually, to generate public life and activities (Whyte, 1980; PPS, 2000). However, these open spaces are most often found to be closed due to poor or lack of management and are not open to the residents on a daily basis (Chitrakar *et al.*, 2017b). The publicness and utility of the open spaces, therefore, have been compromised on several occasions as these spaces operate at the discretion of neighbourhood management committees to control their access and use (Chitrakar *et al.*, 2022).

The use of public open spaces has also been affected by the lack of regular maintenance. Scholars argue that the physical condition of public open space can influence its use (Carr *et al.*, 1992; Gehl, 1987; Whyte, 1980). However, in the Kathmandu Valley, studies have found that the present condition of public open spaces in the new neighbourhoods is largely unsatisfactory due to poor maintenance as evident in littered spaces, unpaved surfaces and broken walls (Chitrakar *et al.*, 2017b; Chitrakar *et al.*, 2022). The poorly maintained public open spaces have failed to invite people as the users do not feel safe and comfortable in such spaces

(Dempsey & Burton, 2012). Gehl (1987) suggests that optional activities in public open spaces take place when there is a favourable physical condition. However, the current unsatisfactory condition of public open spaces has led to a low level of optional activities taking place daily in the new neighbourhoods. Moreover, studies have also found that residents are not able to use some of the open spaces because these have been leased out to private parties for financial returns, and controlled by those who operate them (Chitrakar *et al.*, 2022). This supports the views made by Carr *et al.* (1992) on the potential disadvantages of increasing private control of public space. As a result of all these changes, there is a noticeable shift in the use of public open spaces, which has been confined to very few activities and locations and often for a limited time of the day.

5. SOCIAL SUSTAINABILITY OF THE NEW GROWTH AREAS

In the previous section, we noted that due to the problems with controlling the urban development process and the lack of planning guidelines, the nature of public open spaces has changed significantly in the new neighbourhoods of the Kathmandu Valley as compared to traditional neighbourhoods. But, what does it mean for the social sustainability of the new growth areas? This section will focus on finding answers to this critical question.



Figure 7: Public Open Spaces in the Gongabu Residential Area, which is a Planned New Neighbourhood

The concept of sustainability has returned to the approaches in contemporary urbanism following the publication of the report *Our Common Future* (also commonly known as the Brundtland Report) by the UN World Commission on Environment and Development in 1987 (see Brundtland & Khalid, 1987); it has now become a key concern of urban development among architects, planners and policymakers (Davidson, 2010). According to Dempsey *et al.* (2011), sustainability is no longer about environmental concerns only, but it also incorporates economic and social dimensions. Although the social dimensions of sustainability have received less attention in academic and policy debates (Davidson, 2010), in recent years, there is a growing consensus that urban development should aim to create sustainable

communities. This has helped to integrate social sustainability into the contemporary urban development process as we explore the role of cities and neighbourhoods in developing communities that meet the physical, social and psychological needs of the residents. But, has contemporary urban development in the Kathmandu Valley resulted in the creation of sustainable communities in the new growth areas? Or to what extent, has the process of building sustainable communities been affected by the changing nature of public open spaces?

According to Woodcraft (2011, p. 16), social sustainability “combines [the] design of the physical realm with [the] design of the social world – infrastructure to support social and cultural life, social amenities, systems for citizen engagement and space for people and places to evolve”. On a similar note, Dempsey *et al.* (2011) argue that both the physical and non-physical factors contribute to the realisation of urban social sustainability. Some of the physical factors include an attractive public realm, accessibility (to public facilities, including open spaces and green areas), local environmental quality and sustainable urban design, whereas quality of life and well-being, social capital, social interaction, social networks and sense of community are some key non-physical factors (Dempsey *et al.*, 2011). If we consider these factors as a tool to measure the social sustainability of the new growth areas in the Kathmandu Valley, the picture looks grim. While the design of the built environment can have a direct impact on building social relationships and thus, contribute to the development of social capital, the overall loss or unsatisfactory development of public open spaces in the new neighbourhoods suggests that the new growth areas have very little to contribute to supporting the social life and activities of the residents. The residents are largely deprived of both the physical and psychological benefits of using public open spaces. This has not only affected the quality of life and had their social well-being compromised but there is a visible decline in the public realm due to limited opportunities available for social networking and exchange in physical space.

Public open space is a key physical feature of urban neighbourhoods with the potential to offer a host of subjective meanings (Cattell *et al.*, 2008). According to Abu – Ghazze (1996), public open space in urban neighbourhoods has meaning for people as it invites them to use and participate by creating a common platform in its provision. However, the current provision of public open spaces in the Kathmandu Valley has impacted how they are used, with consequences on their ability to offer a psychological meaning for the users. Studies have found that the existing public open spaces are less successful in offering any meaning for the residents of the new neighbourhoods in the changing urban context (Shrestha, 2001). Evidence also points out a relatively poor development of a sense of community among neighbourhood residents using public open spaces (see Chitrakar, 2016a; Chitrakar, 2016b). In the unplanned new neighbourhoods, the sense of community is almost non-existent, due to the loss of public open spaces and social life and activities. In the planned new neighbourhoods, it is weak and inadequate (Chitrakar, 2016b).

Residential neighbourhoods have long been linked with the notion of a community formed based on physical proximity, with the development of social ties and

relationships among residents (Gregory *et al.*, 2011). However, in the Kathmandu Valley, this community building process has been affected by residents' lack of ability to develop a satisfactory level of sense of community (Chitrakar, 2016a). The residents of the new neighbourhoods have a relatively good knowledge of their neighbours and the prevailing ethnic diversity does not seem to have negative influences on social acquaintances. Yet, such acquaintances are limited among neighbours located in very close proximity, suggesting a little tendency to generate formal social networking and exchange (Chitrakar, 2016a). This indicates that, in the valley, proximity-based social interactions are not taking place sufficiently, thereby not contributing much to building a sense of community. At the same time, the inadequate development of social interactions and formal social networks, which are considered integral aspects of social capital (Forrest & Kearns, 2001), indicates that new neighbourhoods are struggling to cope with the prevailing social change. As scholars have claimed in the Western contexts (see Madanipour, 2003; Wirth, 1938), contemporary society in the valley has also become individualised to a large extent, due to the fragmentation of social groups in different geographical locations as they migrate from one place to another. Also, the traditional basis of socio-cultural associations has largely been lost in the new neighbourhoods as an outcome of the changing demographic composition (Chitrakar, 2015). Without any doubt, these consequences have had a negative impact on the process of building sustainable communities and therefore, the sustainability of social life has emerged as a major challenge of contemporary urban development- the major factor behind these consequences being the current transformation of public open spaces in the new neighbourhoods of the Kathmandu Valley.

6. CONCLUSION

Public open spaces are an important part of the urban fabric that offer a physical setting to perform a range of social activities within a community. Cities in the past demonstrated the tendency to develop urban open spaces that would contribute to social life and activities through their physical layout and configuration. However, the nature of public open spaces is changing in contemporary cities due to their rapid transformation, with consequences on the nature of the public realm and a sense of community.

Not only has contemporary urban development in the Kathmandu Valley been influenced by the global forces of urban change, but there is a lack of an effective mechanism to control urban growth and change to further complicate the problem. This is evident in the severe shortage of community facilities, including open spaces and green areas and other public amenities in the new growth areas. Over the past few decades, the new neighbourhoods of the valley have witnessed a dramatic loss of public open spaces, resulting in poor provision of communal meeting areas, and with a considerable impact on social life and activities. While public open spaces no longer remain the central elements of these neighbourhoods and do not provide a common platform for social networking and exchange, the changing nature of public open

spaces has affected the quality of life and social well-being of the residents. The consequent decline in the public realm and sense of community has not only hindered the process of building sustainable communities in the new growth areas of the Kathmandu Valley, but social sustainability has emerged as a major challenge of contemporary urban development.

It has now become imperative that the development of residential neighbourhoods needs to integrate the process of building sustainable communities as a major feature of urban development in the new growth areas of the Kathmandu Valley, with meticulous assimilation of social elements into neighbourhood governance and organisation to enhance social networking and exchange among residents. There is also a need for devising a proper mechanism to cope with socio-demographic changes that are taking place within the new growth areas so that these changes do not hinder the process of community development. The challenge also remains to develop residential neighbourhoods that incorporate all the elements of physical and socio-cultural significance, including open spaces, to support the social life and activities of the residents. Maintaining the social quality of urban life is important and possible through better provision and use of public open spaces. Future urban development plans for the Kathmandu Valley should consider this factor and attempt to establish public open space as a critical social amenity in the new growth areas.

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The Impact of Digital Platform on Food Green City Sustainability

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ABSTRACT: The Food Green City (FGC) program emphasizes a human settlement where the residents can experience a quality of life by utilizing resources that are friendly to nature, culture, and the future. The main goal of the program is to transform carbon dioxide into carbohydrates to minimize carbon emissions and to free society from hunger. Nepal Academy of Science and Technology (NAST) initiates the FGC program in Nepal. It has been organizing the training, workshops, hands-on programs focusing on rooftop gardening and also practicing urban agriculture like hydroponic, aeroponic, vertical farming, and container gardening on hardscape. A digital platform is an internet-based technology that facilitates performing multiple tasks under the same roof. The principal target of it is to develop an amicable working environment between the producer and the consumer to interact with each other. In the modern age, digital platforms can bring revolutionary changes in all domains, including FGC program. Using digital platforms, namely social media, smart phones, SMS, internet calling apps (Viber, WhatsApp, Zoom meeting, etc.), promotes knowledge exchanging, updating, and connecting people of the same fraternity easily. So, digital platforms are an indispensable technology to conduct programs like FGC effectively. Like digital platforms, NAST has developed a nexus where stakeholders can stay under an umbrella through the internet called the farming network (FN). The FN guarantees the sharing of the best farming practices and technologies, encouraging permaculture and soilless vertical and organic farming with integrated pest management. It also boosts urban farmers by exploring and creating technical supports, establishing small-scale industries, and developing food product sectors.

Keywords: Food Green City, Digital Platform, Hunger Free, Zero Carbon Emission, Urban Agriculture, Farming Network.

1. INTRODUCTION

Since 2007, over 50% of the total global population has been living in urban areas and is anticipated to exceed 68% by 2050.¹ Agricultural land has been transformed into a concrete forest due to ongoing rapid urbanization. Thus, expanding city area creates colossal trouble in the food production impacting on the

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consumption patterns and demand cycle. To minimize the food crisis to some extent, a novel program called, Food Green City (FGC) has been in operation practice. Based on the concept of FGC, several urban areas have been practicing greenery by planting food-producing and medicinal plants in addition to common plants. Increasing greenery helps ameliorate both carbon emission and food hunger while transferring polluting carbon dioxide into carbohydrate.²

Urban farming would play a crucial role in sustainable food supply with numeral advantages.³ The benefits of urban agricultural techniques are helping urban waste to food production through the process of Phyto sanitation. It has helped in the production of fresh fruits and vegetables, improving the economic sector, and converting each home of a city into greenery. Roof top gardening is one of the essential farming practices for urban settlements that serve in the management of food security problems and encourage sustainable agriculture.⁴ Various types of roof top farming namely hydroponics, aeroponics, and green roofs or container gardening have been practiced.⁵ The roof top gardening acts as an air purifier, carbon dioxide absorber and consumer of storm water.⁶ Having significant advantages, the roof greenery, recent advances have developed green walls. These green walls also help in regulating temperature. It also supports for developing a sustainable city with the help of lessening the food insufficiency to which today's world is combating.

City greening practices have utilized the artificial intelligence (AI) technology, and utilizing digital platforms (DP). The use of AI and DP has become daily routines to assist in everyday daily chores seems impossible without their usage. DP is a network where people can share and exchange their novel thoughts and opinions worldwide. It is an internet-based meeting place. In today's world, digital platforms have brought dramatic changes to all sectors.⁷ The effective DP like social media, smart phone, SMS, internet calling apps (Viber, Whatsapp, Zoom meeting) has become popular online meeting site.⁸ The question arises of how the role of DP is helpful to accomplish food green city program. Of course, DP doesn't support in extending urban farming space but provides ideas to cultivate suitable food plants desirable to the available spaces. Experts or experienced farmers can share his/her own experiences about difficulties facing and their adequate solutions through DP. Sharing ideas, concepts and experiences is one of the keyways to add a pillar in the FGC program. Other advantages of using DP are getting information to utilize resources more efficiently and effectively and connecting community people to the nexus of food, water, energy, nutrition, and human health. Additionally, DP spreads the knowledge to generate circular economy. The economy is designed to be restorative and regenerative. The circular economy is possible when people use maximum quantity of recycling and reusing materials than the non-cycling materials for the betterment of natural, economic and social capital growth. So, the DP plays a significant role for developing a sustainable FGC.

Nepal Academy of Science and Technology (NAST) is an initiative institute working on FGC program. It envisages creating a digital platform to develop an

interface among its stakeholders. The FGC program mainly include urban and peri-urban communities, municipalities, academia, schools, and/NGOs delivering services on environment, food, and health. They will get connected through a digital platform developed as a web portal by NAST named the farming network (FN). The FN provides digital space for sharing ideas and knowledge on food products marketing, land suitability, local food plants species and community of practice. Furthermore, FN promotes the best farming practices and technologies, encouraging permaculture, soilless vertical farming, organic farming with integrated pest management, and wall greening for both aesthetic and temperature regulations. Also, urban farmers can explore technical support for developing food products and establishing small-scale industries as the FN connects the farmers with food technicians and entrepreneurs.

2. MATERIALS AND METHODS

2.1 Stakeholders' Connection by Digital Platform

DP connects relevant stakeholders living around the globe in the rapidly urbanized environment. DP supports in sharing experiences, information, and best practices with a multi-actor approach, including farmers, researchers, agronomists, and industries. The platform assures the confidentiality of specific outcomes and data with its members and related organizations. The most important aspect of using a digital platform is facilitating the exchange of goods, services, and information among relevant people. Many types of digital platforms are accessible to a layman as well. Most of people uses following digital platform:

- (a) Social media (Facebook, Instagram, twitter LinkedIn)
- (b) Media sharing platform (YouTube, Vimeo)
- (c) Knowledge sharing platform (Quora digestive, yahoo)
- (d) Video calling platform (Viber, Whatsapp, Skype, Messenger, Google voice Zoom, Google Talk, Microsoft Teams)
- (e) Others (website, portal, email)

2.2 NAST's Proposed Plan for Connecting Stakeholders

To connect Nepalese stakeholders, NAST has signed an MOU with 16 municipalities, including Lalitpur metropolitan and Dhulikhel municipality, and the MOU is going steadily with the rest of the cities. The detailed strategy connecting NAST with both national and international stakeholders in farming network (FN) is depicted in Figure 1. The academy has made FN, which is an online site to communicate with the FGC partners globally. Those farmers can be members of FN which will be nominated by local government and has MOU signed between NAST and the local communities. Individuals person, entrepreneurs, R&D institutes, food producers, and cottage industries can be members of FN. In addition, policymakers, local, provincial and central government are the main stakeholders.

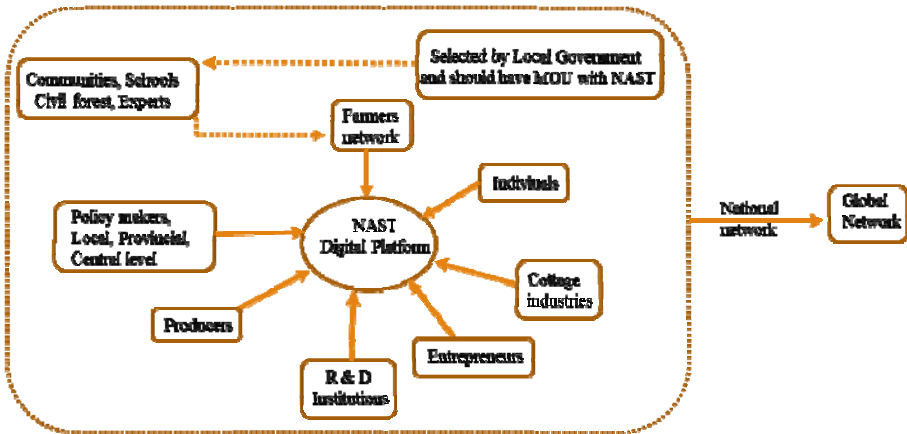


Figure 1: NAST’s Proposed Strategy for Farming Network

NAST would prioritize FGC program as follows:

1. **Administrators:** Human resources recruitment in a specific field is the primary step to conduct a new program. Regarding FGC program, people with special experience in the field of procurement, accounting and information technologist needs to be enrolled in the inception time. The number of staff would be determined with respect to the program succession.
2. **Financial Aspects:** NAST creates its own funds by collecting Rs. 2000 and 10000 from the annual and life members, respectively. Scientists/researchers working in the program can apply for a grant to several funding agencies like UNDP, UNEP, ADB, etc., which would be robust financial supporters. The FGC program can collect some funds by sharing our experts’ knowledge through conferences, seminars, and workshops.
3. **Trade and Marketing:** Informing and sharing the food products produced by city farmers will be done through online marketing. In this program, NAST creates a farming network through which producers, consumers, and industries will be connected. Urban agricultural products would get marketed through the FN. Non-urban farmers can also get access using this network and are able to get a fair price directly without the involvement of a negotiator. Especially, the FN platform is designed only for urban farmers where city dwellers will be able to consume fresh foods at a reasonable cost.
4. **Research and Information:** NAST will carry out the research relating to nutrition, value added, and new lucrative technologies that are involved in quality food production by urban cultivation. Conducting research in horticulture, herbs, and MAPs farming would be the priority sectors of the program. Our institute will disseminate research information and output done on its premises among stakeholders through the FN. Sharing research activities will update to the current situation in the need of city farmers.

2. **Less air pollution:** Virtual conferences and workshops help to reduce the number of vehicles on the road and reduce carbon dioxide emissions. The environment would be less polluted if vehicles were limited. That's a way, FN is one of the principal factors in reducing air pollution. Air quality determines the quality of life of city dwellers.
3. **Hunger Free Society:** FN assists in instantly connecting producers and end-consumers. A farmer can get adequate value for his/her food products without the involvement of a middleman, and consumers can get fresh food at a reasonable price. In this way, the chances of wasting food products are minimal. So, FN will solve food scarcity to some extent.
4. **Improving Economic Status:** Farmers take advantage of FN to sell products at a fair price instead of wasting them. Urban farmers can gain economic support by selling food items. Farmers can use the money saved on traveling to different fields, which helps to improve the economic situation.
5. **Knowledge Exchange Platform:** FN makes a farmer accessible to an expert staying elsewhere on the planet. The essential information and knowledge can be obtained in a second. There is no time boundary to call a meeting like physically attending does. Problems would be solved and can share experiences instantly using FN platform. Sharing knowledge and experiences among stakeholders is compulsory to make a sustainable FGC.

4. CONCLUSION AND PROSPECTION

Focusing on the strategic needs of DP in FGC, this article provides the benefits of social media in promoting FGC program. DP circulates ideas and techniques needed for a sustainable urban by zero-carbon emission. Using digital platforms like social media, virtual meeting apps, and mobile SMS is the best way to show a big impact on FGC. Virtual meetings by means of Zoom and Microsoft Teams have shown remarkable effects to reduce air and noise pollution, saving traveling costs and time, minimizing traffic, lowering the chances of road accidents, and amplifying ideas in a group. There is no time boundary to call a meeting by means of the DP. Considering the above benefits, the city dwellers can start feeling a quality of life, which is the main criterion for establishing FGC. All in all, DP plays a crucial role in developing a sustainable FGC program. One of the main targets of DP program is disseminating knowledge and technologies for planting fruit trees and medicinal plants on the avenues and vacant sites. These plants produce medicine and fruits for city dwellers and also make a less carbon-emitting society.

In this paper, NAST has developed FN to bring all allies in a group. NAST anticipates that the FN platform would be an effective tool for sharing knowledge, conducting seminars, conferences, and workshops. The platform works as a bridge between producers and end-consumer directly without the involvement of negotiators. Along with, FN is aimed to sell/buy fresh food at a fair price. Both consumers and producers would benefit equally.

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Urban Forestry as a Tool for Disaster Risk Reduction in Rapidly Urbanizing Areas: Study of Dudhauri and Siraha Municipalities

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ABSTRACT: The rapid urbanization of Nepal has transformed it from one of Asia's least urbanized countries to one of the world's top ten fastest urbanizing nations, bringing unprecedented challenges in disaster risk management and environmental sustainability. Urban forestry represents a critical intersection of environmental science, urban planning, and ecological management, and offers vital solutions for cities facing rapid urbanization and increasing disaster risks. This study investigates how urban forestry can serve as a tool for disaster risk reduction in Nepal's emerging urban centers, with a specific focus on Dudhauri and Siraha municipalities along the flood-prone Kamala River. Using a secondary literature review and building upon existing research, including recent studies by Kayastha (2024) on land use changes, this study examined how urban forestry can be a useful tool for reducing disaster risk in rapidly urbanizing cities such as Dudhauri and Siraha municipalities. According to Kayastha (2024), these municipalities experience significant land-use changes due to urbanization and face heightened vulnerability to floods and environmental degradation. The analysis of land use changes from 2010 to 2023 revealed that Dudhauri experienced a 312.68% increase in built-up areas, while forest cover declined from 67.36% to 63.37%. Similarly, Siraha witnessed a 171% growth in built-up areas, accompanied by a reduction in agricultural land from 88.65% to 80.88%. The study concluded that urban forestry offers a viable solution for disaster risk reduction, particularly in flood mitigation and soil stabilization. However, successful implementation requires a comprehensive approach, including mandatory green space requirements, incentive programs, and strong community engagement. These findings provide valuable insights for policymakers and urban planners in developing disaster-resilient cities through the strategic integration of urban-forestry initiatives.

Keywords: *Urban Forestry, Urbanization, Disaster Risk Reduction, Flood, Community Resilience, Land Use Change, Sustainable Urban Planning.*

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1. INTRODUCTION

Urban forestry is a sophisticated discipline that highlights the complex relationship between urban landscapes and tree ecosystems, representing a critical intersection of environmental science, urban planning, and ecological management (Miller *et al.*, 2015). According to Dietrich (2018), beginning in the middle of the 20th century, researchers at the University of Toronto first recognized the need for a methodological approach to tree management in urban settings in 1965, marking the beginning of urban forestry's official academic acknowledgment. This new concept has rapidly emerged as a key aspect of sustainable urban growth, acknowledging trees as more than just decorative accents but as vital infrastructure. The importance of urban forestry for the ecosystem cannot be neglected, as research conducted by Nowak and Crane (2002) suggests that urban trees improve the quality of life in cities by providing a wide range of ecosystem services. In addition to being important carbon sinks, a typical mature hardwood/deciduous tree can absorb 48 pounds of carbon dioxide each year, which it then stores in its fibers until it burns or decomposes, over a lifespan of 40 years (Kazamia, 2024; CO2Meter, 2024). As cities are essentially islands of warmer temperatures and the temperature is warmer in a city compared to the surrounding rural areas (as shown in Figure 1), strategic planting of trees in urban areas can help to reduce the effects of urban heat islands by lowering local temperatures by 2–4 degree Celsius (Nowak & Heisler, 2010). According to research conducted by the Lawrence Berkeley National Laboratory, carefully placed trees can lower urban ambient temperatures through shade and evaporation by providing a natural and affordable climate adaptation method (Akbari *et al.*, 2001).

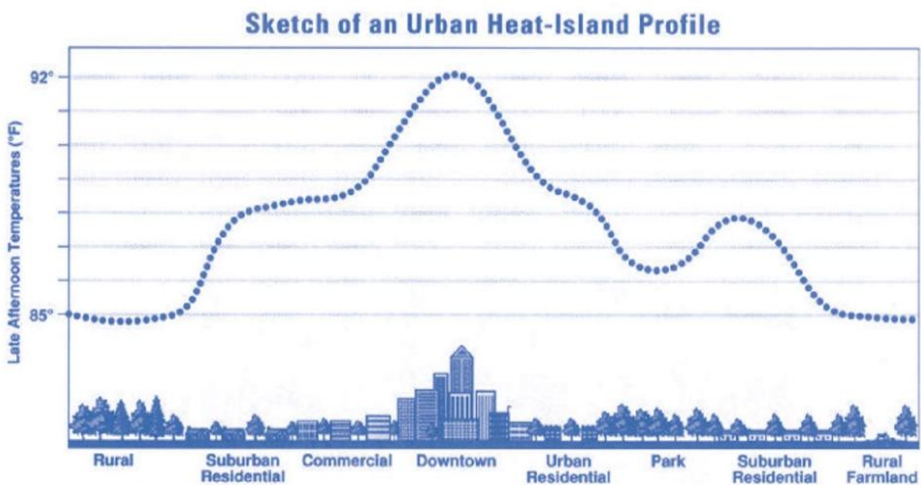


Figure 1: Sketch of an Urban Heat-Island Profile Representing Higher Temperature in Urban Area Compared to Surrounding Rural Areas

Source: Nowak & Heisler, 2010.

Urban forestry can be considered a lifeline for cities dealing with the dual challenges of rapid urbanization and environmental degradation. As urban areas expand, they face rising pressures, polluted air, congested living spaces, and the ever-looming threat of natural disasters (Beauregard, 2015). According to Poe *et al.* (2013), urban forestry offers a way to address these issues by weaving nature into the fabric of cities. Urban forestry is more than planting trees; it is about creating a sustainable balance between urban growth and environmental preservation. For a country like Nepal, which is at a crossroads in its urban development journey, urban forestry presents a unique opportunity to build cities that are not only livable but also resilient to disasters (Bhattarai & Conway, 2020).

2. LEARNING FROM ONGOING GLOBAL SCENARIO

According to Tyrväinen *et al.* (2005), cities worldwide have shown how urban forestry can transform urban landscapes and improve the quality of life. For example, despite its limited land area, Singapore has embraced the vision of becoming a “City in a Garden”. Through innovative approaches like vertical gardens, rooftop greenery, and lush public parks, the city has integrated nature into its urban fabric (Yi, 2020). This has not only improved air quality but also made the city more resilient to climate change by reducing the urban heat and managing storm-water runoff. Similarly, Scandinavia countries such as Norway and Denmark have prioritized green spaces in their urban planning, creating natural barriers against climate change by incorporating forests, wetlands, and green belts into their cities (Randrup & Persson, 2009). Spain has also made significant developments by focusing on urban parks and reforestation projects to combat air pollution and enhance public well-being (Jennings *et al.*, 2017). Some of these examples demonstrate that urban forestry is not only an environmental solution but also a holistic approach to creating healthier and more sustainable cities.

Though, not all cities have succeeded in this endeavor, to the same extent Delhi, India, serves as a cautionary tale. Despite having millions of trees, Delhi struggles with some of the worst air quality in the world (Kandpal, 2024). The reason? Unchecked industrial emissions, vehicular pollution, and rampant construction. This highlights the importance of adopting comprehensive policies that address pollution control and afforestation. In contrast, Beijing’s transformation from a smog-choked city to a cleaner, greener metropolis demonstrates what can be achieved with strict pollution controls and large-scale urban forestry initiatives (Boehmer-Christiansen, 2017).

3. URBANIZATION, DISASTER RISKS AND URBAN FORESTRY

Urbanization can be defined as the shift of population from rural to urban areas or the growth of population in urban areas more than in rural areas. The United Nations affirms that the world is becoming rapidly urbanized, and more than half of the global population lives in urban areas today (United Nations, 2018). According to the UN, the global urban population is expected to reach 68% by 2050, with

approximately 6.7 billion people living in urban areas. In Nepal, this transformation has been rapid, with the urban population increasing significantly after the adoption of the new constitution. The proportion of people classified as urban residents surged from 17% in 2011 to 66% in 2021 (Bhattarai *et al.*, 2023). The current trend of urbanization poses challenges for disaster risk management as urban areas become more vulnerable to multiple natural hazards, including climate change. This has led to increased losses from climate-related events, emphasizing the need for mitigation and adaptation measures (GU, 2019).

Rapid urban expansion often leads to changes in land use, particularly the conversion of permeable land surfaces into impermeable surfaces, such as roads, buildings, and other infrastructure. This transformation reduces the natural capacity of the land to absorb rainwater, leading to increased surface runoff and overwhelming urban drainage systems. Similarly, Bazrkar *et al.* (2015) argued that the impact of urbanization on flooding is not only physical but also systemic, altering local climate dynamics such as increased temperatures and reduced albedo due to built-up environments. Their study on Tehran illustrated how urban heat islands and altered hydrological cycles increase the intensity of local rainfall events, which, combined with poor urban planning, exacerbate flood risks. This systemic view highlights the complexity of the urbanization-flooding nexus and the need for integrated urban planning approaches to mitigate these risks.

This is where urban forestry comes in. By integrating trees, green spaces, and natural ecosystems into urban planning, Nepal can address these challenges head-on. Urban forestry is not just about beautifying cities; it is about creating environments that are resilient to disasters, supportive of biodiversity, and conducive to public health. Dudhauri Municipality, situated between the Siwalik and Mahabharat ranges to north and south, has a rugged terrain with elevations ranging from 158 to 2106 meters, distinguished by gentler southern slopes and steeper northern slopes and houses a population of 70,207 across 14 wards. Meanwhile, Siraha Municipality, located in the southern Terai region at approximately 100 meters above sea level, supports a population of 95,410 across 22 wards. Both municipalities face significant challenges from flooding due to their proximity to the Kamala River, while experiencing rapid urbanization that threatens their natural environments.

These emerging urban centers present unique opportunities to integrate urban forestry into their development plans, potentially serving as models for sustainable urban development in Nepal. Nepal's emerging urban centers, Siraha Municipality in Siraha District and Dudhauri Municipality in Sindhuli District, have a unique opportunity to integrate urban forestry into their development plans. These municipalities are still in the early stages of urbanization, which means they can avoid the mistakes of unplanned development and instead build sustainable and resilient cities.

For example, Siraha Municipality could establish green corridors along riverbanks to prevent flooding and promote biodiversity. Dudhauri Municipality, located in a hilly

region, could focus on afforestation to prevent soil erosion and landslides. Both municipalities could also leverage urban forestry to boost local economies through eco-tourism and increased property values. By incorporating green spaces into their urban planning, these cities can enhance their resilience to environmental and disaster risks while improving the quality of life for their residents.

“This chapter offers a clear plan for all the readers, outlining urban forestry as a tool for reducing disaster risk. It starts by explaining urban forestry, its history, and why it’s important in today’s urban planning and environmental efforts. Using examples from around the world, it shows how urban forestry has been successfully included in city planning in different situations. Then, the chapter focuses on Nepal’s urbanization, looking at how fast urban growth is increasing disaster risks. The chapter uses Dudhauri municipality of Sindhuli district and Siraha municipality of Siraha district as examples, showing how land use has changed, what environmental problems they face, and what people think about these issues. Next, it examines how urban forestry can help with specific disaster risks in these cities. The chapter ends with advice for policymakers and practical ways to include urban forestry in plans for cities that can withstand disasters, both locally and nationally.”

4. OBJECTIVE

To understand land use changes, disaster vulnerabilities, and the ecological and socioeconomic advantages of urban forestry, the potential of urban forestry as a disaster risk reduction tool in Dudhauri and Siraha municipalities must be evaluated.

5. MATERIALS AND METHODS

The chapter is based on survey of literature, such as the research conducted by Ar. Smriti Kayastha under the thesis “Trend of Urbanization and Disaster Risks: A study of Dudhauri and Siraha Municipalities”, which was done under project named Improving Climate and Disaster Resilience of Communities at Risk in Kamala River Basin supported by University Grant Commission.

6. NEPAL’S RAPID URBANIZATION AND ENVIRONMENTAL IMPACTS

Nepal’s landscape has seen significant changes over the past few decades. Nepal, which was once among the least urbanized countries in Asia, is now one of the top ten fastest-growing countries in the world. Reasons such as population increase, rural-to-urban migration, reclassification of rural areas as urban areas, and state reform have contributed to the rapid urbanization in Nepal. By 2050, the United Nations projects that 68% of the global population, approximately 6.7 billion people, will reside in urban areas, with urbanization slowing down while rural populations gradually decline (United Nations, 2018). Rapid urbanization has been a defining feature of the 21st century. Nepal, once one of the least urbanized countries in Asia, is

now among the world's ten fastest urbanizing nations. This rapid shift is driven by factors like migration, industrial growth, economic liberalization, and technology; global trends that are clearly visible in Nepal's changing urban landscape (Pandey, 2023; Sapkota, 2022). With 5,130,000 urban residents and a 3% urbanization rate in 2014, its urbanization rate was 18.2%.

This increase in urban population coincided with a growth in municipalities from 217 to 293. The lines separating developing urban areas from vanishing rural towns have become hazier because of the growth of legally designated urban zones. Following state restructuring in 2017, 753 local political units were established, including 450 rural jurisdictions and 293 municipalities of various hierarchies in Nepal. The conversion of several farming lands into urban development has occurred in various parts of Nepal, and this trend has been driven by a combination of factors, including rural-to-urban migration, natural population growth in cities, and reclassification of rural areas as urban (Bhattarai *et al.*, 2023).

Urbanization in Nepal has presented challenges such as unclear policy frameworks, inadequate municipal services, disaster risks, environmental vulnerabilities, informal settlements, and the prevalence of the informal economy (Mugambwa & Katusiimeh, 2018). Environmental issues, including pollution and deforestation, have also arisen (Sharma *et al.*, 2014). In the context of Nepal, urban development is unavoidable, as urban areas provide employment opportunities, marketing channels, and inputs and services to the rural hinterland and provide the basis for diversifying agricultural production and increasing agricultural productivity (Sharma, 2003).

However, unregulated and unguided trends of urbanization have their own problems, as demonstrated by deteriorating environmental conditions of many large cities such as Kathmandu (K.C., 2015). According to Singh and Dhakal (2024), cities like Kathmandu are growing rapidly, which is marked by unplanned development, deforestation, and pollution are threatening the very qualities that make these cities unique. Kathmandu, surrounded by lush green hills, still benefits from its natural surroundings, but the unchecked expansion of concrete structures is eroding this advantage. If no action is taken, Kathmandu and other emerging urban centers in Nepal risk becoming overcrowded, polluted, and vulnerable to disasters.

Urban growth in developing countries lacks planning and resources, resulting informal settlements and slums that is highly susceptible to disasters (Satterthwaite *et al.*, 2020). Disasters can cause significant damage to critical infrastructure, disrupt services, and result in loss of life and property (Lindell, 2013; Klinenberg, 2018). Cities located in disaster-prone areas, particularly in riverine areas, face increased risks of flooding due to changing patterns of rainfall in the era of climate change and rapid urbanization (Bettencourt *et al.*, 2013). Nepal faces various natural disasters, including earthquakes, landslides, floods, fires, glacial lake outburst floods, and droughts, due to factors like steep slopes, monsoon rains, seismic activity, environmental degradation, and climate change (Khanal, 2020; Pandey *et al.*, 2023). Landslides and floods are also common, particularly during the monsoon seasons,

leading to loss of life, displacement, and destruction (Gyawali *et al.*, 2022). The Nepalese government has implemented measures to address these risks but requires more comprehensive long-term solutions for urban resilience (UNDRR, 2019).

Pradhan-Salike and Pokharel (2017), highlight that in Kathmandu Valley, Nepal, the imperviousness increased from 25% in 1990 to 75% in 2010, significantly increasing flood volumes and frequency of urban flooding events. They further noted that current urban drainage systems, designed for past climate conditions, are increasingly inadequate under the pressures of urbanization and climate change, with the potential for a 40% increase in flooding under future scenarios.

7. ENVIRONMENTAL AND SOCIAL CONSEQUENCES OF URBANIZATION

In Nepal, urbanization has come at a high cost, resulting in several environmental and socioeconomic issues, particularly in regions that are vulnerable to natural disasters (Bhattarai & Conway, 2010). Land use and land cover (LULC) patterns are significantly affected by urbanization, which is a global phenomenon and is defined as the process of population growth and spatial expansion of urban areas (Kumar & Singh, 2023). The demand for housing, infrastructure, and economic activities puts pressure on the surrounding environment as cities grow, leading to the conversion of non-urban land, such as agricultural fields, forests, and wetlands, into urban areas (Dewan & Yamaguchi, 2009). Since land is an essential part of the Earth's surface, land use and land cover interact with the atmosphere and lithosphere. Human activities like industrialization and urbanization have contributed significantly to the land's recent rapid changes (Samal & Gedam, 2015). Rathore *et al.* (2022), predict that by 2100, LULC change will have a greater impact on global biological systems than threats from invading species and climate change combined.

8. URBAN FORESTRY AND DISASTER RESILIENCE

Nepal is no stranger to natural disasters. Earthquakes, landslides, and floods are recurring threats, and climate change is only exacerbating these risks (Nyaupane, 2022). Urban forestry can play a crucial role in disaster risk reduction. For instance, trees and vegetation stabilize soil, reducing the risk of landslides in hilly and mountainous regions (Lange *et al.*, 2018). In cities like Kathmandu, where landslides are a constant threat, urban forestry can serve as a natural defense mechanism.

Green spaces and urban forests also act as natural sponges, absorbing rainwater and reducing surface runoff (Song, 2022). This can help mitigate the impact of floods, which are becoming increasingly common due to erratic rainfall patterns and deforestation. Additionally, urban forests help regulate local climates by reducing temperatures and mitigating the urban heat island effect (Murugadoss *et al.*, 2024). This is particularly important in the context of global warming, which is making extreme weather events more frequent and intense.

According to Verma (2024), beyond the physical benefits of urban forests, green spaces provide safe havens during disasters. Parks and urban forests can serve as evacuation sites and emergency shelters, offering refuge to communities in times of crisis. They also promote mental well-being, which is crucial for communities recovering from traumatic events.

9. CASE STUDIES: DUDHAULI AND SIRAHA MUNICIPALITIES

Dudhauri municipality of Sindhuli district and Siraha municipality of Siraha district, located along the Kamala River, also encounter multiple urban development challenges. These municipalities were also declared by annexing several of the then VDCs and are currently undergoing rapid changes due to increasing urban population and haphazard urbanization. Many communities that are located along the river face growing risks from flooding, erosion, and other water-related hazards while the haphazard urbanization trends continue (Maskey *et al.*, 2023).

Dudhauri Municipality, spanning 390 km² between the Siwalik and Mahabharat ranges with elevations from 158–2106 m, hosts a population of 70,207. In contrast, Siraha Municipality covers 94 km² in the southern Terai region at approximately 100 m elevation, with a larger population of 95,410 (National Population and Housing Census, 2021). Both municipalities are characterized by a mix of urban and rural areas, with significant agricultural activity and a growing built-up area. The Kamala River flows through Dudhauri and Siraha Municipalities, making it highly susceptible to flooding during the monsoon season. Both municipalities have experienced significant flood events in recent years, resulting in the loss of life, property, and agricultural land. The increasing urbanization has further exacerbated the region's vulnerability to disasters, as more people and infrastructure are exposed to flood risks.

The urbanization trend in Dudhauri and Siraha municipalities is gradually increasing, though at a varying pace. In Siraha, while 31.8% of respondents consider urbanization to be moderate, a significant portion (34.7%) perceives it as slow, and 26.5% believe it is occurring very slowly. Only a small percentage (4.7%) see rapid urbanization. Similarly, in Dudhauri, the trend is also progressing gradually, with 42.3% of respondents describing urbanization as very slow, 30.7% as slow, and 19.5% as moderate. A minority (7%) consider the process rapid, with just 0.5% perceiving it as very rapid. These responses indicate that while urbanization is advancing in both municipalities, it is perceived as a slow-moving process by most residents (Kayastha, 2024).

10. LAND-USE/LAND COVER CHANGE ANALYSIS OF DUDHAULI AND SIRAHA MUNICIPALITY

As urbanization continues in both municipalities, land use changes from 2010 to 2023 in both municipalities reveal significant urbanization impacts. Dudhauri experienced a 312.68% increase in built-up areas, expanding from 248.49 to

1,025.47 hectares, while forest cover declined from 67.36% to 63.37% after 2017. Agricultural land saw a dramatic reduction from 28.97% to 14.05%, while grassland areas increased substantially from 2.03% to 17.96% (Kayastha, 2024). Similarly, Siraha witnessed a 171% growth in built-up areas, reaching 1,345.18 hectares, accompanied by agricultural land reduction from 88.65% to 80.88% and dense vegetation decline from 3.63% to 2.79% (Kayastha, 2024).

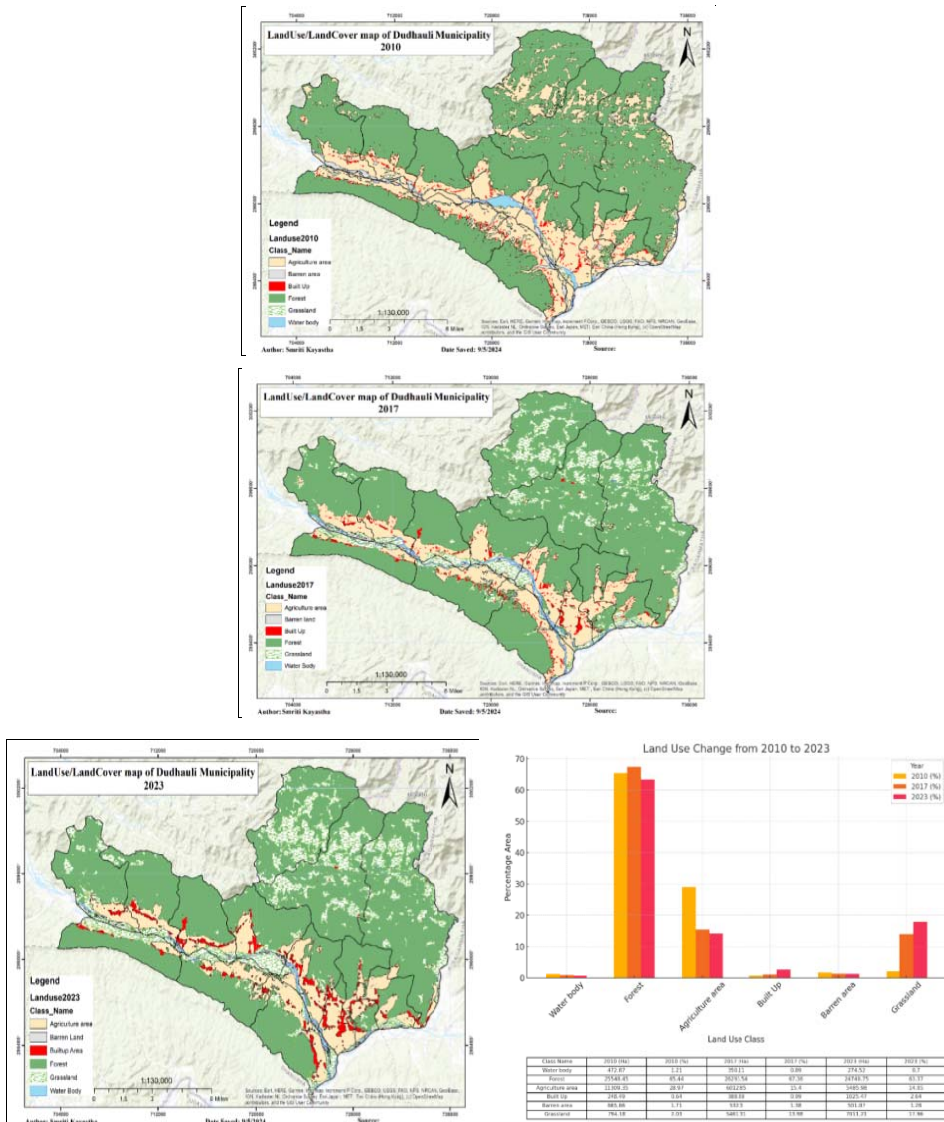


Figure 2: Land-Use/Landcover Map of Dudhauri Municipality for the Year 2010, 2017 and 2023

Source: Kayastha, 2024.

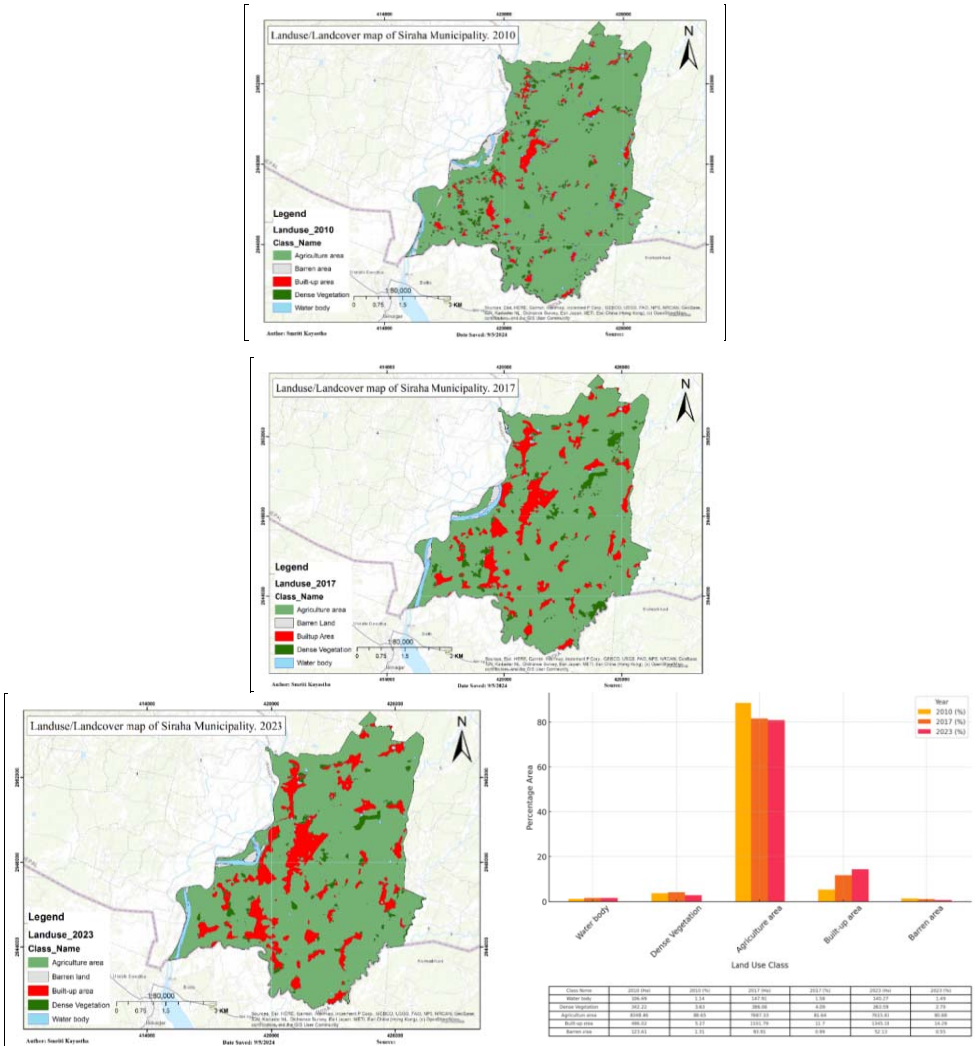


Figure 3: Land-Use/Landcover Map of Siraha Municipality for the year 2010, 2017 and 2023
 Source: Kayastha, 2024.

As increasing urbanization, the natural landscape in Siraha and Dudhauri municipalities is experiencing incremental changes. According to research conducted by Kayastha (2024), in Siraha, 30.6% of respondents perceive a moderate environmental impact, 27.6% a slight one, 22.9% a significant one, and 3.5% a severe one. In Dudhauri, 29.8% report a moderate impact, 26.5% minimal, 25.6% slight, 15.3% significant, and 2.3% severe. These findings indicate that while urbanization is reshaping the environment, the perceived intensity of its effects remains moderate to slight for most residents. However, the ongoing expansion of built-up areas, deforestation, and land-use changes continue to contribute to

environmental degradation, highlighting the need for sustainable urban planning (Kayastha, 2024).

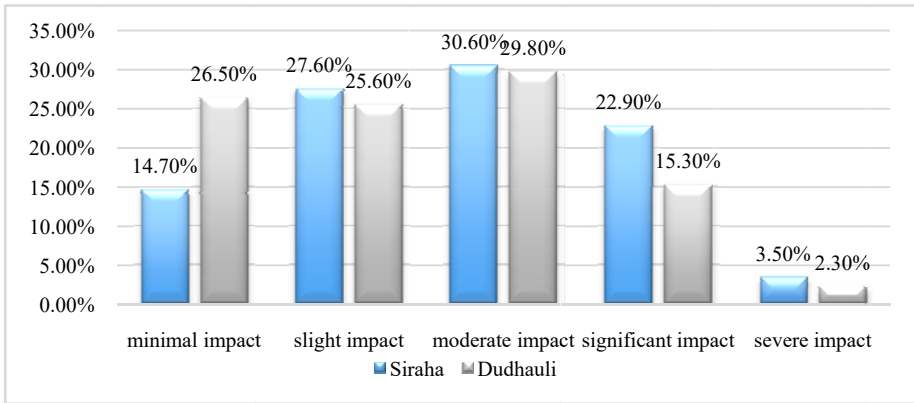


Figure 4: Intensity of Urbanization’s Impact on the Natural Environment

Source: Kayastha, 2024.

With increasing urbanization, both municipalities face significant flood vulnerability due to their proximity to the Kamala River, with approximately 67.6% of respondents in Siraha municipality considering floods a severe threat to livelihoods, while 25.3% view them as moderately concerning, and only 1.8% see them as insignificant. Similarly, in Dudhauri, 68.8% report floods as a major concern, 24.7% as moderate, and 1.9% as minor. These findings demonstrate that flooding significantly impacts daily life and livelihoods across both municipalities. (Kayastha, 2024)

Rapid urbanization in Nepal has come up with both challenges and opportunities in cities like Siraha and Dudhauri municipalities. These municipalities are not only growing but are also becoming more vulnerable to disasters and environmental degradation. This emphasizes how critical it is to implement disaster risk reduction strategies like urban forestry and sustainable urban planning to reduce these effects and increase resilience in quickly urbanizing regions.

11. THE ROLE OF URBAN FORESTRY IN DUDHAURI AND SIRAHA MUNICIPALITY

In rapidly urbanizing municipalities like Dudhauri and Siraha, urban forestry plays a very important role in reducing disaster risks. As these areas keep on developing, natural landscapes are being replaced by concrete structures, which increases vulnerabilities of factors such as flooding, soil erosion, and rising temperatures. These risks can be mitigated through integration of urban forestry into city planning which promotes environmental sustainability and enhance community resilience.

Flood risk reduction is one of the most significant benefits of urban forestry. Trees and green spaces serve as natural water regulators that help in water retention, decrease surface runoff and prevent overwhelming of urban drainage systems. In flood-prone

areas like Dudhauri and Siraha, trees should be planted along rivers and in the urban areas to slow down the storm water flow and reduce the severity of floods. Also, green spaces enhance *groundwater recharge*, which means that there is more water stored in the ground and less likelihood of flash floods.

One of the most crucial roles of urban forestry is *preventing soil erosion and stabilizing land*. Deforestation because of urbanization leads to soil weakness and thus increases the risk of landslides and erosion. Trees also assist in retaining soil through their root systems and thus prevent erosion and protect the land from being washed away by rainwater. The reforestation of degraded lands and the establishment of tree buffers along rivers in Siraha and Dudhauri, especially in the hilly regions, is very important in the restoration of soil stability and the ecological system.

Urban forestry plays a very important role in *climate resilience*. Built-up areas not only absorb and retain more heat, but it also leads to *higher temperatures and urban heat island effects*. Incorporating trees and green spaces helps to keep the area cool by *reducing extreme heat risks, improving air quality, and lowering energy demands for cooling*. These benefits are particularly crucial for ensuring a livable environment as temperatures continue to rise due to climate change.

Beyond disaster risk reduction, urban forestry also enhances *community well-being*. Green spaces *serve as natural shelters during disasters*, provide recreational areas that support mental and physical health, and offer economic opportunities through ecotourism and sustainable afforestation projects. Community-led tree-planting and conservation efforts *provide environmental stewardship and ensure long-term sustainability*.

12. CONCLUSION

Urban forestry can be an essential and feasible approach for reducing disaster risks in Nepal's rapidly growing towns, especially in the areas of Dudhauri and Siraha municipalities, situated along the flood-prone Kamala River basin. Highlighting an alarming trend of swift urban growth paired with environmental harm, this research calls for quick and strategic action. The examination of land use changes from 2010 to 2023 vividly illustrates the environmental consequences of urbanization. Dudhauri Municipality saw a staggering 312.68% rise in developed areas, accompanied by a notable reduction in forest cover (from 67.36% to 63.37%) and agricultural land (from 28.97% to 14.05%). Likewise, Siraha Municipality experienced a 171% increase in developed areas, with agricultural land decreasing from 88.65% to 80.88%. The changes have heightened disaster risks, with more than 67% of residents in both areas viewing floods as significant threats to their livelihoods.

The research highlights that urban forestry delivers a range of benefits that go beyond just improving the environment. As a tool for reducing disaster risk, urban forestry offers essential ecosystem services, such as mitigating floods through natural water retention, stabilizing soil to prevent erosion and landslides, reducing urban heat islands, and boosting community resilience.

Global examples, such as Singapore's "*City in a Garden*" initiative and the green infrastructure strategies of Scandinavian countries, illustrate the significant impact that well-planned urban forestry can have. Nonetheless, the research indicates that merely planting trees is insufficient for urban forestry to thrive. It necessitates comprehensive policy frameworks, sufficient financial support, strong community involvement, and alignment with broader disaster risk reduction strategies. The contrasting examples of Delhi's air quality challenges despite extensive tree cover versus Beijing's successful transformation underscore the importance of holistic approaches that address both afforestation and pollution control.

For Nepal, positioned as one of the world's fastest-urbanizing nations while facing increasing climate-related disasters, urban forestry presents an opportunity to build disaster-resilient cities from the ground up. Dudhauri and Siraha municipalities, still in early urbanization stages, offer unique laboratories for testing and implementing integrated urban forestry approaches that can serve as models for other emerging urban centers across Nepal and similar developing contexts.

13. RECOMMENDATIONS

To tackle the rising environmental challenges and disaster risks in Dudhauri and Siraha, it is crucial to bring urban forestry into the heart of local planning and development decisions. One practical step forward is for municipalities to make it compulsory for all new urban projects to set aside 25% of their total area for green spaces. This will help ensure that urban forests, parks, and trees are built into the fabric of these towns right from the start. To motivate developers, the approval process can be made quicker for projects that go beyond the minimum green space requirement. Considering that 67% of residents in both municipalities see floods as a major risk to their lives and livelihoods, flood protection should be a top priority.

Urban forestry can play a key role here especially through focused tree planting along the Kamala River and in other flood-sensitive zones. Creating green buffer belts with native, flood-resilient species and designing elevated green areas that can serve as public parks and emergency shelters would add multiple layers of protection. These efforts will only last if communities are part of the process. Involving schools and local groups in running small tree nurseries, introducing household-level "adopt-a-tree" campaigns, and creating jobs in tree care and nature-based tourism can help generate local ownership while boosting the local economy.

The next stage demands a seamless integration of urban forestry into both infrastructure design and broader regional planning frameworks. Major construction projects should include green infrastructure elements right from the design stage. Linking scattered natural areas through green corridors will not only support local ecosystems but also help manage excess rainwater during heavy downpours. Urban drainage systems designed with vegetation can reduce surface runoff and the urban heat effect. Private landowners and businesses should be encouraged to join these efforts through tax benefits for keeping their land green. In addition, access to

carbon markets could help tap into climate finance, contributing to Nepal's climate goals. Urban forests can also be promoted as community assets for eco-tourism, creating a steady stream of income for upkeep.

Strengthening technical skills through urban forestry advisory services will ensure that tree planting is guided by local knowledge, ecological needs, and climate resilience principles. Tools like GIS and satellite mapping can help track changes in green cover over time. To secure these gains for the future, it's important to plan for urban forests that can survive changing weather patterns. Setting up seed banks for native tree varieties and investing in research partnerships with academic institutions will support long-term innovation.

So, last but not the least, Dudhauri and Siraha must not work in isolation. Regional coordination with nearby towns will allow for shared tools, knowledge, and emergency response systems laying the foundation for greener, safer, and more climate-resilient urban development across the region.

14. KEY POLICY IMPLICATIONS AND RECOMMENDATIONS

14.1 National Urban Planning Legislation Reform

Nepal's Local Government Operation Act should be amended to mandate the inclusion of green infrastructure in municipal development plans. Urban forestry must be legally recognized as a critical part of urban infrastructure. Specific land allocation thresholds (e.g., 25% for green space in new developments) should be defined and enforced to guide urban planning across all municipalities.

14.2 Disaster Risk Reduction (DRR) Mainstreaming

Urban forestry should be formally integrated into the Disaster Risk Reduction and Management Act. This recognition will ensure eligibility for DRR funding and institutionalize green infrastructure as a nature-based disaster mitigation strategy. The National DRR Strategic Action Plan should include urban forestry indicators and targets to strengthen vertical accountability.

14.3 Climate and Environmental Policy Alignment

Urban forestry must be embedded within Nepal's Nationally Determined Contributions (NDCs) under the Paris Agreement. This alignment would unlock access to international climate finance and help meet both mitigation and adaptation goals. Updating the Environment Protection Act to secure urban green spaces is critical for long-term ecological health.

14.4 Provincial and Municipal Bylaw Development

Provincial governments should develop adaptable model bylaws on urban forestry, enabling municipalities to implement and enforce green infrastructure standards.

These regulations should include compliance mechanisms, penalties, and performance-based incentives. Municipal land use plans must be revised to integrate urban forestry from the outset of planning processes.

14.5 Revenue and Financing Mechanisms

Local governments require enabling policy to generate income from urban forestry initiatives through ecosystem service payments, green user fees, and eco-tourism. Provincial frameworks should enable municipalities to offer property tax benefits to encourage the conservation of private green spaces, providing them with a strategic financial tool for local environmental preservation.

14.6 Cross-Sectoral Coordination

Urban forestry requires collaboration across urban development, forestry, disaster management, and environmental protection sectors. Inter-agency coordination frameworks should be established with shared indicators, pooled budgets, and defined roles. Strong collaboration among stakeholders will improve policy alignment and help prevent overlapping initiatives or redundant actions.

14.7 Private Sector Participation

Public-private partnerships should be encouraged through policies that offer incentives and integrate CSR frameworks. Building codes and EIAs should require private developers to support urban forestry. Their involvement in planting, maintaining trees, and introducing green innovations can play a key role in expanding and sustaining urban green spaces.

14.8 Public Awareness and Education

Urban forestry must be rooted in public consciousness. Environmental education should be integrated into school curricula, and nationwide campaigns are launched to raise awareness about the importance of urban greenery. Community-led greening programs can foster ownership and ensure sustainability.

14.9 Budget Allocation & Institutional Capacity

Dedicated budget lines for urban forestry should be introduced at all levels of government. These allocations must be tied to performance-based results and supported by institutional capacity-building, including urban forestry extension services and technical training for local officials.

14.10 International Cooperation and Climate Finance Access

Nepal should actively pursue international funding opportunities by enhancing project development capacity, establishing verifiable monitoring systems, and creating clear institutional arrangements for fund management. Urban forestry can serve as a flagship area for green recovery and resilience investments.

14.11 Innovative Financing Approaches

Policies should support the development of green bonds, blended finance, and payment-for-ecosystem-services mechanisms. These tools can mobilize both public and private capital for urban greening initiatives, provided that strong social and environmental safeguards are maintained.

14.12 Monitoring and Adaptive Governance

Policy frameworks must establish robust monitoring systems using GIS and standardized indicators to track forest cover, disaster risk reduction outcomes, and ecosystem services. An adaptive governance approach is essential allowing policies to evolve in response to new evidence, community feedback, and changing environmental conditions.

14.13 Why Now? For A Greener, Healthier Future

Urban forestry is more than just an environmental initiative; it is a vision for the future of Nepal's cities. By integrating green spaces into urban planning, Nepal can address the challenges of rapid urbanization and disaster vulnerability. Cities like Kathmandu, Siraha, and Dudhauri have the potential to become models of sustainable development, demonstrating how urban forestry can enhance resilience, improve public health, and foster economic growth.

The time to act is now. With the right policies, proactive measures, and community involvement, Nepal can avoid the pitfalls of unplanned urbanization and create cities that are not only livable but also resilient to the challenges of the 21st century. Urban forestry offers a pathway to a greener, healthier future, one where cities thrive in harmony with nature, setting an inspiring example for other nations facing similar challenges.

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Harnessing Ethnobotany and Ethnopharmacology for Better Urban Health and Sustainability

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ABSTRACT: This chapter looks at the connections between ethnobotany and ethnopharmacology, highlighting their importance for improving urban green biodiversity for health and supporting sustainability. Throughout history, people have relied on medicinal plants and passed down this vital knowledge through generations. Even with modern advances in medicine, around 80% of the world's population still depends on traditional medicine. The chapter highlights various plants and the drugs made from them, stressing the need to protect biodiversity as deforestation continues. It also explores urban ethnopharmacology, showing how urban migration encourages a mix of cultures and medicinal practices. Ethnobotanical gardens and community projects in cities illustrate how urban agriculture can boost environmental resilience and social ties. Improvements in pharmacological testing and computational drug discovery have transformed drug development, making it easier to identify and study therapeutic compounds. The chapter wraps up by discussing the important topic of intellectual property rights. It calls for fair protection of indigenous knowledge and equitable sharing of benefits in drug development. In the end, we conclude that ethnobotany and ethnopharmacology provide useful ways to enhance urban indigenous knowledge, cultural integration, and global health.

Keywords: Ethnobotany, Ethnopharmacology, Biodiversity, Indigenous Knowledge, Indigenous Knowledge.

1. INTRODUCTION

From time immemorial, man used various nature gifted materials for medicinal purposes (Lev & Amar, 2002) among which the plants play important role. By trial and error method, people acquired knowledge of uses and characteristics of medicinal plants which were consequently transferred from one generation to another (Ghorbani, 2005). Many modern drugs have been isolated from natural sources based on their use as traditional medicine. Even today, about 80% of the

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world's residents depend on traditional medicine for their health care (Organization, 2013). Perhaps the earliest use of traditional medicine derived from plants was described in the Hindu religious scripture, "the Vedas" from about 4500 to 600 B.C. It demonstrates the ancient depository of mankind's consciousness containing the knowledge of 67 plant species. One of the traditional system of medicine practiced abundantly in Nepal and India, i.e. Ayurveda, furnishes additional features for the curative application of about 290 medicinal drugs (Manandhar, 1980). As we look from ancient literature to present day scientific records, there exists enough evidence about the traditional medicinal knowledge being in vogue (Sheng-Ji, 2001).

Plant-derived medicinal drugs have high importance which can be evident from their eminence in marketplace: In the 1976's National Prescription Audit, Fabricant & Farnsworth (2001) showed an analysis where a fact was revealed that 25% of all prescriptions issued in Canada and United States contain active agent isolated from higher vascular plants. As the forests all over the world are being deforested turning to loss of biodiversity, there is urgent need to reexamine use of the plants across the plant kingdom for developing new pharmaceuticals (Cox, 1990). Through scientific investigation of indigenous plants used worldwide, many drugs are derived for use widely in today's world, such as tubocurarine, ergometrine, atropine, reserpine, digoxin-as the table 1 shows a list of few examples of drugs derived from plants (Heinrich *et al.*, 2012). From 119 compounds found globally reported by Fransworth *et al.* (1985), 90 plants were used as single entity medicinal substances. Notably, plants identified on the basis of their ethnomedical uses were about 77%. The overall plants used as medicinal substance commercially all over the world is not known, but they are at least 1000 in China alone (Kuebel & Tucker, 1988).

This chapter presents various terminologies and concepts of ethnobotany and their relevance to urban green city idea, and ethnobotanically important medicinal plants that can be grown in the urban farms and related ethnopharmacological aspects.

2. TERMINOLOGIES AND CONCEPTS

Ethnobotany and ethnopharmacology are interrelated and integrated disciplines of research which focus distinctively at the factual native knowledge regarding medicinal agents and their implied health benefits, and the possible toxicological threats associated with such remedies (Heinrich *et al.*, 2012).

2.1 Ethnobotany

The term Ethnobotany was first suggested in 1896 by John Harshberger in order to fix a particular discipline of botany as the use of plants by autochthonous people (Montagne, 1997). Before the use of the term ethnobotany, many botanists had previously included the use of plants by people within their studies (Davidson-hunt, 2000). In deep sense, ethnobotany is the study of the association between plants and people. The two vital fractions of Ethnobotany are substantiated within the word itself: "ethno" means the study of people, and "botany" means the study of plants

(Davidson-hunt, 2000; Maleki, 2011). In the 21st century, the scope of ethnobotany has been expanded from the natural study of plant uses by native people as noticed by western scientists to a broad span of interests of plants in ecological and cultural contexts (Ford, 1994).

Ethnobotany encompasses various branches of science including biochemistry, pharmacognosy, medicine, toxicology, botany, evolution, agriculture, nutrition, sociology, history, medicine, comparative religion, anthropology, linguistics and archeology. The multifaceted character of ethnobotany permits access and utilization of a broad array of plant resources and facilitates the path for many scientists to study the plant uses through various approaches (Alexiades, 1996).

2.1.1 *Applied Ethnobotany*

Ethnobotany has advanced along with wider methodology, covering several aspects of the natural environment, in addition to establishing a quantitative framework for the assessment of ethnobotanical data. Because the discipline offers to assess the interaction between people and their immediate environment, as well as how societies interact with the outside world, including the impact of herbal and medicinal plants on national economies and personal lives, ethnobotanists increasingly designate themselves as ethnobiologists or ethnoecologists. Since 1992, the study of how humans and plants interact has given rise to a new term, “applied ethnobotany,” which refers to research and methods that enable direct collaboration with indigenous people and traditional healers. This allows for better management of native people’s knowledge and the development of management structures that better shape their useful practices and social dynamics (Aumeeruddy-Thomas *et al.*, 2003).

2.1.2 *Ethnoecology*

According to Martine (1995), ethnoecology is a subject that unifies a wide range of academic disciplines. All disciplines that relate to the interaction between indigenous people and the ecosystem are collectively referred to as “ethnoecology,” encompassing subfields like ethnobiology, ethnobotany, ethnoentomology, and ethnozoology. In practical terms, the field of ethnoecology studies relates to how humans perceive and interact with other living things, such as animals, plants, and inanimate objects found in a given environment (Davidson-Hunt, 2000).

2.1.3 *Quantitative Ethnobotany*

Prance and colleagues’ invention of quantitative ethnobotany in 1987 defines quantitative ethnobotany as “the application of quantitative techniques to the direct analysis of contemporary plant use data” (Prance *et al.*, 1987). In order to improve the traditional compilation-style approach, these concepts have been introduced to increase the indicative value of ethnobotanical studies. In recent years, efforts have been made to do this by incorporating suitable quantitative research methods in the collection, processing, and interpretation of ethnobotanical data. Quality information is produced with the use of quantification and related hypothesis testing. Techniques

used in this regard include log-linear modeling, regression analysis, cluster and primary analysis, and analysis of variance (Davidson-Hunt, 2000; Peters, 1996; Phillips & Gentry, 1993).

2.1.4 *Ethnopharmacology*

This term was first used in the title of a book on hallucinogens “Ethnopharmacologic Search for Psychoactive Drugs” in 1967 (Kline, 1967), “The observation, identification, description and experimental investigation of the ingredients, and the effects of the ingredients, and the effects of such indigenous drugs is a truly interdisciplinary field of research which is very important in the study of traditional medicine. Ethnopharmacology is defined as the interdisciplinary scientific exploration of biologically active agents traditionally employed or observed by man” (Heinrich *et al.*, 2012; Bruhn & Holmstedt, 1981). This explanation brings recognition to the assessment of primordial usage and does not obviously mark the concern of searching for new biological active ingredients for drug discovery, even though the last mentioned matter has been at the center of the public’s attention (Heinrich & Gibbons, 2010).

Table 1: Botanical Drugs Used in Indigenous Medicine and of Importance in Development of Modern Drugs (Heinrich *et al.*, 2017)

<i>Botanical Name</i>	<i>Indigenous Use</i>	<i>Origin</i>	<i>English Name</i>	<i>Active Compounds</i>	<i>Medicinal Uses</i>
AdhatodavasicaNees	Antiseptic, antispasmodic, insecticide	Srilanka, India	–	Vasicin	Oxytotic, antispasmodic
Ananascosmosus (L)	Anthelmintic, abortifacient, expectorant	South America	Pineapple	Bromelain	Anti-inflammatory
Camptothecaacumniata Decne	–	South and South-eastern Asia	–	Camptothecin	Cancer chemotherapy
Aesculushippocastanum L	Anti-inflammatory	South eastern Europe	Horse chestnut	Aescin	Chronic inflammatory conditions, circulatory problems
Atropabelladonna	Pain relief, asthma, inflammatory conditions	Europe, Middle East	Deadly nightshade	Hyoscamine	Parkinsonism, anti-emetic
Catharanthusroseus	Madagascar	Diabetes mellitus	Madagascar periwinkle	Vincristine, vinblastine	Cancer chemotherapy
Cinchona succirubra	No indigenous uses	Northern South America	Jesuits’ bark	Quinine	Malaria, cardiac arrhythmia

<i>Botanical Name</i>	<i>Indigenous Use</i>	<i>Origin</i>	<i>English Name</i>	<i>Active Compounds</i>	<i>Medicinal Uses</i>
Curcuma xanthorrhiza Roxb. and spp.	Cholagogue, stomachic, carminative	India	Turmeric (curcuma)	Curcumin, essential oil	Hepatic disorders
Daturametel	Hallucinogen	Middle America, Asia and Africa	Thorn-apple	Scopolamine	Preoperative medication, Travel sickness
Digitalis spp.	Dropsy	Europe	Foxglove	Digital glycosides	Cardiac arrhythmia, atrial fibrillation
Ephedra sinica	Chronic cough	China, Northern Asia, Europe	Ephedra	Acetyl salicylic acid, Forskolin	Cough suppressant, Pain
Gingko biloba	Asthma, antihelminthic	Eastern Chins, today widely cultivated	Ginkgo	Ginkgolides	Dementia, Alzheimer disease
Papaversomniferum L	Pain relief, tranquilizer, hallucinogen	Europe	Henbane	Hyocyanine	Anticholinergic
Hypericum perforatum L	Rheumatism, gout, menstrual problems, wounds	Europe	St John's wort	Codeine, Papaverine, Codeine, Physostigmine	Topical for inflammatory conditons, pain, cough, antispasmodic, Mild form of depression, Glaucoma
Psoralea carylifolia L	Stomachic, various skin infections	Asia	-	Psoralen	Psoriasis

2.2 Applications of Ethnopharmacology

The study into the botanical origin and physiological effects of the arrow poison shows the application of early ethnopharmacological approach. Heinrich and Gibbons (2010) highlighted the evolution of ethnopharmacological research through a series of historical and contemporary case studies. These range from 19th-century investigations of the Amazonian arrow poison curare by Alexander von Humboldt and Claude Bernard—who traced its use among South American tribes to botanical sources like *Chondrodendrontomentosum* to 20th-century ethnobotanical studies of hallucinogenic mushrooms by R. Gordon Wasson, and firsthand explorations of traditional Mexican indigenous healing practices. These foundational studies, which combined indigenous knowledge with experimental pharmacology, laid the groundwork for biomedical

applications such as the development of tubocurarine as a muscle relaxant (Heinrich *et al.*, 2012). Over time, early descriptive accounts have evolved into more scientifically rigorous, interdisciplinary inquiries. Today's research builds on the application of this field with greater emphasis on methodological precision, cultural sensitivity, and sustainable bioprospecting—reflecting both the discipline's rich potential and the ethical and scientific challenges that lie ahead.

On further exploration, a drug used as antidote for snake bite by mangooses in ancient days, i.e. Reserpine from a traditional medicinal plant is very interesting. This medicinal plant is *Rauwolfia serpentina* also known as Chotachand in Hindi, which has been used by native people of Himalayan Mountains. Mangooses used to feed on *Rauwolfia* plant before getting involved in combating with cobra. Besides, using the plant as an antidote, it had also been used as potent drug for treating epilepsy, insomnia, and insanity by people in Bihar Province of India (Balick & Cox, 2020). *Rauwolfia* has also been used to treat hypertension as potent drug Reserpine can be isolated from it. Besides *Rauwolfia* plant, native people also claim a plant named *Verbascum* found in Iran to be used in treating snake bites (Ghorbani, 2005).

While *Rauwolfia* has ultimately drawn attention from experts, scientists haven't still made detailed investigations on *Verbascum* species. In addition, ethnopharmacology should gaze at symbolic and intellectual aspects, as ethnopharmacology is a science acting as bridge filling the gap between anthropology and natural sciences. Humans select plants not only because of their particular pharmacological actions but also due to figurative strength they assume to be present in a plant. In order to understand these aspects, cognitive and symbolic analysis of data needs to be understood (Heinrich *et al.*, 2012).

Next fascinating instance from field studies is the use of the seeds of *Peganum harmala* leaves for evil eye in Turkmen Sahra area. Despite the fact that seeds contain many alkaloids, the smoke from the seeds when grilled is used by native people for nullifying evil eyes, forming also a part of their healing process (Ghorbani *et al.*, 2006).

2.3 Ethnopharmacology and Bioprospecting

Various research used a flock of ideas and methodologies while dealing with medicinal plants, and also their active ingredients. In most of the areas, interdisciplinary studies are used combining diverse fields such as pharmacognosy, pharmacology, pharmaceutical biology, anthropology, toxicology, plant physiology and others. Two conceptually and methodologically distinct but intimately related approaches: bioprospecting and ethnopharmacology (Table 2) are used for analysis of strength and weakness of medicinal plants, particularly of the consequences of the research. 'Bioprospecting' focuses on the growth of novel drugs for large markets of the North. Looking at the chemical and biological diversity of varieties of resources available in the ecosphere of the earth, there is potential for producing new hugely profitable medicinal products through research and development (R&D) that, however, requires enormous financial investments. Initiating the R&D from gathering biogenic specimens such as fungi, micro-organisms, plants, animals proceeding with subsequent

investigations of biological-pharmacological actions and the study of organism's natural products, ending up with discovery of novel drugs. As High-throughput screening systems are established by international pharmaceutical industries, they are important in this search. The source materials for these test batteries are eco-diversity derived products which contribute as an initiating point for pharmaceutical growth. Few industries have been visualizing the screening of 5,000,000 samples per week against a single target. Hence, it is important to have varieties of chemically different samples available (see below).

The other method is more accurately described as "ethnopharmacological". A very small number of highly well-recorded helpful plants (mainly medicinal, but sometimes those known to be poisonous or employed in nutrition) are often documented as consequences of ethnobotanical investigations. The creation of better efficacious medicines for use by locals is a major goal in ethnopharmacology. Information on the bioactive components of these plants, their relative contribution through the effects of the extract (such as synergistic or antagonistic effects), the toxicological profile of the extract and its constituents, and improved galenic preparations that can be made under local conditions are all crucial.

By limiting ethnopharmacology to the assessment of indigenous uses, we can draw attention to the fact that even a defined interdisciplinary approach, as it is, for example, used by the editors of the *Journal of Ethnopharmacology*, does not account for the necessity of developing research strategies for assessment of indigenous uses:

When early man faced illness and disease, he found a variety of beneficial medicinal substances in the animal and plant kingdoms. Oral tradition was used to transmit through generations the empirical knowledge of these drugs' usefulness or poisonous potential, which was later recorded in herbals and *materia medica* manuscripts. Through the research of folk medicines, several important modern medicines (such as atropine, ephedrine, tubocurarine, digoxin, and reserpine) came into use. In their ongoing quest to create medicines that are both more efficient and less dangerous, chemists continue to employ plant-derived pharmaceuticals as prototype products (such as morphine, physostigmine, quinidine, theophylline, and emetine). The pursuit of pharmacologically novel principles from existing traditional medicines is ongoing and supports the successful innovation in contemporary medicine.

A primary objective of truly multidisciplinary ethnopharmacological research must be to understand the significance of such naturally derived compounds in the healthcare of the people who had this knowledge first. Accordingly, ethnopharmacology may aid in the creation of fresh pharmaceuticals for the markets of the North, although this is only seen as a secondary benefit. True ethnological (or anthropological) study on medicinal plants needs to encourage both indigenous advancements to make better use of these products as well as to bring about thorough understanding of these remedies. For instance, Bruhn & Holmstedt (1981)'s definition from the introduction subtly implies this.

The two techniques, ethnopharmacology and biodiversity prospecting, have previously been noted as not being mutually incompatible, and the concepts of

“ethnopharmacology” and “bioprospecting,” as they are presented here, are rarely realized in such an extreme form. Instead, most studies are often motivated by ethnopharmacology and biodiversity, contributing in varying degrees to both of them. The explanation in the preceding sentences should specifically bring attention to the unique benefits and functions of both strategies. The application of ethnobotanical knowledge in bioprospecting programs focused on infectious diseases is undoubtedly highly beneficial and promising (Lewis, 2000). In the case of cancer treatment, however, this is not always the case.

Table 2: Comparison between Bioprospecting and Ethnopharmacology (Heinrich *et al.*, 2012)

	<i>Bioprospecting</i>	<i>Ethnopharmacology</i>
Overall goals	<ul style="list-style-type: none"> - Drug discovery for the international market - Pure natural products as drugs 	<ul style="list-style-type: none"> - (Herbal) drug development, especially for local uses - Complex plant extracts (phytotherapy) - Social importance of medicinal and other useful plants - Cultural meaning of resources and understanding of indigenous concepts about plant use and of the selection criteria for medicinal plants
Main disciplines involved	<ul style="list-style-type: none"> - Biology (ecology) - Pharmacology and molecular biology - Phytochemistry 	<ul style="list-style-type: none"> - Biology including (very prominently) ecology - Pharmacology/molecular biology - Pharmacognosy and phytochemistry
Pharmacological study	<ul style="list-style-type: none"> - The assay is not selected on the basis of local usage, instead high-throughput screening systems are used 	<ul style="list-style-type: none"> - Preferably using low-throughput screening assays which allow a detailed understanding of the local or indigenous uses
Number of samples collected	<ul style="list-style-type: none"> - Inventory (expanded herbaria) economically sustainable alternative use to destructive exploitation (e.g. logging) - As many as possible, preferably several thousand 	<ul style="list-style-type: none"> - Development of autochthonous resources (especially local plant gardens, small-scale production of herbal preparations) - Very few (up to several hundred)
Key Problems	<ul style="list-style-type: none"> - Local agendas (rights) and compensation to access 	<ul style="list-style-type: none"> - Safety and efficacy of herbal preparations

3. EVOLUTION OF NATURAL-PRODUCT DERIVED DRUG DEVELOPMENT

3.1 Traditional Ethnopharmacology and Ethnobotany

The subjects of ethnopharmacology and ethnobotany are closely related. Ethnobotany is the study of the intricate connections between cultural plant practices, with a

particular emphasis on how different communities utilize, manage, and interpret the usefulness of plants. On the other hand, ethnopharmacology is the multidisciplinary study of biologically active substances and traditionally used indigenous medications (Pirintsos *et al.*, 2022; Soejarto *et al.*, 2005; Mukherjee *et al.*, 2010). To explore physiologically active substances from plants, minerals, animals, fungi, and microorganisms, ethnopharmacology has a larger scope. In all domains, the initial step is to describe the usage of extracts in a particular condition without examining any potential causative relationships with the chemicals or substances contained in them (for a specific example), see (AhmetSargin, 2015). The field studies of indigenous and traditional medicinal knowledge and the biodiversity component to which such information is tied have greatly benefited from ethnopharmacology.

This ancient practice of using plants can be alternative to the uses of modern pharmaceutical agents in contemporary world. Many of the population's medical requirements in China are still being met by traditional Chinese medicine. Due to the comprehensive documentation of the therapeutic benefits of the plants, contemporary medical care has been greatly enriched. To advance traditional Chinese medicine, a number of organizations with training facilities have been founded such as the Academy of Traditional Chinese Medicine. Traditional medicine is a separate department that almost all hospitals have. It's interesting to note that the Chinese government suggested combining traditional Chinese medicine with Western treatment to treat pneumonia caused by SARS-CoV-2, with promising outcomes (Zhao *et al.*, 2020).

Western civilizations, on the other hand, have largely lost their traditional medical practices, while some of the plant's therapeutic qualities have persisted. Promoting the ethnopharmacological use of plants are phytotherapists or naturopaths who work within alternative and complementary health care systems. Herbal medicine is made safe, efficient, and standardized in some nations where practitioners go through training that is more or less controlled (often by responsible authorities) and has associations that recognize certified members (Jäger, 2015). Contrarily, some other nations do little more than encourage the use of medicinal herbs without implementing any regulatory measures, which hastily causes the extinction of long-standing customs. The use of whole plants or unprocessed plant extracts constitutes the practice of ethnopharmacology and ethnobotany in the latter nations. However, it is important to note that, in certain circumstances, using a full plant, a crude extract, or a combination of multiple plant extracts without isolating the components produces a superior therapeutic impact than taking individual chemicals (Thomford *et al.*, 2018).

3.2 Pharmacological Testing

A research done in the area of ethnopharmacology by Yeung *et al.* (2020) demonstrates that although there is still study going on the medicinal plant species used in traditional medicine, there has been a tremendous growth in the evaluation of particular qualities or therapeutic effects of extracts and chemicals. It is interesting

to note that the impact of the research articles was inversely correlated with the number of native species in the nations of the authors. The focus of research has recently changed from identifying and cataloging the medicinal plant species used in conventional medicine (AhmetSargin, 2015; Alzweiri *et al.*, 2011; Dafni *et al.*, 1984) to analyzing the properties or therapeutic effects of crude plant extracts or specific naturally derived products, such as flavonoids(Górniak *et al.*, 2019), alkaloids (Adamski *et al.*, 2020), tannins(Pizzi, 2021), saponins (Metwaly *et al.*, 2019), phenols (Lu & Foo, 2002), and terpenoids(Yang *et al.*, 2020). An examination of the selected bibliography and an application of methodology is shown in Table 3.

Table 3: The focus of early research has shifted from naming and cataloging the medicinal plant species used in conventional medicine to analyzing the characteristics or therapeutic effects of crude plant extracts or specific naturally derived chemical compounds

<i>Title</i>	<i>Year</i>	<i>Author</i>	<i>Reference</i>
Ethnobotanical/Ethnopharmacological studies on traditional medicine			
Ethnopharmacological survey of wild medicinal plants in Showbak, Jordan.	2009	Al-Qura'n, S.	(Al-Qura'n, 2009)
Ethnobotanical survey of medicinal plants in Bozyazi district of Mersin, Turkey	2015	AhmetSargin	(AhmetSargin, 2015)
Ethnopharmacological survey of medicinal herbs in Jordan, the Northern Badia region	2011	Alzweiri et.al	(Alzweiri <i>et al.</i> , 2011)
Ethnopharmacological survey of medicinal plants in Jordan, Mujib Nature Reserve and surrounding area.	2009	Hudaib <i>et al.</i>	(Hudaib <i>et al.</i> , 2008)
The herbal market of Cyprus: traditional links and cultural exchanges.	2011	Karousou <i>et al.</i>	(Karousou & Deirmentzoglou, 2011)
The botanical materiamedica of the Iatrosophikon—a collection of prescriptions from a monastery in Cyprus	2006	Lardos, A	(Lardos, 2006)
Ethnobotanical survey of medicinal plants in northern Israel.	1984	Dafni <i>et al</i>	(Perianayagam <i>et al.</i> , 2006)
Ethnopharmacological survey of medicinal herbs in Israel, the Golan Heights and the West Bank region.	2002	Said <i>et al.</i>	(Said <i>et al.</i> , 2002)
Evaluation of specific properties or treatment effects of crude plant extracts			
Studies on the anti-inflammatory and related pharmacological properties of the aqueous extract of <i>Bridelia ferruginea</i> stem bark	2000	Olajide <i>et al.</i>	(Olajide <i>et al.</i> , 2000)

<i>Title</i>	<i>Year</i>	<i>Author</i>	<i>Reference</i>
Antioxidant activity of extract from <i>Polygonumcuspidatum</i>	2007	Hsu <i>et al.</i>	(Hsu <i>et al.</i> , 2007)
In vitro and in-vivo anti-inflammatory activity of <i>Mangiferaindica</i> leaves extract	2004	Garrido <i>et al.</i>	(Garrido <i>et al.</i> , 2004)
Studies on the anti-inflammatory and related pharmacological properties of the aqueous extract of <i>Brideliaferruginea</i> stem bark	2000	Olajide <i>et al.</i>	(Olajide <i>et al.</i> , 2000)
Anti-inflammatory activity of <i>Trichodesmaindicum</i> root extract in experimental animal	2006	Perianayagam <i>et al.</i>	(Perianayagam <i>et al.</i> , 2006)
Pharmacological evaluation of aqueous extract of <i>Althaeaofficinalis</i> flower grown in Lebanon.	2011	Hage-Sleiman <i>et al.</i>	(Hage-Sleiman <i>et al.</i> , 2011)
Evaluation of particular properties of crude plant extracts			
Black Ginseng and Its Saponins: Preparation, Phytochemistry and Pharmacological Effects.	2019	Metwaly <i>et al.</i>	(Metwaly <i>et al.</i> , 2019)
Advances in Pharmacological Activities of Terpenoids	2020	Yang <i>et al.</i>	(W. Yang <i>et al.</i> , 2020)
Comprehensive review of antimicrobial activities of plant flavonoids.	2019	Górniak <i>et al.</i>	(Górniak <i>et al.</i> , 2019)
Biological Activities of Alkaloids: From Toxicology to Pharmacology.	2020	Adamski <i>et al.</i>	(Adamski <i>et al.</i> , 2020)

3.3 Computational Drug Discovery

About 90% of drug discovery process fails during the clinical trial period for FDA approval and only few finally reach the consumer market. Modern high-throughput screening (HTS) procedures may assay thousands of molecules with robotic automation, reducing the need for human labor in compound screening. But this process is quite expensive and requires tons of ligands and resources. Ultimately pharmaceutical companies have been replacing drug development process and have replaced with Computer aided drug design (CADD) tools (Bukowski, 2012). As a crucial component of CADD, the use of rational drug design offers helpful insights into the knowledge of the binding affinity and molecular interaction between target protein and ligand. Likewise, the advent of supercomputing resources, parallel processing, and improved software, algorithms, and tools has made lead identification in pharmaceutical research easier (Macalino *et al.*, 2015).

With the use of CADD technologies, fewer ligands will need to be screened in experimental assays, which are a useful tool. The use of virtual (i.e., in silico) HTS is

the most well-liked supplemental strategy to HTS. By guaranteeing that the best lead molecule enters animal trials, computer-aided drug discovery and design not only lowers the expenses involved with drug development, but it may also shorten the time it takes for a medicine to reach the market. It serves as a “virtual shortcut” in the pipeline for discovering new drugs. CADD techniques can forecast efficacy and potential adverse effects, help improve the bioavailability of potential therapeutic compounds, and select lead drug molecules for testing. For instance, it was discovered in a recent research of CADD that it is feasible to generate proteasome inhibitors by adding a triphenylphosphine group to the base molecule pyridazinone (Yang *et al.*, 2016).

Pharmacophore modeling, quantitative structure activity relationship (QSAR), molecular docking, quantum mechanics, and statistical learning approaches are a few of the techniques used to find novel inhibitors from chemical databases (Leelananda & Lindert, 2016). If broadly classified, the two primary categories of CADD techniques are structure-based (SB) and ligand-based (LB) drug discovery. In contrast to ligand-based drug design, which depends on knowledge of ligands that interact with a specific target receptor, structure-based drug design uses the three-dimensional structure of the target receptor and its active sites to understand the molecular interaction between the receptor and ligand (Huang *et al.*, 2010).

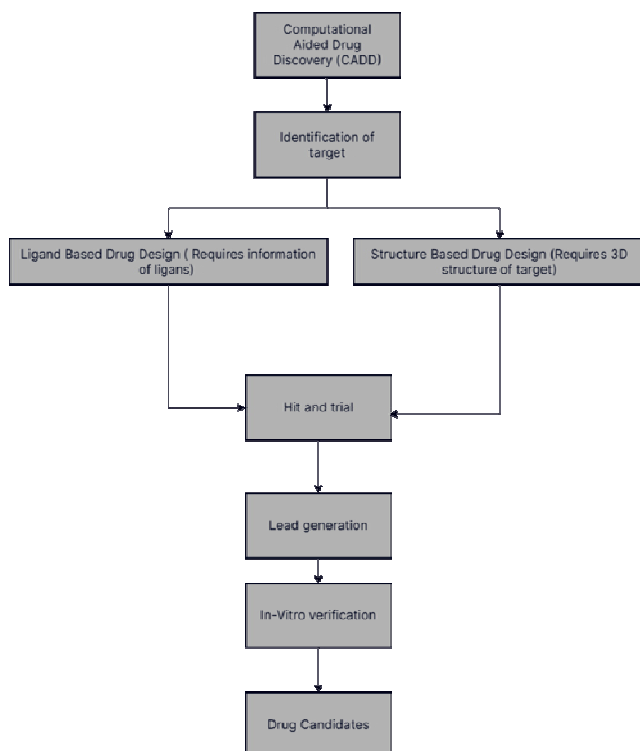


Figure 1: An Illustration of a Pipeline for Computer-Aided Drug Discovery (CADD)

Table 4: List of Drugs Discovery Through Computational Method and Approved by FDA

<i>Drug</i>	<i>Description</i>	<i>Reference</i>
Norfloxacin (Noroxin)	It is broad spectrum antibiotic with protein target on Topoisomerase II, IV .It was approved by FDA in 1986 A.D, it was developed with methods like SBVS, LBDD and QSAR Modelling	(Chierentin & Salgado, 2016)(Sabe <i>et al.</i> , 2021)
Crizotinib	It is a selective and potent cMet/ALK dual inhibitor which was approved by FDA in 2011.	(J. J. Cui <i>et al.</i> , 2011)
Dorzolamide	It is a carbonic anhydrase inhibitor which was approved by FDA on 1995.	(Balfour & Wilde, 1997)(Vijayakrishnan, 2009)
Captopril	It is active inhibitor of angiotensin-converting enzyme used as antihypertensive drug approved by FDA in 1981	(Mary Jo Kreitzer <i>et al.</i> , 2002)(Talele <i>et al.</i> , 2010)
Ritonavir	It is a HIV protease inhibitor used in combination with other antivirals in the treatment of HIV infection, approved by FDA in 1996.	(Vijayakrishnan, 2009)(Drie, 2007)
Crizotinib	It was approved by FDA in 2011. It has proven to be clinically effective in preventing lung, lymphoma, and esophageal malignancies from amplifying the c-MET gene.	(W. Cui <i>et al.</i> , 2020)
Vaborbactam	In 2017, the FDA authorized the drug vaborbactam for the treatment of pyelonephritis and complex urinary tract infections (cUTI), both of which are brought on by certain bacteria.	(Bell, 2022)
Axitinib	The FDA has authorized axitinib as a novel medication for VEHG in advanced renal cell carcinoma. When it binds to the VEGF kinase domain in the DFG-out conformation, axitinib acts as an inhibitor. Axitinib was created using a structure-based drug design approach.	(W. Cui <i>et al.</i> , 2020)(Bukowski, 2012)(Meadows & Hurwitz, 2012)

4. URBAN ETHNOPHARMACOLOGY

Urban ethnopharmacology focuses on the study of medicinal plants and related products which are used by the people of town and city. In short, we can define it as the interrelation between medicinal plants and people in cities and towns (Dutta *et al.*, 2021). Urban ethnopharmacology has recently received significant attention due to the fact that several of the historically used plant species are now at risk of extinction. Traditional knowledge spreads as a result of international migration. Despite the availability of allopathic medicines and other conventional drugs, migrants continue

to use their traditional cures when they reside in new cities or towns. Because information on this topic has always been passed down orally from one generation to the next, there is a dearth of literature in this area. (Pieroni & Privitera, 2014)

The inclusion of traditional medicine in public health care practices is significantly hampered by the paucity of literature in this area because traditional knowledge has been passed down orally from generation to generation and the only literature available is in the form of vernacular, insignificant ethnographic publications (Petkeviciute *et al.*, 2010). Another drawback may be that past ethnobotanists primarily studied the commercially significant plants in specific areas, vehemently ignoring the plants that were present in their areas but were used in other areas (*Totem and Taboo: An Ethnologic Psychoanalysis*, n.d.).

The cultural nature of urban ethnopharmacology is one of its distinctive features. The idea of pluralism holds that participation in various cultures leads to the development of individual identities (Crivos *et al.*, 2007). In contrast, multiculturalism means different cultural groups living together in a society while focusing on keeping their unique traditions in the same space. Although groups can interact, multiculturalism does not need cultural integration or blending.

In contrast, pluralism emphasizes the changing relationships between ethnic groups and the new ideas that come from shared resources, customs, and values. Pluriculturalism supports flexibility and cultural mixing, while multiculturalism often tries to keep cultural boundaries intact. As people move to urban areas, isolated ethnic and rural groups begin to interact more, promoting pluralism—a coexistence of various values, practices, and perspectives (Dutta *et al.*, 2021).

4.1 Urban Ethnopharmacology in North and South American Countries

There are a lot of South American books about the use of plants as alternative medicine in cities, particularly from Brazil. Numerous South American cities, including Petrópolis, Nova Francisco, Rio Claro, Abaetetuba, etc., have seen extensive research (Hurrell *et al.*, 2015). This demonstrates the value and maintenance of traditional knowledge among city dwellers. Nevertheless, despite these practices, ethnobotanical knowledge was found to be inversely correlated with education and socioeconomic level in Brazil, highlighting the need for its preservation and general awareness (Arenas *et al.*, 2013).

4.2 Urban Ethnopharmacology in Asia

Asia is renowned for its biodiversity and rich cultural legacy. As a result, a significant amount of literature about the use of botanical products in metropolitan areas today was documented. Southern Asia, which includes both established and developing countries, produced the majority of the literature (Astutik *et al.*, 2019). The countries with the most publications were Bangladesh, Indonesia, Pakistan, India, and China. Plants have long been used in Chinese traditional medicine (Tang & Eisenbrand,

1992). Quinine-resistant *Plasmodium* sp. could be killed by *Artemisia annua* L. (Asteraceae), while *Ephedra sinica* Stapf (Ephedraceae) was found to be useful against constipation, and *Coix lacrymajobi* L. (Poaceae) demonstrated strong anti-tumor properties (*Science*.299.5604.188, n.d.).

5. URBAN AGRICULTURE FOR SUSTAINABLE CITIES

In response to a number of issues, including urban sprawl, pollution, traffic jams, economic decline in wealthy nations, and fast urbanisation in emerging nations, sustainable urban development has been adopted globally since the 1990s. Throughout the past century, the idea of sustainability has been extensively explored by a variety of academic fields (Mayen Huerta & Utomo, 2021). Increasing environmental consciousness regarding the usage of natural resources in urban areas was the goal. Thirty years later, some scholars questioned whether the sustainability paradigm is enough given the current climate catastrophe and its impacts (Angelidou *et al.*, 2018). As a result, this paradigm is challenged from a standpoint that highlights the growing scarcity of natural resources and global development disparities. The pursuit of even more progressive approaches to urban “development” has resulted from this criticism. These approaches are characterised by concepts like degrowth, nature-based solutions, urban metabolism (UM), circular economy (CE), urban resilience, and ecological renewal (Nowysz *et al.*, 2022). Urban development plans that include green spaces such as allotment gardens and community gardens can provide viable opportunities for biodiversity of plants grown, including medicinal plants, which have ethnopharmacological and bioprospecting values.

5.1 Allotment Gardens

Due to industrialisation and urbanisation, allotment gardens arose in 19th-century Europe, especially in the UK and Germany, where they were utilised by unemployed rural migrants to produce food (*Continuous_Productive_Urban_Landscapes*, n.d.). Named for Moritz Schreber, Germany’s Schrebergärten were first used as parks before developing into allotment gardens with social and educational programs (Rogers, 1986). The Leipzig garden (1868) served as a prototype and is currently housed in the German Allotment Gardens Museum (Nowysz & Trocka-Leszczynska, 2021a). Ebenezer Howard’s 1898 garden city plan, which was influenced by utopian urban rhetoric, incorporated allotment gardens into worker communities to encourage self-sufficiency and green areas (Hall *et al.*, 2006; Nowysz & Trocka-Leszczynska, 2021b).

Nowysz *et al.* (2022) cited German architects Theo Effenberger and Hans Thomas who created the fan-shaped layout of the Wrocław allotment park, ROD Wytchnienie, in 1930. It features modernist residential buildings in the north and gardens in the south, joined by linden tree-lined pedestrian paths (Nowysz *et al.*, 2022). In keeping with the garden city idea, it has been mainly unaltered since 1945 and features a central square that was influenced by the Schreber model. Today,

allotment gardens fulfil social and ecological purposes by promoting community interaction, serving as urban green spaces, and assisting with urban ventilation. Access limitations, however, provide difficulties since they restrict public use because of worries about theft, damage, and illegal entrance. Some scholars categorise them as semi-private areas, but some argue that to make them more accessible, some areas should be turned into community gardens (Crouch & Ward, 1988).

5.2 Community Gardens

Important programs that include local populations in urban agriculture and promote urban renewal are community gardens (59). Their smaller size and absence of subdivision set them apart from allotment gardens, which are managed collaboratively by community members in collaboration with authorities (Hanna & Oh, 2000; Iles, 2012). Community gardens were first set up in abandoned areas for food cultivation in North America in the late 19th century, as demonstrated by Detroit's Pingree's Potato Patches in 1894 (Hanna & Oh, 2000). They became important as patriotic food sources during both World Wars (Draper & Freedman, 2010). In the post-war period after 1945, interest in urban agriculture was rekindled with the counterculture of the 1960s and the energy crises of the 1970s (Lawson, 2004; Birky & Strom, 2013).

As evidenced by the National Vacant Properties Campaign, a large number of community gardens in America today are growing in abandoned properties, encouraging urban renewal but also posing gentrification problems (Schilling, 2008; Wilkinson, 2011). Initiated in 1995 at Berkeley's Martin Luther King School, the Edible Schoolyard Project is a prime example of gardening education, promoting sustainability, ecological awareness, and food conscience through water conservation and composting (Wilkinson, 2011). Community gardens in Europe sprang from allotment gardens, which were frequently started without the help of architects. They reflect "architecture" and promote social inclusion, especially for minorities (Calvet-Mir & March, 2019; van der Jagt *et al.*, 2017).

The Prinzessinnengärten in Berlin, Germany, was created on an empty lot and includes a restaurant, educational facilities, and mobile plant growing, all of which support local identity and economic sustainability (Tonkiss, 2013). As demonstrated by San Francisco's rehabilitation initiatives and Detroit's gardens that feed food banks, community gardens also serve more general societal purposes by promoting education, rehabilitation, and economic support (Vietrova *et al.*, 2022). By encouraging social interaction, sustainable urban planning, and local food production, these gardens improve urban resilience.

6. INTELLECTUAL PROPERTY RIGHTS (IPR)

The world's biodiversity has been greatly improved and conserved because of indigenous and traditional people. Although this is increasingly acknowledged in international debate, the globalized economy threatens these people's rights to maintain their traditional ways of life. Global tendencies that replace the holistic idea

of the just balance with economic and utilitarian paradigms need to be reversed along with increasing the protection of indigenous and traditional peoples' rights for combatting these threats (Posey & Plenderleith, 2002).

At the moment, the issue of intellectual property rights is one of the most hotly debated ones in the chemistry and biology of natural products. Along with many other different aspects mentioned by authors, Reid *et al.* (1993) also mentioned some highlights regarding intellectual property rights. It was acknowledged long before the Convention on Biological Diversity, or the so-called Earth Summit, that nations had the legal right to own their biological property, including both marine and terrestrial species, and that indigenous peoples also had the right to defend and pursue recompense for the knowledge they had amassed over many generations based on their local biodiversity (Reid, 2021). Many of these intellectual property issues were defined by the Convention on Biological Diversity (CBD), which also gave countries the mandate to create plans to record and protect their biodiversity and indigenous knowledge (Cordell, 2000). 178 nations have now ratified the CBD, with Thailand and the United States being prominent exceptions.

Balance between rights of indigenous people and scientific investigation has been done by different approaches among few are written below: 1) Both those who possess the resources and those who seek them can reasonably anticipate that local communities will be protected, paid for their indigenous knowledge, and given access to the biome (Reid, 2021). 2) The licensing of substances from other parties is another method through which pharmaceutical businesses acquire physiologically significant chemicals (academia, research institutes, or other companies). These contracts often provide for upfront cash payments or stock exchanges, followed by milestone payments based on how well the compound or its derivatives perform during the development of a final, marketable product (Ukrainets *et al.*, 2011).

New standards will need to be proposed in the future for natural goods to succeed in this environment. Indigenous communities must be ensured that their rights are not being violated, and those who make significant investments in the creation of new goods must believe that their added value may be protected. Sharing information and resources is so crucial. Natural goods also need to find a new discovery niche where innovative biology would be prioritized for protection much more so than novel chemistry. This is because there is a very high probability that many of the "old" compounds will be discovered to have novel, intriguing, and potentially lucrative biological activities given the number of known natural products (*vide infra*) and the intense innovation currently underway in developing new bioassays (Cordell, 2000).

7. CONCLUSION

In summing up, ethnobotany and ethnopharmacology are essential to comprehending how plants and human societies interact, especially when it comes to the creation of therapeutic medications. These disciplines combine information from chemistry, pharmacology, botany, and anthropology to provide a basis for both contemporary

drug development and traditional treatment. The importance of maintaining indigenous knowledge, which still influences bioprospecting and pharmaceutical discoveries, is highlighted by the study of ethnobotanical traditions across cultural boundaries. The field of ethnopharmacology has a bright future thanks to developments in pharmacological testing and computational drug discovery, which can help create new medicinal agents while maintaining ethical principles like benefit-sharing and intellectual property rights. In the end, utilizing natural goods' potential for global health and well-being requires interdisciplinary cooperation and sustainable practices. Urban development plans that include green spaces such as allotment gardens and community gardens can provide viable opportunities for biodiversity of plants grown including medicinal plants that have ethnopharmacological and bioprospecting values.

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Compiled Biographies of the Authors



Ambika P. Adhikari (*Editor*) is a Distinguished Adjunct Fellow at the Institute for Integrated Development Studies (IIDS), Nepal, and a former Principal Planner at City of Tempe, Arizona, USA who headed its Long-range Planning Division. He is a Senior Global Futures Scientist (an honorary position), JAW Global Futures Laboratory, and a former Program Manager and Research Professor at Arizona State University (ASU) in Arizona, USA. For more than two decades in the Phoenix Valley in Arizona, Ambika worked on many important plans that have helped shape the urban development in cities and communities like Phoenix, Tempe and Indian Reservations. Several of the plan and policy documents he helped author have won awards and have been recognized as pioneering strategies in the planning arena in the Valley. His work has included development of housing strategies, urban landscape plans, sustainability strategies, general plans, character area plans, master plans, neighborhood plans, and specific plans.



Apil KC is a Ph.D. candidate in Urban and Regional Planning at the University of Michigan, Ann Arbor. His research focuses on equitable urban resilience and disaster governance, examining how collaboration among government, communities, and the private sector can strengthen cities' capacities to adapt to climate-induced shocks. He holds degrees in architecture and urban planning from the Institute of Engineering, Nepal, and brings over a decade of academic and professional experience. Apil has served as a faculty member in architecture schools and worked with institutions such as the World Bank, JICA, and USAID. He is the former General Secretary of the Society of Nepalese Architects (2021–2023) and continues to actively contribute to public discourse on architecture and urbanism.



Dilip Bhandari is a development professional with over 25 years of global experience advancing food security and sustainable agriculture, particularly for small holder farmers. As Senior Director of Programs at Heifer International, he leads Signature Programs in Asia and supports global strategies in livestock systems and One Health. Dilip specializes in livestock production, pro-poor value chains, and agricultural transformation. He has worked across 20+ countries and contributed to major initiatives through Heifer and other professional organizations. With a veterinary science and international development background,

Dilip has authored publications on smallholder livestock development. His expertise lies in enabling smallholders to achieve living incomes through integrated approaches to productivity, animal health, and rural resilience.



Keshav Bhattarai (*Editor*), a forester by training and a geographer specializing in spatial analysis, has established a distinguished career that integrates natural resource management, agriculture, demography, land use dynamics, climate change, and geopolitics. He began his professional journey in 1984 as a Forestry Officer with His Majesty's Government of Nepal, where he focused on agroforestry, plant canopy interactions, urban forestry, ecosystem services, and watershed management. His innovative research in community forestry, canopy modeling, and sustainable agroforestry practices in dryland regions earned him international recognition, including a Food and Agriculture Organization (FAO) scholarship to pursue advanced studies in Natural Resource Management at the University of Edinburgh, Scotland, and the Gorkha Dakshin Babu IV medal from the Head of State of Nepal.



Rajjan Chitrakar is a highly motivated and passionate educator and researcher with a strong background and track record in architecture and urbanism. He holds a PhD in Urban Design and Planning from Queensland University of Technology, Australia and has more than 20 years of academic and industry experience in Australia, the Philippines and Nepal. Dr. Chitrakar is currently working as a Lecturer in Architecture and Urbanism at Melbourne Polytechnic, Australia. He is the editor of the book titled *Revisiting Kathmandu Valley's public realm: Some insights into understanding and managing its urban spaces* (Nova, 2020). He has published book chapters with Routledge and Springer Nature and peer-reviewed papers in highly ranked international journals. He is an Associate Fellow of the Higher Education Academy, UK and serves on the editorial board for the international journal *Urban Planning*.



Yamuna Ghale holds Ph. D. on Food Security Governance from AFU and M.Sc.Ag. from Wageningen Agricultural University, the Netherlands. She has professional experience of 30 years on NRM, agriculture and food, and GESI issues. She was Portfolio Manager at the Embassy of Switzerland in Nepal, served as Manager/Agriculturist/Gender Expert at ICIMOD; Team Leader for Livelihoods and Economic Rights in Action Aid International; and NRM Expert in SNV Nepal.

Currently, she is engaged with UNDP, FAO, WFP, UN Women, IFAD focusing on agriculture, food security, renewable energy, gender and inclusion. She is also actively engaged with Government of Nepal as a Member for Federal Land Use Council, expert member at NPC, Ministry of Agriculture and Livestock Development; Member of Board of Trustees (BoT) of Gandaki University and Senior Research Fellow at Institute of Integrated Development Studies. She is also serving as Advisor for South Asian Women Development Forum and Federation of Women Entrepreneurs' Association of Nepal.



Sita Ram Ghimire is a seasoned agricultural scientist and policy analyst currently serving in the Australian Government's Department of Agriculture, Fisheries and Forestry, where he focuses on compliance, regulation and policy analysis. Prior to this role, he spent over a decade as a crop science researcher at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), contributing to innovations in plant resilience against abiotic stress. His early career includes seven years as an agronomist with Nepal's Department of Agriculture.

Dr. Ghimire holds a PhD in Agronomy and a Master's degree in Agriculture from Kyungpook National University, South Korea, where he was awarded competitive fellowships from both the Korea Research Foundation and the university itself. His postgraduate and postdoctoral research in South Korea centered on crop physiology against abiotic and biotic stress, resulting in numerous peer-reviewed publications and book chapters. Beyond academia, Dr. Ghimire has served as an adjunct faculty member at Far Western University in Nepal between 2022 and 2024, co-supervising students in research. He remains deeply engaged with diaspora-led knowledge exchange and institutional collaboration through organizations such as the Non-Resident Nepali Association (NRNA), Nepal Policy Institute (NPI), and the Nepalese Association of Agriculture, Forestry and Environment in Australia (NEPAFE), where he is a founding life member and adviser. With a career spanning in research, extension, policy, and international collaboration, Dr. Ghimire brings a systems-level perspective to urban agriculture bridging scientific rigor with community-driven innovation.



Arun Kafle is a Joint Secretary at the Ministry of Agriculture and Livestock Development, Nepal. He has been working on agriculture policy, planning and evaluation monitoring with more than 19 years of extensive work experience in the agriculture sector development of Nepal. He has completed M.Sc.Ag. (Agricultural Economics) from the Tribhuvan University, Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal. He got the University President

Scholarship at the University of South Australia, Australia where he completed a Ph.D. in environmental science- Urban Agriculture as a major field of research. His research focused on the study of trade-offs and synergies between potential economic, environmental and social outcomes of urban agriculture based on development divergencies. He has published several articles related to the agriculture sector in national and international peer-reviewed journals. He has worked as the editor of Nepalese Horticulture Journal and Journal of Agriculture and Environment and reviewer of many international peer reviewed journals. He has an interest in sustainable agriculture with a particular focus on urban farming.



Abishek Karn is a seasoned development strategist with over 15 years of experience driving transformative change across Nepal's urban and rural landscapes. Having served in key roles with the United Nations and led high-impact programs in livelihood, governance, and civil society, he is known for building strong donor relations, mobilizing funds, and navigating complex stakeholder ecosystems. His work spans grassroots empowerment to national policy influence, with a deep focus on sustainable enterprise and inclusive development. A featured delegate at global forums, including conferences in China on capitalism, regional strategy and the Belt & Road Initiative, Abishek is also a prolific writer whose thought-provoking articles explore economics, politics, and youth leadership. His career reflects a powerful blend of vision, execution, and firm commitment to social equity.



Smriti Kayastha is a recognized architect and urban development expert whose career bridges design, governance, and inclusive development. With over a decade of experience, she has led multidisciplinary teams, collaborated with government, and partnered with civil society to shape equitable, resilient urban futures. Her academic foundation in Architecture and Urban Studies, combined with expertise in disaster-sensitive planning and gender-responsive governance, positions her as a strong voice in reimagining cities that serve everyone, especially those often left behind. Internationally acknowledged, she received a Special Mention at the IV Golden Trezzini Awards in Russia and has been profiled by the American Institute of Architects (UK Chapter), *Archi Voice Women-E Magazine*, and *Bombay Film-Fame Magazine*. Smriti's work blends technical excellence with a powerful social vision, earning her a reputation as a rising changemaker in the global built environment.



Deegendra Khadka received his PhD degree from Inha University, South Korea in 2012. Since then, Dr. Khadka has been working as a senior scientific officer at Nepal Academy of Science and Technology (NAST) as well as served as a visiting faculty at the Central Department of Chemistry, Tribhuvan University, Nepal from 2013 to 2018. His academic journey and laboratory experience span molecular biology, enzymology and in vivo studies using animal models.

Dr. Khadka has conducted significant research on anti diabetic and antiobesity properties of plant extract including in vitro assay. His interests also include molecular docking, gene cloning and protein expression. He has published more than 30 papers in national and international journal and several book chapters with reputed publication houses. He is actively involved in academic writing and collaborative research under fellowships such as the NAM S&T fellowship. His work reflects a passion for translating traditional medicinal knowledge into modern therapeutic approaches for non-communicable disease.



Niranjana Koirala received his Ph.D. in biochemistry (pharmaceutical) from Sun Moon University, South Korea in 2016. He completed his Postdoctoral research fellowships one from the Universidad Nacional Autonoma de Mexico, (UNAM, 2018) and another at University of Macau, Macau SAR-China (UM, 2020). After PhD, he served in a college of Pokhara University, Kathmandu, Nepal in the capacity of the Head of the Biochemistry Department. Post Covid-19 he joined Gandaki Province Academy of Science and

Technology (GPAST), Government of Gandaki Province, Nepal as a Scientist and Spokesperson and he is currently working as a Researcher for Nepal Academy of Science and Technology (NAST)-Specialized Research Center, Gandaki, Nepal. Dr. Koirala's publications have been cited a total of 4400 times according to Google Scholar, thereby demonstrating that these publications are widely recognized and relied upon in the field of pharmaceutical biochemistry.



Kamal Kowlessur started his career as Lecturer in Electrotechnics at the University of Mascareignes in Mauritius around 2 years after obtaining his Bachelor's degree in Electrical and Electronics Engineering and Master's degree in Information and Communication Technology at the University of Mauritius. He delivered courses in Automation and Electrotechnics, encouraging active learning before joining the Energy Services Division, Ministry of National Infrastructure, as a Registered

Engineer. With his 22 years of expertise in providing electrical consultancy services, he has contributed substantially in ensuring the continuity of the electrical services in major government buildings including hospitals and designed electrical installation to included power fencing and high mast lighting for the first largest new prison in Mauritius.



Mahendra Nath Lohani worked for Heifer International for 30 years in various capacities from the grassroots level to the global executive leadership level before retiring as Senior Vice President of Programs in 2023. He also founded and led modern commercial poultry enterprises in Nepal after leaving 14-year-long government job. Academic degrees of Dr. Lohani include a Bachelor's in Veterinary Science, MS & PhD in Animal Science and Agricultural Economics.

Currently, Dr. Lohani is writing a book documenting his experience and learnings about sustainable locally led development and socio-economic transformation of rural communities around the globe where Heifer works.



Alina Maharjan is a Lecturer and researcher at Amrit Science Campus (ASCOL), where she actively contributes to student mentorship and academic research in B.Sc. Environmental Science Program. She holds a Master's degree in Environmental Science from the Central Department of Environmental Science, Tribhuvan University (2014–2017), where she was awarded a research grant from the Institute for Social and Environmental Transition (ISET), Nepal, and the

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With over seven years of experience in academia, consulting services, and research, she has developed strong expertise in laboratory analysis, environmental assessments, biodiversity, and conservation. Her research interests lie in the areas of water, environment, climate change, and sustainable development.



Bijaya Maharjan is currently serving as a Teaching Faculty and Research Fellow at the Faculty of Science, Health, and Technology, Nepal Open University (NOU) for the Master's in Geoinformatics with major course of GIS, Remote Sensing and Disaster Risk Management. He is also an Assistant Professor at Lumbini International Academy of Science & Technology (LIAST), affiliated with Lumbini Buddhist University, contributing to the M.Sc. in Disaster

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Pawan Kumar Neupane is an environmental researcher currently serving as the Senior Scientific Officer at the Nepal Academy of Science and Technology (NAST). His research focuses on natural resource and watershed management, environmental modeling, climate change, groundwater, ecosystem-based adaptation, urban environment and environmental policy. Mr. Neupane holds a Master's degree in Environmental Science with distinction from Tribhuvan University (2009). His career spans a variety of roles in natural resources research, environmental pollution, and

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ABOUT THE NAM S&T CENTRE

The Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre) is an inter-governmental Organisation with a Membership of 47 developing countries spread over Asia, Africa, Middle East, Europe and Latin America. Besides the above, 9 S&T agencies and academic/research institutions are Members of the “NAM S&T-Industry Network” of the Centre. The Centre was set-up in 1989 to promote South-South Cooperation in Science & Technology through mutually beneficial partnerships among scientists & technologists and scientific organisations in the NAM and other developing countries.

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The Centre has so far organised 155 international workshops and training programmes, implemented 4 R&D collaborative projects and brought out 101 publications, including 81 technical books, 9 workshop proceedings, 4 status reports and directories in various priority areas and 7 Monographs.

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Further details are available at:
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This book is a synthesis of innovative concepts, practices, and policies aimed at transforming cities into ecologically sustainable, environmentally sound, and climate-resilient food systems. It brings together interdisciplinary perspectives that address the critical nexus between urbanization, food systems, environmental quality, and sustainable development. The volume presents a compelling vision for how cities—particularly in the Global South—can achieve this transformation through the integration of urban planning with urban forestry, urban agriculture, composting, and green infrastructure.

This volume, published as the key outcome of the International Workshop that was organized jointly by the Nepal Academy of Science and Technology (NAST) and the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), showcases research and policy contributions from interdisciplinary scholars and practitioners representing Nepal and other developing nations, including their diaspora academics.

The book explores concepts of urban forestry, green infrastructure, composting, rooftop agriculture, and ethnobotanical urban design to advance the “Food Green City” model—where cities evolve as self-reliant, regenerative ecosystems. Drawing on evidence-based research, policy perspectives, and comparative analyses of cities across continents, it presents replicable models that link environmental regeneration with social inclusion and economic opportunity. By aligning urban planning, environmental management, and community participation, the volume demonstrates how local innovation and policy integration can transform urban challenges into pathways for sustainable and equitable growth.

Intended for researchers, graduate students, urban planners, environmental scientists, and policymakers, this book offers both theoretical foundations and applied knowledge. It serves as a valuable reference for those engaged in designing and implementing urban sustainability strategies that bridge science, technology, and community engagement in the context of global climate challenges.

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