Walter Leal Filho *Editor*

Climate Change Research at Universities

Addressing the Mitigation and Adaptation Challenges

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Preface

Many universities across the world perform state-of-the art research on matters related to climate change, both in respect of mitigation and adaptation. Yet, as shown by the latest 21st Conference of the Parties of the UN Convention on Climate Change (COP 21), held in Paris in December 2015, there is much room for improvements in the role played by universities in the negotiations and in influencing decision-making on a matter of such a global importance.

There are unfortunately relatively few events where a multidisciplinary overview of university-based research efforts and projects on climate change can be showcased, and where researchers from across the spectrum of the natural and social sciences have had the opportunity to come together to discuss research methods, the results of empirical research or exchange ideas about ongoing and future research initiatives focusing on climate change mitigation and adaptation. It is against this background that the Symposium "Universities and Climate Change: the Role of Higher Education Institutions in Addressing the Mitigation and Adaptation Challenges" was organised by Manchester Metropolitan University, UK, and HAW Hamburg, Germany, under the auspices of the International Climate Change Information Programme (ICCIP), and was held in Manchester, UK, in September 2016. The event involved researchers in the field of climate change in the widest sense, not only from traditional climate science, but also from the fields of environment, human geography, business and economics, arts, administration and media studies.

This book is one of the outcomes of the event, and focuses on the role of higher education institutions and research centres in addressing the mitigation and adaptation challenges, hence contributing to the further development of this fast-growing field. The aims of this book are as follows:

I. to showcase the research and projects performed by researchers at universities and research centres from across the world on issues pertaining climate change;
II. to document and promote ideas and experiences acquired in the execution of research projects, especially successful initiatives and good practice;

III. to introduce methodological approaches and projects which aim to offer a better understanding of climate change across society and economic sectors

This book is divided in two main parts:

- Part I Research and Education on Climate Change Mitigation: in this section, a set of papers addressing mitigation aspects have been compiled, focusing on energy issues as well as on means to reduce fossil fuel emissions.
- Part II Research and Education on Climate Change Adaptation: in this section, papers with a strong adaptation component are gathered, illustrating a diversity of means via which adaptation initiatives are implemented.

Whereas the emphasis of the papers in each section is on mitigation and adaptation, respectively, it is noticeable that the borders between the two modalities of response are not very strict and sometimes tend to overlap.

We thank the authors for their willingness to share their knowledge, know-how and experiences, as well as the many peer reviewers, which have helped us to ensure the quality of the manuscripts.

Enjoy your reading!

Hamburg, Germany
Spring 2017

Walter Leal Filho

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Part I
Research and Education on Climate Change Mitigation

Integrating Farmer's Traditional Knowledge and Practices into Climate Change Sectoral Development Planning: Case Studies from India

Nidhi Madan

Abstract Change in climate scenario adversely affects water availability; food and energy security; biodiversity etc. which greatly impacts natural resources, health of every living being and their livelihood. Rural communities which are highly dependent on natural resources are significantly affected by climate change. For the rural communities, difficulty in coping with climate change and preparing for climate change risks are further aggravated due to geographic and demographic obstacles; limited economic diversity; higher poverty rates etc. Small farmers based on their traditional knowledge and experiences are implementing various practices in agriculture, water, livestock etc. sectors to adapt the challenges of climate change. These activities are insignificant in combating climate change issues. However, if these small scale activities are integrated with existing sectoral development schemes/programmes, can create a greater impact. This paper presents strategies on how farmer's traditional knowledge and practices are integrated with sectoral development planning by showcasing case studies from various projects/activities in India. This paper provides comprehensive information on the traditional practices for managing natural resources, which would be helpful for policy makers, implementers and researchers to understand the mechanism and opportunities for convergence with the existing schemes/programmes.

Keywords Rural communities · Climate change risk · Traditional knowledge and experience · Natural resource management

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1 Introduction

1.1 Climate Change Impacts at Global Level

Human contribution in enhancing the concentration of greenhouse gases (GHG) in the atmosphere is dominant cause of observed warming since 1950. The report projects that global surface temperature are likely to exceed 2 °C whereas sea level rise would range between 2.6 and 8.2 m by the end of the 21st century [Source: Intergovernmental Panel on Climate Change (2014)]. These changes impact the food supply, water resources, infrastructure, forestry, human health etc. Some of these impacts due to the changing climate on key sectors affecting livelihood and economy are as follows:

1.1.1 Water Resources

Scientific studies confirm that climate change results in *intensification and acceleration* of the global hydrological cycle leading to change in rainfall patterns impacting runoff, water storage and water losses due to evaporation and transpiration. These distress mainly the quantity and quality of water resources; extinction/shifting biotic and abiotic species; loss of rural livelihoods and income; coastal flooding and erosion.

1.1.2 Agriculture

Change in climate has both positive and negative influences on *agricultural yield*. However in absence of adaptation efforts, negative influences of climate change on crop yields are more common than the positive influences. Scientific studies have proven that warming and precipitation variability leads to food insecurity which negatively affects wheat, maize, rice and soybean yields.

1.1.3 Human Health

Changing climate *exacerbates health problems* as it enhances the cases of heat-related mortality, water and vector borne illnesses (e.g.: Malaria, Diarrhoea and Malnutrition), and even death due to intensive heat waves and fires, increased likelihood of under-nutrition resulting from diminished food production especially in developing and least developing nations, risks from lost work capacity and reduced labour productivity in vulnerable populations.

1.1.4 Forest

Increased temperature and variable weather events directly and indirectly affect the *growth and productivity of forest*. Major implications include change in distribution of species, extinction of species, shift in the timing of phenological events and invasion of new pests/pathogens.

1.1.5 Infrastructure

Environmental and social systems near infrastructural assets are also impacted by climate change. Vulnerability due to climate change is sector specific and associated with the technology used for construction and operation e.g. rising temperature and low precipitation leads to reduced efficiency of hydro-power plants; infrastructures in coastal areas such as wind turbines are affected by rise in sea level and coastal erosion etc.

1.2 Impact of Climate Change in India

As highlighted above, climate change has unequivocal impact on all the sectors which are not only related to the global economy but also associated with the livelihood of the population. India, a country with special and mixed bio-geographical features such as mountains, coastal area, forest land, wetlands etc., is severely impacted by vagaries of climate change. Map of India is at Fig. 1.

Implications of Climate Change projected for the country indicate rise in annual mean surface air temperature and sea level from 3.5 to 4.3 °C and 1.3 mm/year respectively by the end of the century [Source: Second National Communication submitted to the United Nations Framework Convention on Climate Change (May, 2012)]. It is also projected that possibility of rainfall intensity will also be enhanced with the alteration in the numbers of rainfall days, which will result in less water flow in most of the river basins. Agriculture, an indispensable sector in Indian economy, is also impacted due to the rising temperature; varied precipitation patterns and glacier melting. Climate Change will also impact the overall health sector in India with increase in frequencies of heat wave; increase in the transmission seasons of vector and water-borne diseases like malaria and dengue; increase in migration impacting the regional imbalance etc. Incidence of extreme weather events and change in the composition of the forest are other major consequences of climate change.

Projected impact of Climate Change on key sectors for various regions of the country (Regions are marked in Fig. 1), are tabulated in Table 1 as follows [Source: Climate Change and India: A 4 × 4 Assessment-A Sectoral and Regional Analysis for 2030s (November, 2010)]:

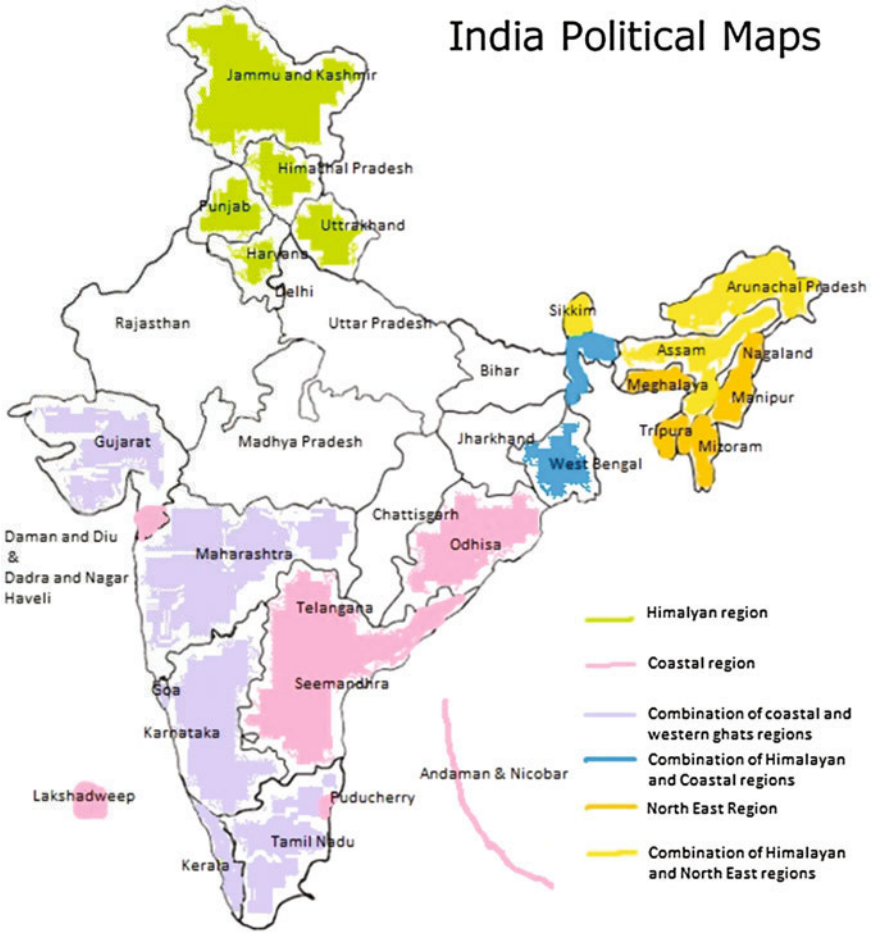

Fig. 1 Map of India highlighting the bio-geographical regions

1.3 Climate Change Impact on Rural Communities

Rural communities are extremely reliant on natural resources such as agriculture, forest, water, fisheries etc. for their livelihood and daily requirements. At present, they are under tremendous stress due to limited carrying capacity of earth and depletion of environmental resources such as water availability and supply, food security, shifts in production areas of food and non-food crops etc.

Climate-related hazards exacerbate these stresses directly impacting rural communities' livelihoods, health, infrastructure etc. [Source: National Action Plan on Climate Change (June 2008)]. In turn these impact disproportionately affect the welfare of the poor in rural areas, such as women because of their lead

Table 1 Projected impact of climate change on key sectors by 2030

S. No.	Bio-geographical region	Impact on key sectors			
		Agriculture	Water	Natural ecosystems and biodiversity	Human health
1	Western Ghats	Productivity of major crops: *Decrease* 1. Rice (by 4%) 2. Maize and sorghum (by 50%) *Increase* Coconut (by 30%)	Variable trend	– 18% of the forest area is likely to undergo change – Net Primary Productivity (NPP) is projected to increase by 20%	No change
2	Coastal area	Productivity of major crops: *Decrease* 1. Rice (by 10–20%) 2. Maize and sorghum (by 15–50%) *Increase* Coconut (by 30%)	Variable trend	– 30% of the forest area is likely to undergo change – NPP is projected to increase by 31%	Reduction in transmission of disease by 34%
3	Himalayan region	Productivity of Apple will decrease	Increase in water yield (by 5–20%)	– 56% of the forest area is likely to undergo change – NPP is projected to increase by 57%	Increase in transmission of disease
4	North-East region	Productivity of major crops: *Decrease* 1. Rice (by 5%) 2. Maize (by 40%)	Variable trend	– 8% of the Forest area is likely to undergo change – NPP is projected to increase by 23%	Increase in transmission of disease

responsibility of acquiring water from long distances and helping their husbands in agricultural activities; people with limited access to land, modern agricultural inputs and infrastructure; illiterate rural families etc.

Rural communities suffer from various geographic and demographic obstacles for mitigating and adapting to the challenges of climate change risks. Remoteness, limited access, limited economic diversity, higher poverty rates, aging population

etc. are some of the many hindrances, which tend to increase the vulnerability of rural communities. As projected by the scientific and social communities, the impact on the rural communities will increase progressively with the challenges of climate change, which forces them to migrate where they can thrive and opt for alternative livelihood practices [Source: Shukla et al. (2003)].

Traditional practices for managing natural resources are being implemented in the fields by farmers. However, a few of these practices have been replicated and integrated with state development policies. Therefore, this paper showcases strategy on how pilot activities on climate change adaptation projects implemented in the country integrates with development scheme/plan for replication and upscaling.

2 Approach

The idea behind developing this paper originated based on GIZ-India's technical support under Indo-German project on 'Climate Change Adaptation in Rural India', which aims to integrate climate change adaptation into development planning and strengthen the capacities of key stakeholders for financing, planning, implementing and monitoring of climate change adaptation measures. This paper is backed by comprehensive research conducted via various secondary literature sources and interviews conducted with key stakeholders, while preparing proposals for accessing climate finance. Successful interventions, which are now part of the country's existing schemes/programmes, have been presented in the paper. It highlights the evolution of policy, methodology, interventions and constraints faced while integrating climate change adaptation activities into development practices. Therefore, impactful case studies have been identified, selected and showcased, which would be helpful for other developing nations as well to undertake adaptation planning.

Traditional know-how is found in abundance at the agricultural fields. However, not all such practices have been integrated into the existing plans/programmes. Finding the right case study for the paper was perhaps the biggest challenge while developing the paper. This constraint was overcome by thorough research from secondary sources of literature and cooperation from various key stakeholders.

3 Farmer's Traditional Knowledge and Practices on Key Sectors

Since decades, farmers are implementing and improvising on their practices and technologies in their agricultural fields for their livelihood needs. Following are some of the traditional practices that have been improvised and implemented over the years based on the farmer's experiences [Sources: India's 12th Five Year Plan document (2012); India's Economic Survey (2012-13); Sharma et al. (June 2015); Livestock and Climate Change (2009); Punjab State Action Plan on Climate

Change (February, 2014); Karnataka State Action Plan on Climate Change (December, 2013); Telangana State Action Plan on Climate Change (June, 2016); Haryana State Action Plan on Climate Change (December, 2011)]:

3.1 Agriculture

- Promotion of *Mulching* for maintaining the micro climate of soil, adding nutrients to the soil, reducing evaporation, and preventing soil erosion.
- Promotion of *Green manuring*[1] for enhancing the nitrogen content in the soil, improving soil fertility, controls pest, diseases and weeds.
- Growing of *Millets* e.g.: Marua, Kodo, Grams, Lentils etc., which are high on nutrition content and demand less water.
- Promotion of *organic material* e.g.: Neem, for agricultural pest control.
- Adoption of *Zero tillage* practices for retaining soil carbon, increasing fertilizer use efficiency, reducing soil erosion and saving labour and energy.
- *Intercropping/mixed cropping* to reduce the risk of crop failure during poor monsoon and effective utilisation of land.
- Development of *Seed banks* to maintain the gene pool and conservation of endangered species.

3.2 Livestock

- Propagation of *indigenous varieties of livestock* for enhancing the pool of pure blooded indigenous livestock which are more productive; demands less fodder and resistant to diseases and heat stress.
- Establishing *Bio-gas plants* near cattle sheds for the collection of dung which can be used for generating methane having high calorific value. This also helps in managing cattle waste.
- Adoption of *drought resistant feed and fodder varieties* especially for the drought prone areas to ensure cattle's productivity during less water.

[1]Green manuring is the cultivation of a forage/leguminous crop having high nitrogen content during the monsoon which will later be used for wheat or other cash crops.

3.3 Water

- Adoption of a system for *storing rain water* in the low lying areas besides the paddy field for meeting the irrigation demand of the crop.
- Promotion of *drip and micro irrigation practices* for vegetable cultivation.
- Construction of *water storage tanks* such as cascade tanks, check dams, gully plugging, contour and vegetative bunds in the undulating areas to store water, improve soil moisture regime, recharge ground water and reduce soil erosion.

4 Mainstreaming and Integration of Traditional Practices into Development Plans

Based on the research conducted by scientific community and farmer's ground level strong knowledge base gained over generations from practical experiences, farmers are implementing these practices successfully pertaining to agriculture, water, livestock etc. sectors. Experiences from the implementation of practices have gained a huge momentum in farming and some of the practices are an integral part of the district plans, for which adequate technical and finance support are provided by the Government.

A major step in this regard is the development of Action Plan for Climate Change at the Sub-National/State level to address the State specific issues on climate change. As India is a country of 36 States/Union Territories, each with its unique feature, development of Action Plan on Climate Change at the sub-national level has been a significant step in this regard. Each State Action Plan on Climate Change (SAPCC) includes the current and future state's climate change scenarios and likely impacts of climate change of the concerned region on sectors such as water, agriculture, energy, tourism, infrastructure, disaster management, coastal area protection etc. Accordingly, strategies were identified and prioritized to address the issues of the vulnerable areas, sectors and communities and their associated risks.

Development of SAPCCs was a comprehensive exercise prepared through consultations with various experts across sectors; Non-Government Organizations; research institutions etc. It is a guiding document for the activities to be undertaken at the State level for each sector in the next 15–20 years. However, in order to operationalize activities envisaged under SAPCCs, the activities are being implemented/planned for implementation in a project/programme/scheme mode based on the scientific and farmer's ground level knowledge.

5 Results and Analysis

This section showcases case studies which depict some of the examples for operationalization of climate change adaptation activities and their integration with the state development plans/schemes. Case studies are as follows [Sources: Towards Climate Resilient Livestock Production System in Punjab (August, 2015); Resilient Agricultural Households through Adaptation to Climate Change in Mahbubnagar district, Telangana (February, 2016); Pandey Rita (August, 2014); Singh Inderjeet et al. (September, 2013); Climate-Smart Villages in Haryana, India (August, 2014) and Rashtriya Gokul Mission (2012)]:

5.1 Sub-surface Water Preservation in Agricultural Based State (Punjab)

Introduction to the area: Punjab, a northern state of the country, is also called as agriculture flourished state. Major crops grown in the state are Barley, Wheat, Rice, Maize and Sugarcane.

Problems:

- Fall in water table level due to extensive rice cultivation and its early transplantation before mid-June in the rice belt of the state.
- Large areas of the state cultivate rice as it is more profitable, stable and less risky crop with assured agriculture market.

Solution: Delay in sowing of paddy leads to delayed transplanting. This is to ensure that the water requirement is fulfilled from rainfall. Picture of an irrigated land of the State during June, 2015 is shown at Fig. 2.

Strategy:

- Punjab State Farmers Commission (PSFC 2007) took legislative steps by drafting a legislation titled 'Preservation of sub-soil water in the State of Punjab', based on the research done by the State Agricultural University.
- Main purpose of the legislation was to prohibit the sowing of Paddy nursery and transplanting the Paddy before the notified dates.
- Large awareness programmes were conducted for farmers through workshops, media channels etc. highlighting the importance of saving ground water just by shifting the dates of sowing and transplantation.
- Even though many farmer programmes were conducted, making farmers adopt these practices was a challenge. In order to successfully implement the activities, strict action was taken like suspension of officers who did not take action or showed laxity towards violating farmers etc.

Fig. 2 Irrigated land in Punjab during June, 2015

- Based on the successful piloting of the legislation for two years, it was promulgated to wider area in 2008 and a dedicated act was prepared by Govt. of Punjab incorporating all procedures.
- The act was retitled to 'The Punjab Preservation of Sub Soil Water Act, 2009'.

Impact:

- Increase in water table level.
- Water demand for Paddy was met by rainfall unless there was a delay in monsoon.
- Reduced electricity consumption.
- Increase in relative humidity.
- Less amount of fine dust.
- Less pollution due to control of burning of rice straw due to less availability of time for sowing of wheat. Therefore, they use new machinery such as happy seeders etc., which helped in sowing while simultaneously cutting and burying the rice stubbles.
- Saving soil micro-organisms and cost.

5.2 Development of Climate Smart Villages (Haryana)

Introduction to the area: Haryana, a northern state of the country and adjacent to Punjab, is also an agriculture rich state.

Problems:

- Weather variability i.e. increasing temperature and variable rainfall, which affects crop yield.
- Over-exploitation of ground water resources.
- Poor management of crop residues leading to pollution.

Solution: Adoption of sustainable agriculture practices resilient to climate change such as zero tillage; residue management; optimization/diversification of cropping system; water management through laser leveller and micro-irrigation; stress resilient cultivars; seed and fodder banks etc. Figures 3 and 4 show some of best practices (sowing and seeding) for a Climate Smart Village (CSV) in Haryana.

Strategy:

- Project activities were first proposed to be piloted in 27 villages of the State.
- Villages were selected based on the climate vulnerability of the targeted villages through a baseline survey.
- Young farmers/entrepreneurs willing to replicate/upscale the project activities in the future, were selected and their skills were developed on effective implementation of agricultural practices through various training programmes and exposure visits.
- A network of knowledge partners was established for providing agro-advisories to young farmers, so that they can help other farmers of the villages on planning the project activities.
- An innovative excellence model in each village was created with provision of latest equipment such as Happy seeder, Multi-crop planter, Maize thresher etc. These equipments were used by villagers on a rotational basis for implementing the activities in their fields.
- Climate resilient practices were successfully implemented in 27 villages. However, there were still some challenges like financial resources for implementing the activities and farmers capacity building for the application of the innovative technology, which were creating hindrance in replicating the activities in other areas.
- However, based on the successful implementation of the project, Government of India provided financial support for replicating the activities in another 250 villages of the state, which also includes support for the capacity building of farmers.

Impact

- Higher agricultural yield (e.g.: wheat and maize yield increased by 6 and 15% respectively).

Fig. 3 Direct seeding by a farmer as part of CSV by farmers on lands of Haryana

Fig. 4 Picture of Happy Seeder for sowing wheat in the fields

- Adequate management of agricultural residue.
- Effective application of nitrogen and fertilizers in the fields.

5.3 Provision of Shelters to Non-productive Stray Cattle

Problem: Orphanage of non-productive cattle.

Solution: Collecting cattle at a single place to prevent it from roaming, accidents, agricultural loss etc. Figure 5 depicts a model shed for stray cattle in National Dairy Research Institute (NDRI), Karnal.

Strategy:

- To prevent unproductive cows from being sent to the abattoir, a project for collecting cattle in a single place was implemented on a pilot scale. This was done with the existing facilities from research institute for dairy development.
- It was observed through the research conducted within the project that when stray cattle are put inside a cooler environment, they show better physiological status.
- Cooling systems essentially alleviate heat load by using the principle of evaporation, leading to improved feed intake and milk production in areas with high environmental temperatures.
- Cattle dung was also collected to generate bio-gas, which also has co-benefits for mitigating the challenges of climate change by reducing methane emissions.

Fig. 5 Model Shed for stray cattle in NDRI, Karnal

- Based on the successful implementation of the project activities, Government of India launched the Rashtriya Gokul Mission in mid-2014, with an objective to conserve and develop the indigenous breeds in a focused and scientific manner. The mission also supports the development of "Gokul Grams" centres, which provide shelters for stray cattle.

Impact:

- Better environment to stray cattle.
- Mild increase in milk yield.
- Bio-gas generation and reduction of GHG.

6 Conclusion

Case studies presented in the paper signify that successful transformation of ground activities into policies/acts is an essential factor to increase the effectiveness of adaptation planning process. Besides taking into consideration farmer's knowledge and experience while planning adaptation processes for vulnerable communities, it is also essential to consider the following:

- Provide incentives to farmers such as subsidy for new technology, awards for successful implementation of project activities etc.
- Conduct awareness programmes for responsible district officers regarding the new scientific studies on climate change, new technologies to adapt/mitigate the challenges of climate change and their cost benefit analysis etc. This will also create competition amongst officers and hence ease in implementation.
- Penalize violating farmers in the fields, actions against the responsible extension officers etc.
- Encourage farmers to provide financial contributions in adopting new technologies, which helps in ensuring farmer's ownership for sustainable implementation of the activities in the fields.

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

Gunjan Gupta and Pradeep Mehta

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

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

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1 Introduction

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

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

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

In order to respond to the challenges of climate change effectively, the government has created advisory council on climate change. The council has a broad base of key stakeholder representative including the government, Industry and civil societies. This council also provides guidance on the matters of domestic agenda

and review of the implementation of National Action Plan on Climate Change including Research and development Agenda. NAPCC will continue to evolve, based on new scientific and technical knowledge as they emerge in response to evolution of multilateral climate change regime including arrangements for international cooperation's (NAPCC, Government of India).

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

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

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

2 Methodology

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