Building Urban Resilience

Assessing Urban and Peri-urban Agriculture in Chennai, India

UNEP

START

global change SysTem for Analysis, Research & Training

Published by the United Nations Environment Programme (UNEP), November 2014

ISBN: 978-92-807-3377-8
DEW/1789/NA

Citation
Nambi, A.A., R. Rengalakshmi, M. Madhavan and L. Venkatachalam. (2014). Building Urban Resilience: Assessing Urban and Peri-urban Agriculture in Chennai, India. [Padgham, J. and J. Jabbour (eds.)]. United Nations Environment Programme (UNEP), Nairobi, Kenya.

A digital copy of this report along with supporting appendices are available at www.start.org/upa/chennai.pdf

Managing Editor: Jon Padgham
Associate Editor/Production Coordinator: Jason Jabbour
Assistant Editor: Katie Dietrich
Copy Editors: Bart Ullstein and Kristie Bates
Layout and Design: Jennifer Odallo and Audrey Ringler
Printing: UNON Publishing Services Section, Nairobi-ISO 14001-certified/D1 No. 14-00111/250
Cover Photo: © Bartosz Hadyniak

UNEP promotes environmentally sound practices globally and in its own activities. This report is printed on paper from sustainable forests including recycled fibre. The paper is chlorine free, and the inks vegetable-based. Our distribution policy aims to reduce UNEP's carbon footprint.

Building Urban Resilience

Assessing Urban and Peri-urban Agriculture in Chennai, India

A. Arivudai Nambi, Raj Rengalakshmi,
Manjula Madhavan and Lingappan Venkatachalam

UNEP

global change SysTem for Analysis, Research & Training

Preface

Food production in and around cities is an integral part of the urban fabric in much of the developing world. In these regions, urban and peri-urban agriculture (UPA) plays an important role in diversifying urban diets and providing environmental services in urban and peri-urban areas. As such, there is growing interest in UPA as a strategic component of urban resilience and climate change adaptation planning. However, advocacy for UPA in this capacity is outpacing the body of evidence regarding important stressors and drivers that act on UPA. Such knowledge is especially critical in the developing world where urban areas are experiencing rapid growth and transformation. In these regions, UPA is facing intensifying pressures from urban encroachment, waste disposal, pollution, and climate change that may undermine the sector's long-term viability.

The need to better understand these critical sustainability dimensions provided the impetus for city-level knowledge assessments of UPA, whose main findings are contained in nine underlying assessment reports including this one. The assessed cities were Dakar (Senegal), Tamale (Ghana), Ibadan (Nigeria), Dar es Salaam (Tanzania), Kampala (Uganda), Addis Ababa (Ethiopia), Dhaka (Bangladesh), Kathmandu (Nepal) and Chennai (India). All of the reports and the synthesis report can be found at *http://start.org/programs/upa*. The assessments were conducted in 2012, with initial stakeholder engagement beginning in 2011. The assessments were led by city-based teams, the composition of which varied, with some of the teams being comprised predominately of researchers and other teams comprising of a mix of researchers, city officials and urban NGO representatives.

The assessments seek to better understand the changing nature of UPA systems, and the critical interactions at the land-water-climate nexus that influence resilience of UPA in rapidly growing developing-country cities. The audience for these assessments includes national and city-level policymakers, sectoral experts and city planners, the research community, and non-governmental organizations (NGOs) that interface with urban farmers and other actors within the broader UPA sector.

The UPA assessments are part of a larger project on strengthening understanding of critical links between climate change and development planning in West Africa, East Africa and South Asia. The premise for the project is that progress towards undertaking effective action to address climate change risks in these regions is hindered by low levels of awareness of global climate change, lack of understanding of the findings of the Intergovernmental Panel on Climate Change (IPCC) and other sources of scientific information, lack of location and sector specific knowledge, and the need for strengthening capacities to undertake integrated assessments that support decision making. This multi-year project has been a collaborative effort between the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), START, the University of Ghana, the University of Dar es Salaam, and the Bangladesh Centre for Advanced Studies (BCAS).

Jon Padgham
Deputy Direct
International START Secretariat

Jacqueline McGlade
Chief Scientist
United Nations Environment Programme

Acknowledgements

We would like to thank the different individuals and institutions who in one way or another contributed to the execution of the larger European Commission-led project. In particular, the successful implementation and completion of the project, and the subsequent knowledge assessments were made possible due to the close cooperation and commitment of the International START Secretariat; the United Nations Environment Programme (UNEP) represented by the Division of Early Warning and Assessments and the Office of the Chief Scientist; the World Meteorological Organization (WMO), the University of Ghana, the University of Dar es Salaam, and the Bangladesh Centre for Advanced Studies (BCAS). Several colleagues across these organizations rendered valuable insight, expert advice, guidance and encouragement during this 4-year endeavor. We would especially like to recognize the efforts and support of Ghassem Asrar, Hassan Virji, Katie Dietrich, Clark Seipt, Chris Gordon, Pius Yanda, Atiq Rahman, Chipo Plaxedes Mubaya, Adelina Mensah, Elaine Tweneboah, Abu Syed, Salif Diop, Audrey Ringler, Jennifer Odallo, Peter Gilruth and Joseph Alcamo as well as Jon Padgham and Jason Jabbour, the project managers and editors of this series.

The overall project and the associated UPA assessments were made possible in large part thanks to funding provided by the European Commission (through project ENV/2008/149690 '*Understanding the Findings of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report "Climate Change 2007"—Integrating Climate Change Adaptation and Mitigation in Development Planning*'), as well as by the United Nations Environment Programme (UNEP), and the Global Climate Change Programme at the US Agency for International Development (USAID). The editors of this series wish to thank these organizations for their financial support.

In addition to the numerous authors listed in each of the separate reports, we are grateful to the following people for providing useful insights and feedback during the early conception of the knowledge assessment, and helpful review comments on the various manuscripts: Rafael Tuts, Anna Skibevaag, Stephen Twomlow, Elizabeth Migongo-Bake, Trang Nguyen, Volodymyr Demkine, Jane Battersby, Marielle Dubbeling, Anna Kontorov, Richard Munang, Jesica Andrews, Fatoumata Keita-Ouane, Jacqueline McGlade, Keith Alverson, Stuart Crane, Martina Otto, Robert Yennah, Beverly McIntyre, and Tom Downing. We would also like to express our sincere appreciation for the generous support of colleagues at the University of Cape Town's *Climate* Systems Analysis Group who with the climate projections for six African cities.

Acronyms and abbreviations

ASA	Area sown more than once in a year
CMA	Chennai metropolitan area
CMDA	Chennai Metropolitan Development Authority
CMFRI	Central Marine Fisheries Research Institute
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board
GIS	Global information system
CRZ	Coastal Regulation Zone
GCA	Gross cultivated area
GDP	Gross domestic product
IAMWARM	Irrigated Agriculture Modernization and Water-Bodies Restoration and Management Project
IMD	Indian Meteorological Department
IITM	Indian Institute of Tropical Meteorology
IT	Information Technology
IPCC	Intergovernmental Panel on Climate Change
IELRC	International Environmental Law Research Centre
INCCA	Indian Network for Climate Change Assessment
MAT	Mean annual temperature
MMaxT	Mean maximum temperature
MMinT	Mean minimum temperature
MLD	Million litres per day
MSSRF	M.S. Swaminathan Research Foundation
NFHS	National Family Health Survey
NREGA	National Rural Employment Guarantee Act
NSA	Net sown area
NGO	Non-government Organization
PMSS	Probable maximum storm surge
QUMP	Quantifying uncertainties in model projections
SIPDWA	South India Packaged Drinking Water Association
START	System for Analysis, Research, and Training
TDS	Total dissolved solids
TWAD	Tamil Nadu Water Supply and Drainage
THI	Temperature-humidity index
TGA	Total geographical area
UPA	Urban and peri-urban agriculture
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

Contents

Executive summary

This report presents the findings of a knowledge assessment on urban and peri-urban agriculture (UPA) for the city of Chennai, India that was conducted in 2012. It examines the state of UPA in the city through the lens of intensifying urban pressures and increasing climate risks with the objective of identifying how these and other drivers potentially interact to affect the long-term sustainability of UPA, and what response options are needed to address existing and emerging challenges. The assessment is intended to:

1) describe the dominant characteristics of urban and peri-urban agriculture, and identify key knowledge gaps in these UPA systems;
2) explore the array of stressors that contribute to vulnerability of peri-urban systems to climatic and other environmental changes; and
3) identify critical areas for strengthening policies and institutional capacities that contribute to sustaining food production within the larger context of resilient cities and food systems.

Food production in peri-urban areas of Chennai is under significant pressure from multiple and interlocking stresses. The main stresses acting on peri-urban food production are rapid urbanization and urban expansion into peri-urban farmland, instability in the irrigation regime, diminishing water supplies for agriculture in favour of urban water needs, saltwater intrusion into aquifers, a strong 'push-pull' dynamic that amplifies agricultural labour costs, and climate change. These factors, plus the increasingly unprofitable nature of agriculture, are contributing to declining production in the rice-based farming systems in peri-urban Chennai. Volatility and instability in the production system intensifies the pressure on farmers, particularly the young, to move out of agriculture in search of more viable employment, resulting in fertile agricultural land either being left fallow or being put to non-agriculture use. This in turn has important implications for food security of the peri-urban region as well as Chennai City in terms of greater food miles (the distance food travels from production to consumption) and resultant higher food prices in Chennai City, as well as in peri-urban areas.

Sea level rise, one of the greatest threats arising out of climate change, will affect Chennai and the peri-urban coastal area in a variety of ways including inundation, flood and storm damage associated with severe cyclones and surges, erosion, saltwater intrusion, and wetland loss. A sea-level rise of 1 m provides a higher base for storm surges and would increase the frequency of flooding associated with them. Climate change may also alter the productivity of fisheries that Chennai and the surrounding area depend upon; there is already emerging evidence that temperature rise in the Bay of Bengal is affecting marine fishing areas that serve Chennai.

Concerted efforts are needed to make food production in this rapidly growing peri-urban region more resilient to the forces of urbanization, water scarcity and, increasingly, climate change. Some of the possible ways to address these issues include policy reform to reduce the unsustainable rate of water transfer from peri-urban to urban uses, creation of incentives for water conservation, increased rainwater harvesting, promotion of low-cost ecologically-friendly water-saving technologies in rice cultivation, and adopting a watershed approach to ensure sustainability of the production system in the light of the various pressures bearing down on water resources. Diversification of cropping patterns to less water-intensive crops such as millets, and the adoption of integrated farming systems to spread the risk involved in farming are other options though their economic feasibility needs to be understood in the context of the multiple forces that are compelling an exit from agriculture. Building the coping capacity of marginal farmers and agricultural labourers through collective farming, and more generally encouraging a platform that gives greater voice to villages affected by the pro-urban bias of policy making are critically important.

The assessment study was initiated for the city of Chennai and its peri-urban areas, covering the adjacent districts of Kancheepuram and Thirivallur. The purpose of the study was to provide an indication of the current status of peri-urban agriculture related to its productivity, ability to support livelihoods, and the water and land resource base upon which agriculture depends in the context of how rapid urban expansion and other socio-economic pressures, water resource degradation and climate risks are impacting on agriculture and agriculturally based livelihoods. The three agricultural components that the study focused on were paddy rice, dairy and eggs; the study also considered fisheries-based livelihoods in peri-urban Chennai, and the vulnerability of Chennai's infrastructure and coastal environments to sea level rise.

© Naes

This assessment aims to inform the state policy making and planning undertaken by the city administration and other relevant stakeholders on the critical linkages between food production, rapid urban growth, climate change, environmental degradation and poverty, and in doing so provide a basis for action. The assessment was carried out through a combination of relevant quantitative and qualitative information collected from various stakeholder meetings and surveys, as well as secondary data available from research institutions, government agencies and archives. A substantial amount of existing literature on the theme has been utilized for developing the theoretical framework and methodology. The assessment is indicative rather than comprehensive, primarily because of data constraints and time limitations. It is envisaged that its findings will provide the basis for conducting more detailed studies in the future, and as such important knowledge gaps and needs are highlighted in the recommendations section.

1 Background and methods

India has witnessed rapid changes in its urban landscape over the past few decades, as existing urban areas have significantly expanded in response to high population growth and rural areas transform themselves into urban centres. Although urbanization is a long-term process, factors such as economic liberalisation in India and other rapidly developing countries accelerate the pace at which it takes place. Urban areas generate both positive and negative externalities. The positive ones include those benefits associated with infrastructure, investment, employment and other income generating activities, the negative ones consist of problems caused by urban poverty, deterioration in the availability of basic amenities and ever increasing environmental degradation.

The urban poor are highly vulnerable to the effects of climate change, which are likely to increase as a greater number of people place strains on administrative and natural-resource provisioning systems that in turn influence vulnerability to climate shocks (Ahmed *et al*., 2009). According to Parry *et al*. (2007) urban populations will need to cope with increased incidents of flooding, drought, air and water pollution, heat stress and vector-borne diseases. In spite of the growing concerns, present adaptation-centered policies and projects have been slow to recognize urban vulnerabilities, instead focusing more on rural livelihoods since these are viewed as far more dependent on climate-sensitive sectors. Nevertheless, there is a dire need to improve understanding and action on climate vulnerability and adaptation in peri-urban and urban areas (Hallegate and Corfee-Morlot, 2011).

Strategies to reduce urban poverty require a better understanding of the links between food and livelihood security and future-focused approaches that consider risks associated with global environmental change, especially but not exclusively climate change. Such strategies have generally failed to adequately recognize the role that increased volatility in regional and global food and food-grain prices play in exacerbating urban poverty because of the large proportion of income that the urban poor allocate for food (Wang, 2010). Urban and peri-urban agriculture (UPA) has been promoted as a means to bring food-focused resilience planning to urban areas (De Zeeuw *et al.*, 2011). Consideration of UPA's contribution to urban food systems requires place-based understanding of its potential as well as its limitations to meet food needs of city residents. This report examines the significant challenges that peri-urban agriculture faces in the rapidly growing mega-city of Chennai.

The Chennai assessment was led by the M.S. Swaminathan Research Foundation (MSSRF). In developing this assessment, the MSSRF worked with a network of institutes, government agencies and stakeholders. The assessment is expected to inform state policy making, the city administration and other relevant stakeholders on critical emerging issues. This assessment examines UPA in Chennai, India in a multi-stressor context of rapid urban growth, climate variability and change, and environmental degradation. It focuses on urban and in particular peri-urban environments of the city, and the farming systems—food crops, livestock and aquaculture—within them. The assessment's conceptual framework illustrates the key drivers and stressors, development factors and peri-urban products and services. The assessment framework is presented in Figure 1.1.

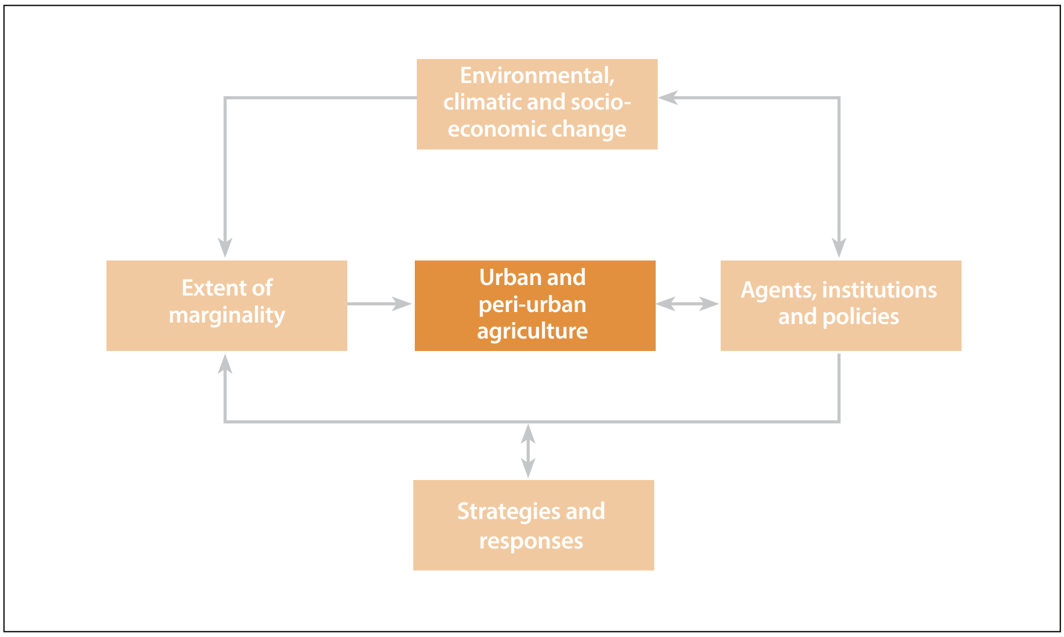
Methods

The study utilized a multi-criteria approach for analyzing the links between rapid urbanization, land and water resource degradation, climate change and peri-urban agriculture, and the implications of these on food prices and poverty. The study defined the peri-urban area as consisting of two districts, Kancheepuram and Thiruvallur, neighboring Chennai city. Quantitative information was collected through secondary and primary data sources, while qualitative information was collected through stakeholder dialogues, group discussions, expert opinions, field visits, media reports, etc.

Considerable effort went into gathering secondary data and information related to demography, socio-economic status, climate analysis, and existing policy frameworks for agriculture and urban planning from a variety of sources including research institutions, government agencies, and archives. Existing research reports on urban infrastructure, peri-urban agriculture, urban poverty and the urban environment pertaining to the study area were extensively utilized to generate relevant information for the analysis.

Global information system (GIS) and processed satellite image data for land use change were obtained from the National Remote Sensing Agency and meteorological data and climate projections were accessed through the Indian Meteorological Department (IMD) and the Indian Institute of Tropical Meteorology (IITM).

FIGURE 1.1
Conceptual framework



2

Current climate and climate change

Chennai has a tropical wet-and-dry climate. The city lies on the thermal equator and is also on the coast, which prevents extreme variation in seasonal temperature; the weather is hot and humid for most of the year. It is hottest in late May and early June with maximum temperatures around 35–40° C (95–104° F). January is the coolest part of the year, with minimum temperatures around 15–22° C (59–72° F). The lowest temperature recorded is 13.8° C (56.8° F) and the highest 45° C (113° F).

Average annual rainfall is about 140 cm, with the city getting most of its seasonal rainfall from the north–east monsoon winds from mid–October to mid–December. During the May to November period, the region is susceptible to cyclones forming in the Bay of Bengal. Prevailing winds in Chennai are usually south-westerly between April and October and north-easterly during the rest of the year. Historically, Chennai has relied on annual monsoon rains to replenish water reservoirs, as no major rivers flow through the area.

The research study specific to temperature trends of Chennai city (Jaganathan and Andimuthu, 2013) shows an increasing trend in mean maximum temperature (MMaxT), mean minimum temperature (MMinT), and mean annual temperature (MAT) from 1951 to 2010. MAT has increased 1.3° C in the last 60 years and MMaxT has increased up to 1.6° C in which the period between 1981–2010 accounts for 75 per cent of the total change during the last 60 years. The study shows MMinT over Chennai has an increase of 1.0° C.

Climate change projections

Climate change projections used in this assessment were provided by the Indian Institute of Tropical Meteorology (IITM) using the PRECIS model downscaled (50 km x 50 km) model carried out for three quantifying uncertainties in model projections (QUMP) for mid-range (A1B) emissions scenario. The periods of the analysis were 1961–1990 (baseline simulation) and three time slices—2020s (2011–2040), 2050s (2041–2070) and 2080s (2071–2098), and included basic climatic parameters of rainfall, surface air temperature, and mean sea-level pressure for the Indian region. The analysis was done for all of India. The analysis of three model simulations indicates that the daily extremes in surface air temperature may intensify in the future. The spatial pattern of the change in the highest maximum temperatures suggests warming from 1-4° C by the 2050s. Increases in minimum night temperatures are greater in all three time slices compared to increases in the daily maximum temperature. A rise of more than 4.5° C in night temperature has been simulated throughout India, except in small pockets of peninsular regions (Krishna Kumar *et al.*, 2011).

A sectoral and regional analysis for the 2030s undertaken by the Indian Network for Climate Change Assessment (using a 1961–1990 baseline) indicates the following.

- About 10 per cent increase in the Indian monsoon rainfall over central and peninsular India in the 2030s. The expected change in the rainfall is within the current monsoon variability, and there are large model-to-model differences, lowering confidence in these projected changes;
- A 1.5–2° C warming in the annual mean temperature over the Indian landmass with winter (January–February) and spring (March–April–May) showing the greatest warming;
- A 3–7 per cent increase in all-India summer monsoon rainfall;
- The cyclonic disturbances surrounding Indian Ocean during the summer monsoon are likely to be more intense, and the systems may form slightly to the south of normal locations;
- The observed trends also indicate that the cyclonic disturbances are five to six times more frequent over the Bay of Bengal than the Arabian Sea. One third of the bay disturbances intensify into storms. The shallow depth of the Bay of Bengal and low flat coastal terrain produces much larger storm surges;

The individual simulations that comprise the ensemble analysis indicate large differences between model results. Thus model projections should be interpreted with caution. These findings are not predictions of future climatic conditions but rather serve as indications of potential change.

Nearly a year after the 2004 Asian Tsunami, displaced people still occupied camps on the peri-urban fringes of Chennai, where they faced serious environmental health challenges © Corbis

3 Population trends and projections

Population trends in the Chennai metropolitan area

Chennai is situated on the north-east end of Tamil Nadu on the coast of the Bay of Bengal. It lies between 12°9' and 13°9' of the northern latitude and 80°12' and 80°19' of the southern longitude on a sandy shelving breaker-swept beach. It stretches nearly 25.6 km along the coast from Thiruvanmiyur in the south to Thiruvottiyur in the north and runs inland in a semi-circular fashion. It is bounded on the east by the Bay of Bengal and on the remaining three sides by Kancheepuram and Thiruvallur Districts (National Informatics Centre, 2013).

The Chennai metropolitan area (CMA) consists of 15 administrative zones and 200 wards. The CMA comprises Chennai City Municipal Corporation (hereafter, Chennai City), 16 municipalities, 20 town panchayats (local administrative bodies) and 214 villages coming under 10 panchayat (unions). The CMA is 10 times larger (1 170 km^2) than Chennai City and its population was estimated to be around 10 million in 2011. Its administrative boundary was expanded in September 2011 in order to better serve the increasing population in the peri-urban areas. Chennai City, with 4.6 million people (2011 census), has become the third most populous city in India, after Mumbai and Delhi. Its population density is nearly 27 000 people per km^2, and it has a 50:50 male/female ratio. The decadal population growth rate in Chennai City has been declining since 1971 (Table 3.1) while the total population of the CMA has been steadily increasing in absolute terms (Figure 3.1).

© P. Kumar

FIGURE 3.1
Population growth, Chennai metropolitan area, 1971–2001
Source: Census of India

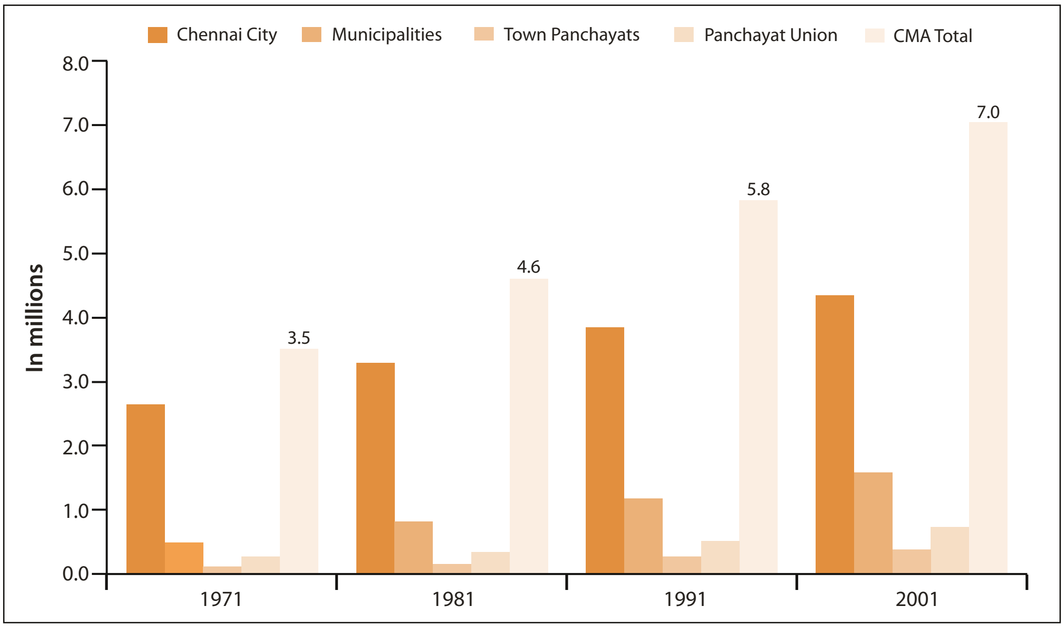


FIGURE 3.2
Population projections, Chennai metropolitan area, 2012–2026
Source: CMDA, 2007

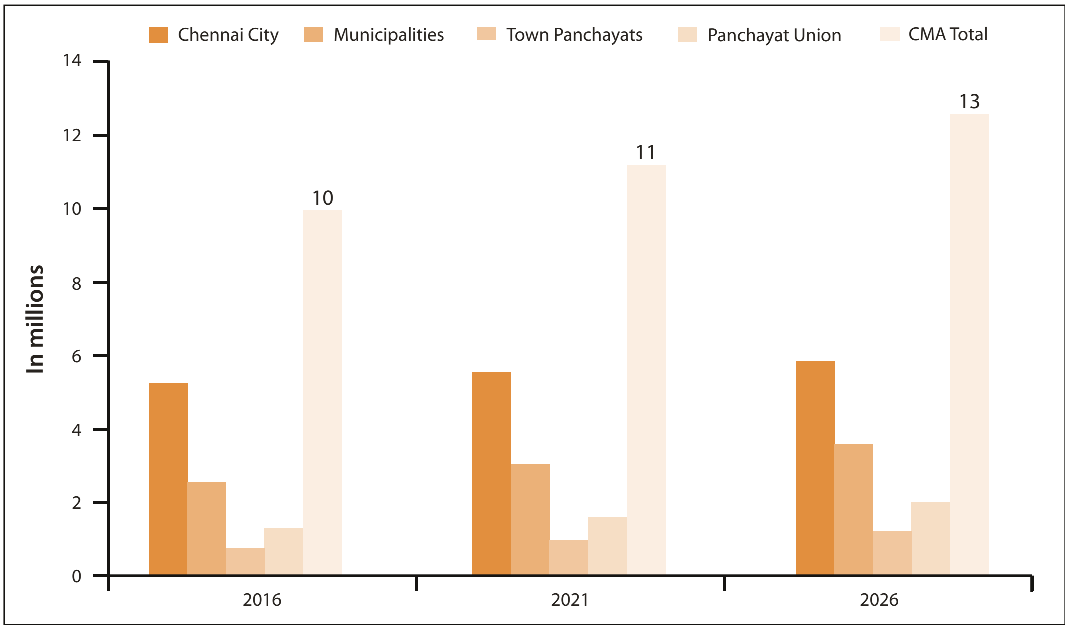


TABLE 3.1
Growth of population in Chennai City, 1951 to 2011

Year	Population	Decadal Growth (%)
1951	1 416 056	-
1961	1 729 141	22.11
1971	2 469 449	42.81
1981	3 266 034	32.26
1991	3 841 398	17.62
2001	4 343 645	13.07
2011	4 681 087	7.77

Source: Census of India, various reports

According to the Chennai Metropolitan Development Authority (CMDA), the population of Chennai City is projected to reach 5.2 million in 2016 and 5.8 million in 2026, and the CMA region about 12.6 million (Figure 3.2).The increasing population in the city has profound implications on the provision of basic amenities. For example, the provision of safe drinking water in adequate quantities to the growing population is a serious issue requiring innovative solutions.

Migration

In-migration to the CMA has significantly contributed to population increase in the city and its surrounding areas, although the rate has been declining over the past five decades. As Table 3.2 indicates, nearly three-quarters of the migrants to Chennai City come from within Tamil Nadu state. Many of the urban amenities provided in the CMA are considered as local public goods, and include such things as water supply and sanitation. Migrants to the CMA are granted equal access to many of these scarce resources causing tensions between existing residents and newly arrived migrants.

TABLE 3.2
Migration to Chennai City, 1961–2001

Year	Population (millions)	Other parts of Tamil Nadu	Other parts of India (excluding Tamil Nadu)		Proportion (%) of migrants to total city population
		%	%	%	
1961	0.172	69.5	26.6	3.9	37.2
1971	0.246	70.6	25.6	3.8	31.6
1981	0.328	71.3	25.3	3.4	30.7
1991	0.384	70.5	26.4	3.0	23.9
2001	0.934	74.5	23.8	1.7	21.6

Source: Census reports, various years

Migration adds stress to the basic infrastructure needs of the CMA, which require large public and private investment in such priority areas as water supply, sanitation, solid waste management and flood prevention. Despite efforts to meet basic infrastructural needs, the people in the CMA are vulnerable to the effects of rapid urban growth and inadequate amenities, including pollution, coastal erosion and seawater intrusion, and are highly sensitive to frequent extreme events such as heavy precipitation as seen during October 2005 (Goswami *et al.*, 2006) and the recent cyclone Nilam, which hit the Chennai coast during October 2012.

The labour market structure of the urban areas has been altered by migration. Between 1991 and 2001, the increase in the number of workers was positive both in the city as well as in the rest of the CMA. It should be noted, however, that the official statistics do not capture the entire labour market because of extensive employment in the informal sphere.

Workforce

Analysis of the distribution of workers across major economic activities in Chennai peri-urban areas reveals a clear shift of the workforce from agriculture to non-agricultural activities. The category which has shown tremendous increase is other workers, which includes all non-agricultural work such as trade and commerce, services, manufacturing, mining and quarrying, etc., but excludes activities classified as household industries, while the number of people engaged in agriculture, as cultivators and agricultural labourers, declined by 15 per cent between 1991 and 2001(Table 3.3). Similarly, Janakarajan *et al.,* (2006), in village-level studies of peri-urban Chennai, found that the growth of non-agricultural occupations was three times greater than that of agriculture over the period of 1985–2000. These studies underscore the generally weakening status of agriculture as a livelihood means in peri-urban areas of Chennai.

TABLE 3.3
Per cent of workers by major activity in Chennai peri-urban areas

Major Economic Activity	Male		Female	
	1991	2001	1991	2001
Cultivators	17	11	13	12
Agricultural Labourers	25	14	59	33
Household Industry	2	4	0	8
Other Workers	56	71	27	47

(Source: Primary Census Abstract, Tamil Nadu, 1991 and 2001)

4
Urban poverty and food security

This section provides official statistics on rates of poverty in Chennai and the implications of that for food security. The topic of food security itself is beyond the scope of this assessment, thus this section is rather limited in detail. The statistics reported in this section provide a thumbnail sketch of urban food security. More in-depth studies are needed to provide updated official statistics and to understand the dynamic set of issues around food access strategies by food insecure groups and peri-urban-urban connectivity issues related to food.

The Planning Commission of India defines people with insufficient income to buy 2 400 calories of food a day as living below the poverty line. Substantial progress was made in the 1990s in reducing the percentage of the population living below the poverty line (Figure 4.1). Updated studies are needed to assess whether this trend is continuing, in light of food and fuel price spikes in recent years.

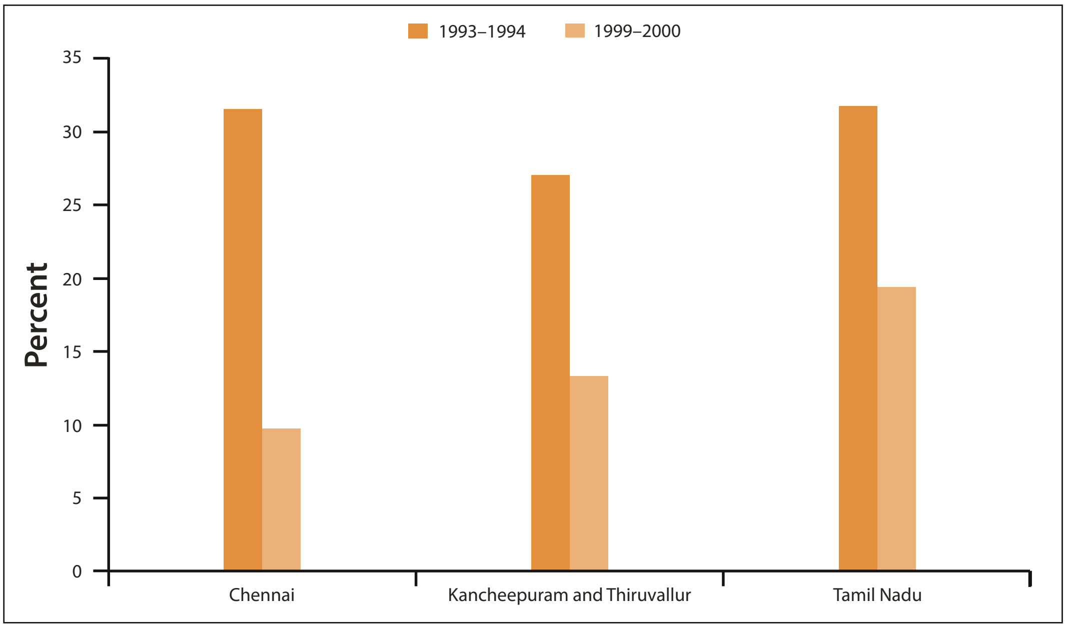


FIGURE 4.1
Per cent population living below the poverty line

Source: Department of Statistics, Government of Tamil Nadu

Economic development in the region combined with government-administered welfare programmes targeting the poor and other vulnerable groups in Tamil Nadu are important factors behind the drop in urban poverty. Under the universal public distribution system almost 20 million households in the state are entitled to 25 kg of free rice, which helps households to meet with their basic food requirements. Apart from free rice, various other essential items, oil, pulses, etc., are provided at highly subsidised rates. The free rice and other essential items are distributed through a large number of networked fair-price shops (Table 4.1).

TABLE 4.1
Fair-price shops in Chennai and its peri-urban areas

District	Number of Shops
Chennai	1 420
Kancheepuram	1 369
Thiruvallur	956

Source: Statistical Handbook of Tamil Nadu, 2011

There are no reliable sources of official data upon which the actual number of poor living in slum areas in Chennai can be assessed. According to the 2001 census[1], more than 25 per cent of the population in Chennai live in slums. However, results of the National Family Health Survey (NFHS 3, 2005–06) reveal that around 40 per cent of the people in Chennai live in slums, which is substantially greater than the 2001 census estimate of 25 per cent. The NFHS 3 was conducted at an all-India level in 2005-06 under the stewardship of Ministry of Health and Family Welfare, Government of India.

The NFHS 3 provides vital information about the nutritional and health status of the urban population in Chennai. The NFHS 3 report found that around 40 per cent of women and 23 per cent of men are overweight, with around 12 per cent of women and 4 per cent men obese. These findings imply that in urban areas it is not only lack of food but also over-consumption and a change in consumption patterns that have to be considered. It should be noted that overall levels of anaemia among women are more than four times that of men. The level of prevalence of anaemia among slum and non-slum women does not differ much, though it is slightly higher for the non-slum women.

© Tatakis

1. The latest census was conducted in 2011 and the results are yet to be released; therefore, the 2001 census data are used, though they are 11 years old.

5

Land-use change in peri-urban areas of Chennai

The peri-urban areas assessed in this study were Kancheepuram and Thiruvallur districts, which surround Chennai City (Figures 5.1 and 5.2). A substantial portion of food grains, fish, milk, and eggs for Chennai are produced in these two districts (see Section 7), although significant amounts are also supplied from other parts of Tamil Nadu and elsewhere in India (Department of Economics and Statistics, GoTN). The two districts are well connected by road and rail networks and therefore, the transaction costs of moving goods and services to Chennai City are minor. Since the transaction cost is one of the key determinants of the price of agricultural commodities, the two neighbouring districts play a major role in supplying the city, with important implications for the urban poor who depend on low-cost foods.

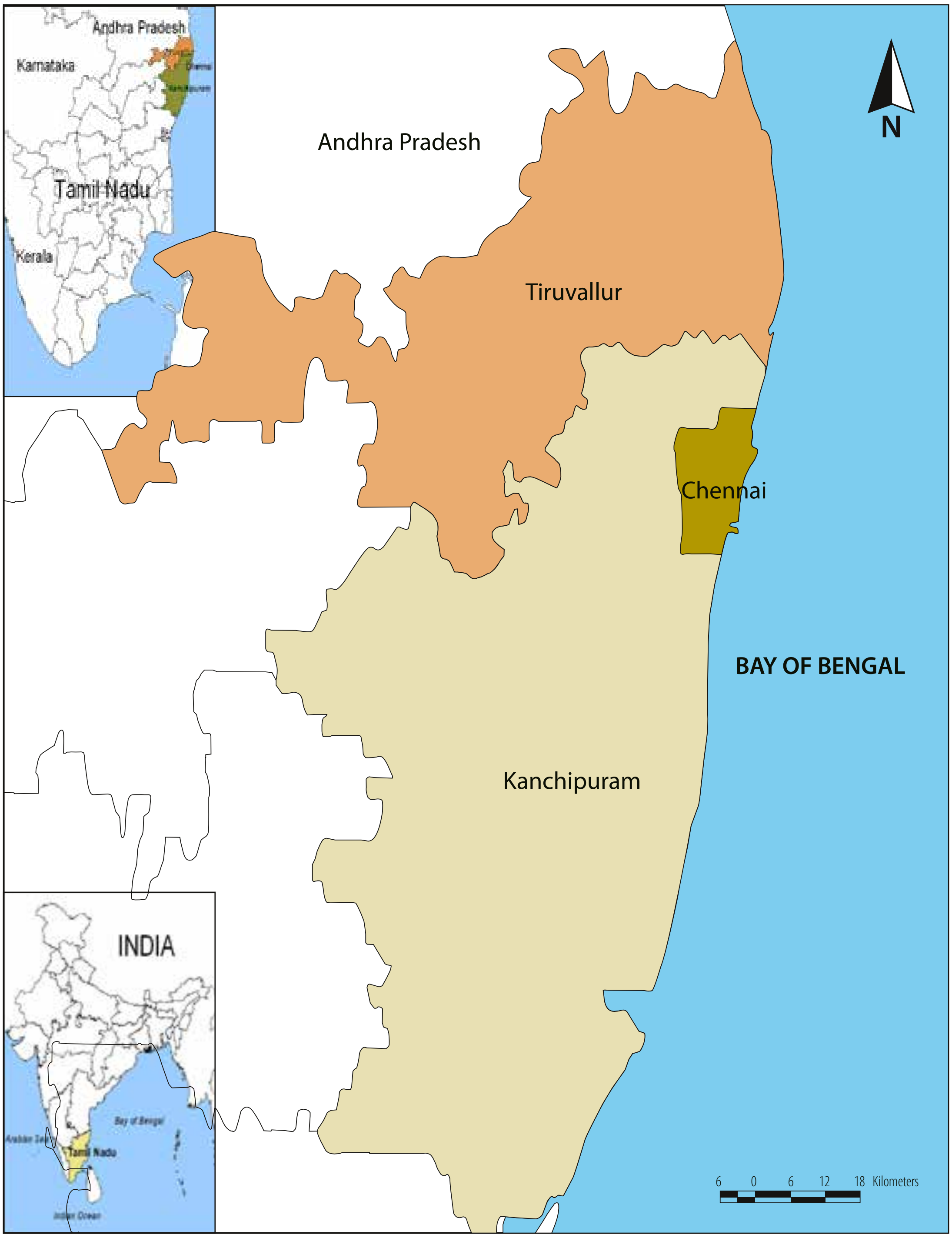
Eighty-five per cent of Chennai City's land area is developed for residential, commercial, industrial and institutional uses, while less that one per cent of the city's land is used for agricultural purposes (Table 5.1). In recent years some city households have taken up garden or roof-top farming although there is no official data on the extent to which this is taking place. In the remainder of the CMA, which includes the peri-urban areas, 54 per cent of land falls into the 'others' category consisting of vacant land, forest land, water bodies, etc. Around 12 per cent of area is used for agriculture (Table 5.1).

TABLE 5.1
Existing land use pattern in Chennai

	Chennai City		Rest of CMA	
	Hectares	%	Hectares	%
Residential	9 523	54.25	22 877	21.87
Commercial	1 244	7.09	390	0.37
Industrial	908	5.17	6 563	6.28
Institutional	3 243	18.48	3 144	3.01
Open space and recreational	366	2.09	200	0.19
Agricultural	99	0.56	12 470	11.92
Non-urban	83	0.47	2 433	2.33
Others (vacant, forest, hills, low-lying, water bodies, etc.)	2 087	11.89	56 507	54.03
Total	17 553	100	104 584	100

Source: CMDA, 2006

FIGURE 5.1
Chennai and its peri-urban districts
Source: UNEP 2014



Land-use analysis for peri-urban areas of Chennai with data from the Tamil Nadu Season and Crop Report for the 50-year period 1960/61–2009/10 indicates a decline in the total cropped area and a corresponding increase in the land area put to non-agricultural use (Figure 5.3). (Similarly, Figures 5.4 and 5.5 indicate a decline in area under cultivation in Kancheepuram and Thiruvallur districts over the previous decade.) Figure 5.3 indicates that land put to non-agricultural use has increased from 17 to 33 per cent of the total geographical area of the peri-urban region over the 50-year period. Of particular note is the area under rice production, which has strongly declined (Figure 5.6). The reduction in the area under irrigation (discussed in Section 6) negatively impacts the sustainability of the rice-based production system, which in turn could have important implications for food security given the region's population growth trajectory.

The trend in land-use change can be expected to continue during the coming decades in the absence ofa concerted effort to address land-use conversion pressures and adapt to climate change impacts on rice production. Arable land could increasingly go out of cultivation and the area of non-agricultural land expands as land markets push up land values in response to pressures of competing demand from housing and commercial purposes.

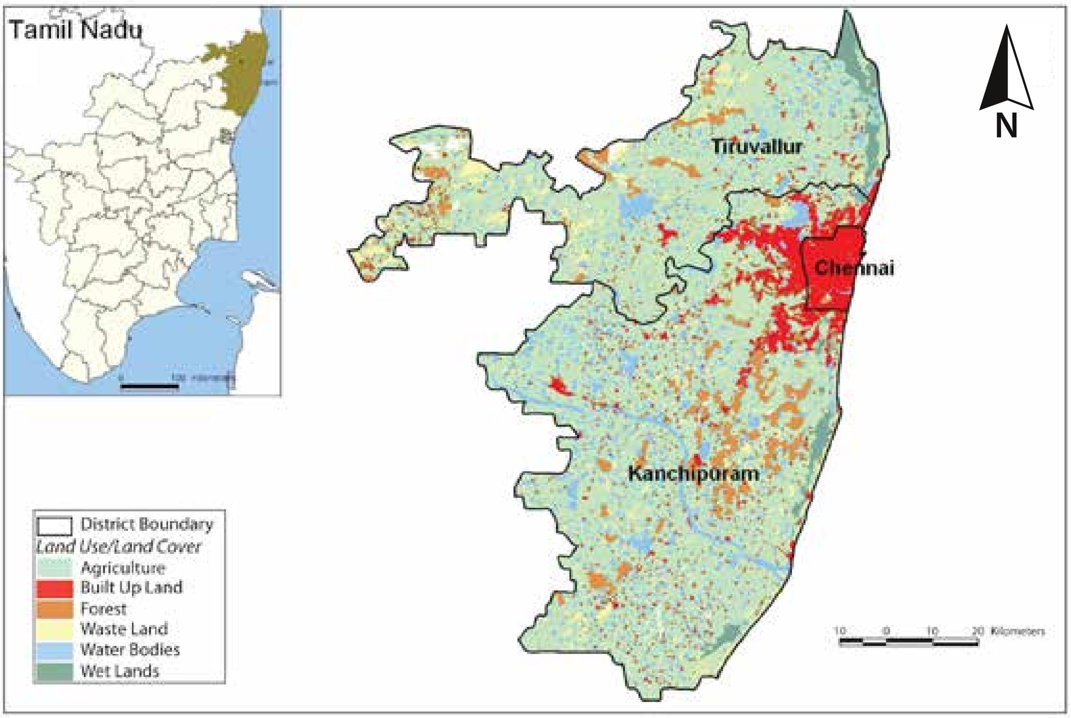


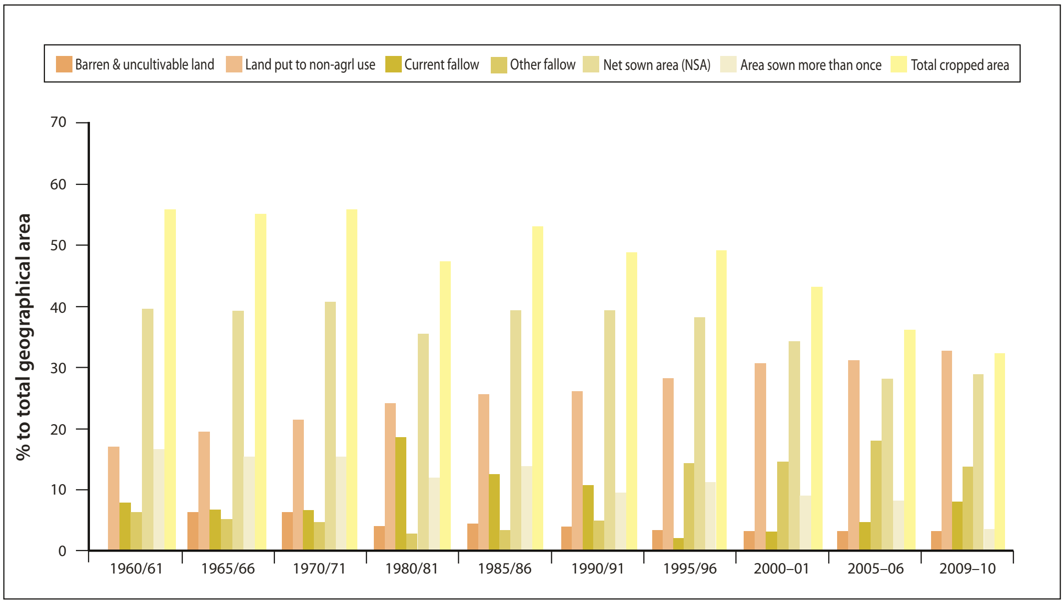
FIGURE 5.2
Land-use/land cover, 2005–2006

Source: State Land Use Board, Government of Tamil Nadu

© Trait2lumiere

FIGURE 5.3
Current trends in land use in Chennai, 1960/61–2009/10

Source: Season and Crop Report, Tamil Nadu



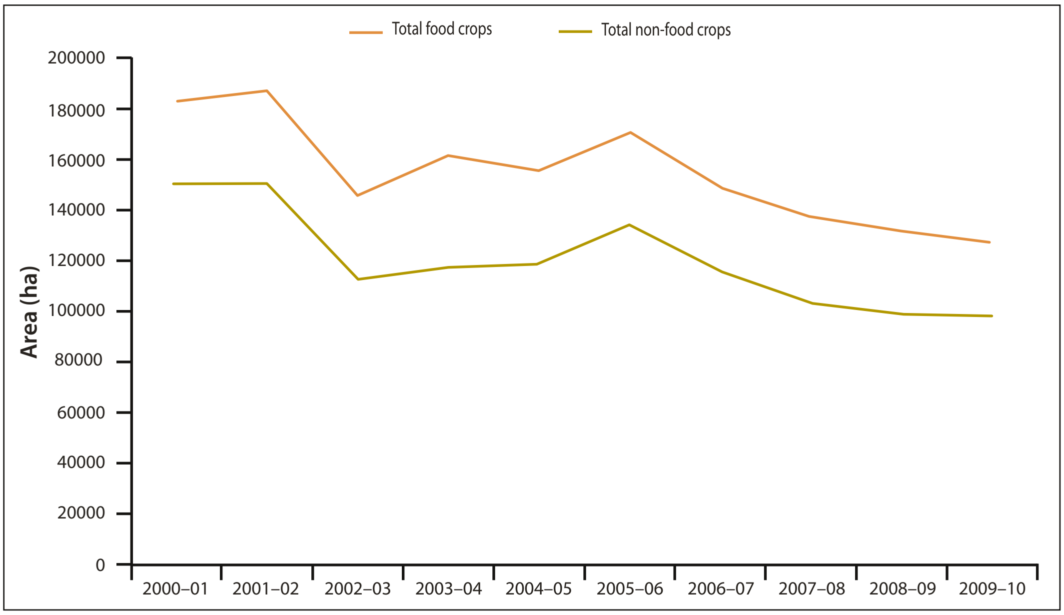


FIGURE 5.4
Food crops, non-food crops and gross cropped area in Kancheepuram District, 2000–2009

Source: Season and Crop Report, Tamil Nadu

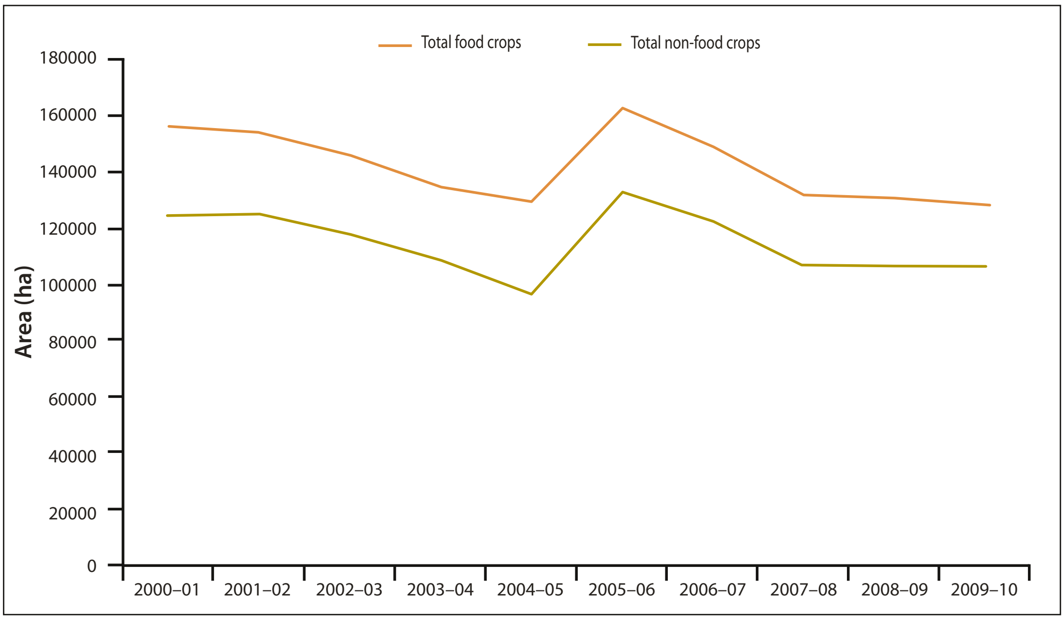


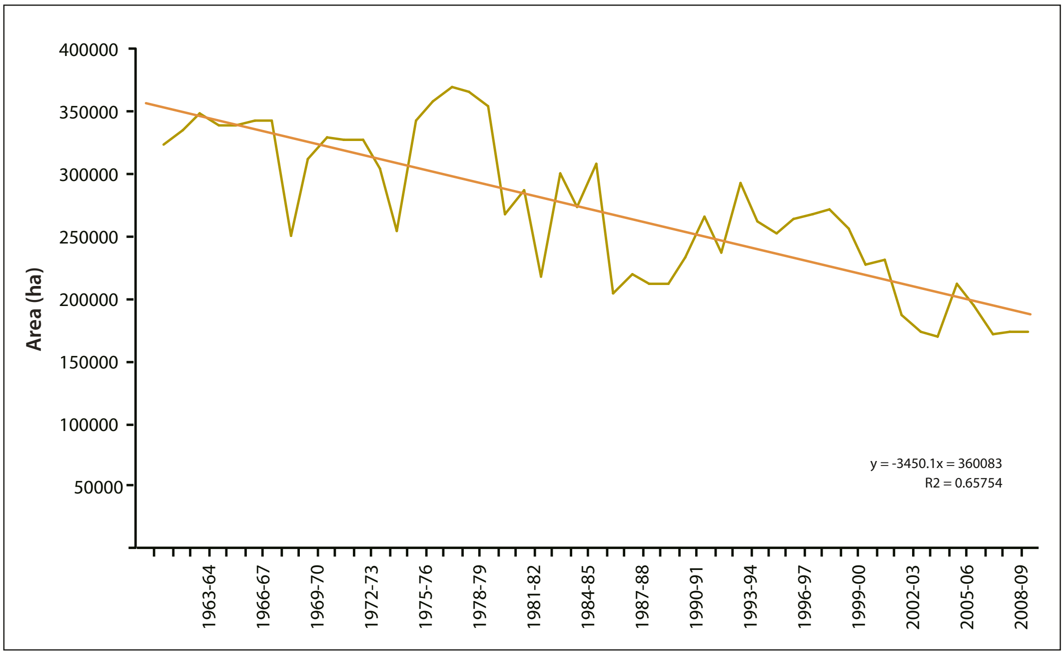
FIGURE 5.5
Food crops, non-food crops and gross cropped area in Thiruvallur District 2000–2009

Source: Season and Crop Report, Tamil Nadu

Note: The major non-food crops in the region are oilseeds, the edible oilseeds

FIGURE 5.6
Current trend in paddy acreage in Chennai peri-urban areas

Source: Season and Crop Report, Tamil Nadu



Land-use change in Tamil Nadu

Trends in land-use conversion at the state level mirror those of the CMA. In Tamil Nadu, the non-agricultural land area increased from just under 10 per cent in the 1950s to almost 15 per cent in the 1990s and exceeded 16 per cent in the 2000s, a pattern that is mainly the result of urbanization and industrialization. As a result, agricultural production has declined in recent years (Table 5.2). Although similar land use change has taken place in the Chennai region, there are no accurate and reliable data to assess its extent due to the fact that conversion is informal and land designated for agriculture is not captured in official government estimates. These factors result in a discrepancy between the government data and what is actually occurring.

TABLE 5.2
Agriculture area and production, Tamil Nadu, 2006–2012

Year	Area (million ha)	% change in the area compared to 2006-07	Production (million tonnes)	% change in the production compared to 2006-07
2006–2007 (last year of 10th Five Year Plan)	0.316	0	0.826	0
2007–2008	0.309	-2.1	0.658	-2.03
2008–2009	0.319	0.08	0.710	-1.40
2009–2010	0.303	-0.41	0.750	-0.92
2010–2011	0.317	+0.10	0.759	- 0.80
2011–2012 (programme)	0.420	-	1.150	-

Source: Season and Crop Report, Department of Economics and Statistics, 2011–2012

© P. Gupte

In recent years, investment in real estate has become more attractive and farmers, therefore, have a greater incentive to sell their lands, which in turn affects agricultural output. Compared with the last year of the 10th Five Year Plan (2006–2007), food-grain production in the state has been declining in the subsequent years due to deteriorating soil health, declining water resources, inadequate investment in rural infrastructure, inadequate research and development activities and spiralling prices of inputs (State Planning Commission, Tamil Nadu).

The real estate boom in the Chennai region and its resulting impact on land conversion is attributed to the rapid growth of the information technology (IT) sector in the region. Anecdotal evidence suggests that the IT sector is growing rapidly in the CMA though no data are available. The growth of the IT sector could affect the agricultural sector through the IT firms locating themselves in suburban or peri-urban areas, agricultural land is being used for the construction of buildings, staff housing, etc., and through the IT professionals obtaining good salaries that make it possible to invest their income in land as it provides them more assured returns than other investments, such as the capital market. Research is needed to understand this dynamic.

The changing land-use situation in the CMA, in which agricultural land near large urban centres is being converted for housing and industry, is typical of changes happening throughout India, where food production has been stagnant or has declined in recent years (Chand and Haque, 1998) and the relative contribution of agriculture to the gross domestic product (GDP) has been steadily declining (Table 5.3).

TABLE 5.3
The share of agriculture in GDP

Year	Share of agriculture in GDP (%)
1950-51	56.5
1970-71	45.9
1990-91	34.0
2000-01	24.7
2006-07	19.55
2007-08	18.51
2008-09	16.4
2009-10	15.7

Source: CSO and Economic Survey, 2009–2010

6 Water resources in Chennai

Water demand and supply

Chennai City receives most of its water supply from Red Hills Lake and Chembarambakkam Lake (Table 6.1). Additional water is received from Veeranam Lake, which is some 250 km from Chennai. At present, the Tamil Nadu Water Supply and Drainage Board (TWAD Board) supplies 645–650 million litres per day (MLD) of which 585 are delivered to domestic consumers in 16 Metrowater Distribution Zones in Chennai City. The remaining 60–65 million litres per day are supplied to other users in the metropolitan area: industry, bulk consumers, 10 peripheral municipalities, five town panchayats, two village panchayats, and the cantonment.

TABLE 6.1
The share of agriculture in GDP for India

Sources	2004 (In million litres)
Veeranam Lake	14 842
Red Hills Lake	4 155
Rain water harvesting	1 691
Chembarambakkam Lake	133
ErattaiEri	207
Well fields	31 195
Southern coastal aquifer	776
Reverse osmosis (R.O) plants	182
TWAD source	275
Porur wells	210
Neyveli aquifer	5 966
Distant sources	21 357
Total	**80 988**

Source: CMDA, 2007

Total water demand from the existing population is estimated at 848 million litres per day, well above the current supply of 645 million litres per day from the Tamil Nadu Water Supply and Drainage Board (TWAD Board). The supply-demand gap of about 200 million litres per day is primarily offset with groundwater sources—around 6 530 deep bore-wells have been drilled at different locations in the city. The TWAD Board relies on rented tanker-trucks to deliver water to consumers free of charge, especially to the slum areas of the city. Estimates by TWAD in 2004 indicated that about 6 000 tanker-trucks, with a capacity of 10 000–20 000 litres, delivered water to the CMA. In addition to this, private trucks make around 700 trips to deliver an estimated 125 MLD of water, purely on a commercial basis. Around 25 per cent of total water demand in the city is being met by the private sector (Janakarajan *et al.,* 2006). The trucks purchase water from the owners of agricultural bore-wells in the peri-urban areas of Chennai.

The private water market plays a significant role in meeting water scarcities faced by the CMA's public sector (Table 6.2). Further, there is a significant informal water sector, worth several million rupees a day in Chennai. Poor people in slums spend a significant amount of their household income on purchasing water from the informal sector, despite the presence of government programmes that provide water free of charge. Increasing the quality and reliability of the public water supply could play a crucial role in reducing urban poverty and improving public health outcomes.

TABLE 6.2
The private water market

Sl. No.	Category	Quantity	Price range	Volume of sales (Rs.)
1	Sachets (250 ml)	5 000 000 sachets	Rs.1/sachet	5 000 000
2	Water bottles (1 l)	75 000 litres (1 litre bottles)	Rs. 10 –Rs.12/bottle	750 000–900 000
3	12 litre cans	100 000 cans	Rs. 18 –Rs. 30 /can	1 800 000–3 000 000
4	20–25 litre cans	25 000 cans	Rs. 20 and above	500 000 (minimum)
5	Tankers	10 000 lorries (12 000 litres/each)	Rs. 700–Rs. 900 per tanker	7 000 000 -9 000 000

Source: SIPDWA, 2005

High rates of groundwater discharge in Chennai are depleting and degrading the city's groundwater sources. For example, at Poondi groundwater dropped from a depth of about 10 m in January 1999 to about 20 m in January 2003 (The Hindu, 2003). A similar case was observed in Tamaraipakkham, where the water table dropped from about 6 m in January 1999 to about 20 m in January 2003. Similarly, a study conducted by the State Ground and Surface Water Resources Data Centre revealed that the groundwater level in Chennai had dropped from 3.8 m in the first quarter of 2006 to 4.2 m in the first quarter of 2007.

Rapid urbanization in Chennai has led to a major increase in slums, poorer living conditions for the most vulnerable people and continued degradation of precious water resources.

In peri-urban areas, many agricultural bore wells have been converted to commercial use, with the drawn water sold to meet urban demand. This raises the issue of the cost of water extraction for other farmers who rely on groundwater to irrigate their crops. The decrease in agricultural output causes particular hardship for farmers on marginal land and landless farm labourers. Farmers stop farming because there is insufficient water for their crops. Struggling farmers may then sell water for non-agricultural uses as an alternative source of income. Government policies are helping to drive the over-exploitation of the groundwater by providing water-right allocations for farmers together with free electricity for pumping water. The combined effect of all these factors encourages farmers to sell their water to urban users, thereby creating cumulative third-party effects. As the demand for water increases in urban areas in response to population growth, industrialization and adaptation to climate change, more and more farmers may sell water rather than using it for production, thus further jeopardizing agricultural output.

In addition to overexploiting the region's aquifers, reliance on groundwater raises questions of equitable distribution of water, with the overexploitation leading to an increase in the number of wells becoming non-functional. States affected by high rates of farmer suicides in the country have shown indebtedness to be a major cause of farmers' deaths in those regions and lack of access to affordable water is an important contributor to debt (IGIDR 2006; Mishra, 2006; Mohanty, 2005; Mohanty and Sangeeta, 2004). In some of the states, the debt incurred was largely to drill wells for irrigation, which dried up after just a few years. If this trend in exploitation of groundwater continues unabated in the region, the risk will grow that Chennai's peri-urban region will begin to witness a similar phenomenon triggering severe agricultural distress in the region. This may not necessarily lead to farmers' suicide in the region, since rapid urbanisation ensures access to non-agricultural livelihoods, but nevertheless it surely will result in agricultural distress in the region.

Access to water in Chennai and surroundings has both physical and social dimensions of scarcity, and there are winners and losers among the peri-urban farmers affected by the high rate of water transfer to urban Chennai. As described by Thapa *et al.,* (2010), peri-urban farmers in Chennai can be divided into independent, semi-independent and dependent groups. Traditionally, independent farmers (those with water rights) primarily sold water to dependent farmers; however, implementation of the Tripartite Agreement of 2000 created a lucrative market of water transfer for industrial and urban uses. This has resulted in both dependent and independent farmers abandoning agriculture but for very different reasons—the former because they can no longer physically or financially access water for rice production and the latter because selling water to the CMDA and through informal channels is significantly more lucrative and stable than farming (Janakarajan *et al.,* 2006; Thapa *et al.,* 2010). This has led to greater integration of rich farmers into the urban economy while poor, marginal farmers and landless agricultural labourers have experienced a loss of livelihoods and increased pressure to find non-agricultural income sources or leave peri-urban villages for the city. Whole villages have become marginalized and increasingly powerless in the face of high demand for urban water uses (Janakarajan *et al.,* 2006).

Another negative externality of groundwater exploitation in the coastal areas of Chennai is that aquifers in the CMA are become increasingly saline due to saltwater intrusion from the Bay of Bengal (Rao *et al.,* 2004). Salinization of groundwater has serious implications for agricultural and non-agricultural water uses, particularly considering that sea level rise associated with climate change is expected to accelerate intrusion of seawater into aquifers (Natesan and Parthasarathy, 2010).

Policy response to groundwater exploitation

Government attempts to address overexploitation of groundwater resources have achieved modest progress. For example, the Chennai Metropolitan Area Ground Water Regulation Act of 1987 gave the Tamil Nadu Groundwater Authority the sole power to regulate digging of wells and extraction and transportation of water to designated areas (IELRC, 2003). This intervention increased the marginal cost of extracting water in these areas because of increased transaction costs imposed by the act. For example, various additional costs are incurred in seeking permission to dig wells, "persuading" officials, paying for the services of intermediaries in order to obtain licences, plus the actual cost of obtaining the licence, the opportunity cost incurred in waiting for the official decision to grant the licence, and other costs in the event of refusal of a license. However, the extent to which these extra costs discouraged well installation is not clear.

A more effective response appears to have been achieved through efforts by the government of Tamil Nadu to implement rainwater harvesting measures. In 2003, the government introduced mandatory rainwater harvesting to further alleviate the negative effects of groundwater drawdown in the CMA. This measure had positive effects on groundwater recharge. According to a Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) report cited in the Times of India, information based on 60 wells scattered across the city suggests that the groundwater level has improved considerably, the average depth in 2007 being 3.45 m compared with 6.18 m in 2004 (Karthikeyan, 2008). Another study conducted by the TWAD Board found that the groundwater table had risen a further 2.5 metres between 2007 and 2008. It has been shown that rainwater harvesting also helps improve the quality of groundwater. For example, the CMWSSB report revealed that the total dissolved solids (TDS), which provides an indication of mineral content, measured in water from wells in the northern part of the

Rainwater harvesting system © SK Babu

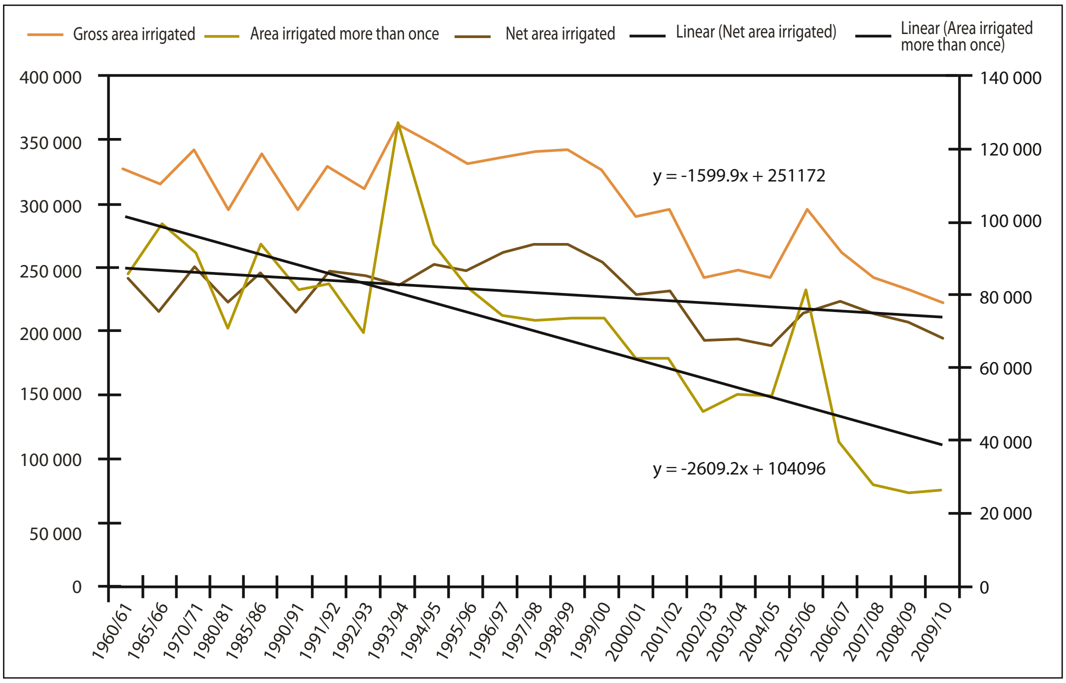


FIGURE 6.1
Chennai region, area irrigated

Source: Season and Crop Report, Tamil Nadu

city fell from 5 000 parts per million (ppm) in 2004 to 300 ppm in 2007. However, information about water quality collected by the TWAD Board shows that improvements must still be made in many other parts of the city.

The success of this rainwater harvesting initiative has potential to make a meaningful dent in the rate of groundwater exploitation. However, the full extent of positive effects of rainwater harvesting is unclear. Agencies may take measurements at different places and the difference in the depth of the water table between these locations can lead to variations in results. Similarly, differences in the frequency of measurement can also give conflicting results. To obtain a truly accurate picture of rainwater harvesting, further detail is needed that includes information on geographical location, rainfall amounts, extraction rates, etc.

Irrigation

The region shows contrasting trends in the use of irrigation. In the last four decades of the preceding century, significant irrigation potential was created using both ground and surface water sources (Figure 6.1). But at the same time the net area irrigated[2] by both ground and surface water sources decreased by 20 per cent (from the early 1960s to the late 2000s) and the gross irrigated area decreased by 32 per cent during the same period, based on data from the Tamil Nadu Season and Crop Report (Figure 6.1). The reasons behind this decline are unclear but selling of water for non-agricultural uses is likely a contributing factor. The most striking reduction has been in the area irrigated for multiple cropping during a calendar year, which has been reduced by 68 per cent over

2 Net irrigated area: The area irrigated through any source once in a year for a particular crop.
Total/gross irrigated area: The total area under crops, irrigated once and/or more than once in a year. It is typically counted as many times as the number of times the areas are cropped and irrigated in a year.

this four-decade period. Irrigation intensity in the region has also declined, from a high of 1.5 during early 1960s to 1.1 during late 2000s. All this points to a very underutilized irrigation capacity, which has important implications for paddy rice production. Packialakshmi *et al.* (2011) report a similar pattern of declining agricultural productivity in peri-urban areas south of Chennai with agricultural production declining by 20-95 per cent in villages that are heavily involved in water transfers to the urban center.

Irrigation tanks provide an important source of irrigation water in the peri-urban areas but in recent years there has been a gradual decline in the number and storage capacity of the these tanks and the land area irrigated through this method. The conversion of containers and tank beds for non-agricultural purposes has been an important factor behind the decline in tank irrigation. Recent policy initiatives on tank irrigation emphasize renovation of traditional tanks in order to more effectively harvest rainwater. For example, the Tamil Nadu government has undertaken a large-scale tank modernization programme, through its IAMWARM project.

7 Agriculture production in the peri-urban region

Crops

Crop production in peri-urban areas surrounding Chennai is dominated by paddy rice cultivation. Paddy rice production is subsidized by a minimum support price (MSP) from the Government of India, which is intended to protect farmers from any adverse consequences of price volatility. Even though demand for other cereals, such as finger millet, is increasing due to changes in the urban diet, farmers prefer not to cultivate these crops on a large scale as they are labour intensive and therefore vulnerable to the acute labour shortage that exists in peri-urban and rural areas. Modern technologies, such as transplanting and harvesting machines, are being widely used as a substitute for labour in paddy-rice cultivation, but technology appropriate to non-paddy crops has not yet been developed on a large scale.

TABLE 7.1
Output of major food crops in Kancheepuram District, tonnes

Crops	2005/06	2006/07	2009/10
Paddy	293 875	395 134	331 434
Sorghum	1	17	11
Pearl millet	26	74	1
Finger millet	993	398	154
Maize	27	13	0
Total Cereals	294 922	395 636	331 600
Total Pulses	2 658	789	144

Source: Department of Economics and Statistics, Government of Tamil Nadu

TABLE 7.2
Output of major food crops in Thiruvallur District, tonnes

Crops	2005/06	2006/07	2009/10
Paddy	271 582	318 468	256 294
Sorghum	139	132	53
Pearl millet	2 343	3 402	556
Finger millet	379	634	502
Maize	0	16	3
Total cereals	274 443	322 652	257 408
Total Pulses	6 556	5 631	1 956

Source: Department of Economics and Statistics, Government of Tamil Nadu

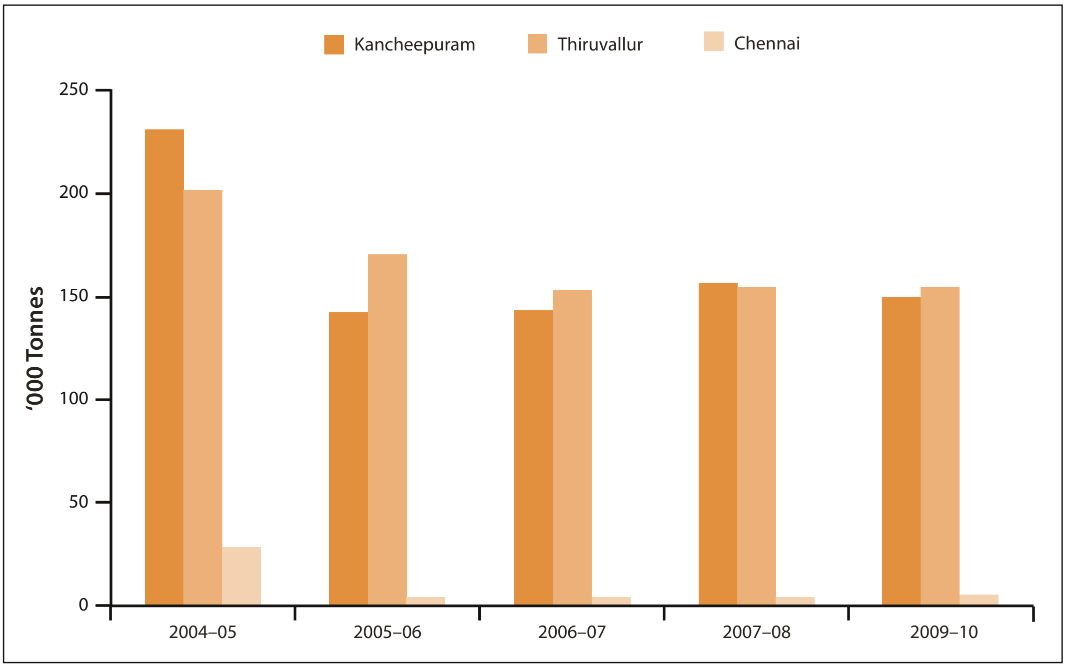
The observed trend in the output of major crops is influenced by many different factors such as weather conditions, water availability and market conditions. Excessive monsoon rains, or the failure of the monsoon and prolonged drought are major determinants of productivity in the agriculture sector.

Milk

Milk is an important part of the diet in Chennai, and demand has increased significantly. However, production of milk in Chennai, Kancheepuram and Thiruvallur districts has stagnated in recent years and lags behind demand (Figure 7.1). Between 2004/05 and 2009/10, the output of buffalo milk declined by about half in the peri-urban areas and about 10-fold in Chennai itself, which is an important factor in the lacklustre performance of the milk production sector. More in-depth analysis, particularly at the village level, is needed to understand why milk output is stagnant.

FIGURE 7.1
Estimated milk production in peri-urban areas of CMA, '000 tonnes

Source: Statistical Handbook of Tamil Nadu 2005, 2006, 2007, 2008 and 2011



Eggs

There has been a general increase in total egg production in both Kancheepuram and Thiruvallur Districts while production has declined in the Chennai district between 2004–05 and 2009–10 (Figure 7.2). Although the neighbouring districts are an important source of eggs for the Chennai District, a larger percentage comes from more distant districts in Tamil Nadu, such as Namakkal and Erode Districts.

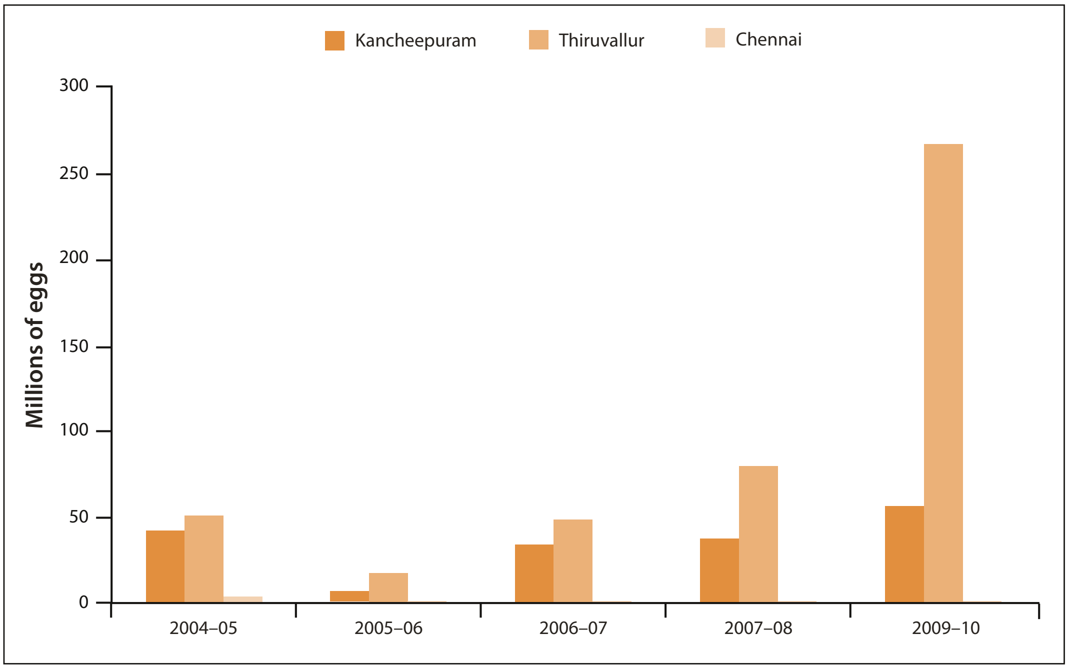


FIGURE 7.2
Estimated egg production of CMA peri-urban areas, million eggs

Source: Statistical Handbook of Tamil Nadu 2005; 2006; 2007; 2008 and 2011

Fish

Fish are an important source of protein for the Chennai region. The total marine fish output has substantially increased between 2004–05 and 2009–10 in the portion of the Bay of Bengal encompassing the study region (Table 7.3). The peri-urban region in the post-tsunami era has witnessed a sharp increase in the number of boats, fishing nets and fish processing facilities leading to an increase in fish production in this region (Venkatesh, 2006). Even though fish output is increasing it has not been possible to estimate whether the current output is sufficient to meet the demand as there is no data on demand. The official estimate of fish outputs is based on the amount of fish landed at major harbours and does not take account of fish from the numerous small harbours in the region. Apart from marine fish, a significant amount of fish comes from inland water sources in the study region (Table 7.4).

TABLE 7.3
Estimated marine fish production by district, tonnes

Year	Kancheepuram	Thiruvallur	Chennai
2004–05	2 185	10 923	14 031
2005–06	7 818	4 805	17 660
2006–07	12 825	6 676	33 374
2007–08	10 570	6 540	31 850
2009–10*	20 078	8 031	31 322

Source: Statistical Handbook of Tamil Nadu 2005; 2006; 2007; 2008 and 2011

* *Provisional*

FIGURE 7.3
Marine fish landing in Tamil Nadu, 1985–2009, tonnes
Source: CMFRI

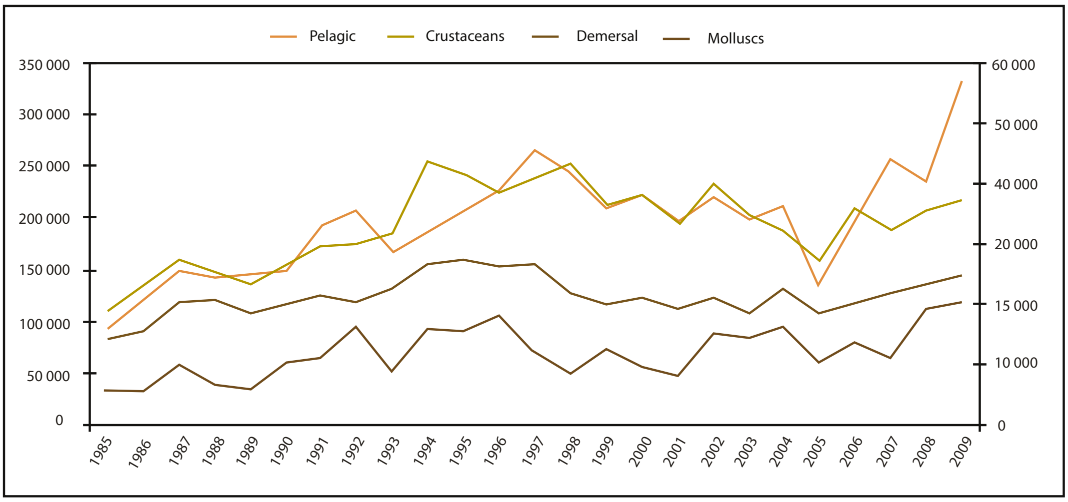


TABLE 7.4
Estimated inland fish production by district, tonnes

Year	Kancheepuram	Thiruvallur	Chennai
2004-05	3 303	4 005	NA
2005-06	11 045	13 591	37
2006-07	11 266	13 951	37
2007-08	11 487	14 331	38
2009-10*	11 659	14 817	39

Source: Statistical Handbook of Tamil Nadu 2005; 2006; 2007; 2008 and 201

* *Provisional*

Vegetables and fruit

Information about the total production of vegetables and fruit in the peri-urban region is not readily available however interviews with the fruit-and-vegetable association members at Koyambedu wholesale market in Chennai suggested 3 000–4 500 tonnes on average arrive each day. The supply of green vegetables stands at 1 500–2 500 tonnes per day and average supply of fruits at 1 500–2 000 tonnes per day. Among the vegetable crops, onion and tomato are important commercial crops grown in the peri-urban area of Chennai; however, productivity is very low.

Markets and institutions related to food production

Despite the rise in food prices, farmer distress is a major problem throughout India, including in the Chennai region. In the following section, we underline some of the measures that would help revive agriculture in the peri-urban region in the coming years.

Asymmetric information and market distortions

Empirical evidence shows a significant oscillation in the prices of some essential agricultural commodities, which badly affects farmers' profits. One possible reason is that farmers' decisions are influenced by the price prevailing in the procurement market rather than the retail market in

© Ponarun Kumar

Chennai. When the prices are low in the procurement market, traders tend to buy less, effectively creating artificial scarcities. Government mechanisms dealing with agriculture and rural development could be more effectively utilized to collect and disseminate information about demand, supply and the price of agricultural commodities in the peri-urban region—for example, village administrative offices, agricultural extension centres, the department of agricultural marketing, agricultural universities, etc., all could play a more proactive role.

Not only is lack of information important but also the prevalence of 'asymmetric information' across different agents involved in agricultural marketing causes distortions and disparities in the prices. In India, there is a disconnect between procurement market (mainly informal) and retail markets in urban areas. This lack of integration widens the gap between procurement prices and selling prices for many agricultural commodities. For example, the intermediaries procure tender coconut for Rs. 6-7 per unit from villages around Chennai and sell it for Rs. 20–25 within the city, which is located just 20 kms away from those villages. The huge price differential is not because of transportation costs, which are negligible, but asymmetric information. In reality, many farmers in peri-urban areas depend largely on the intermediaries / agents for marketing decisions, as there is no other alternative source of information. A problem of asymmetric information arises when the intermediaries / agents possess more information on price, supply, demand and risks involved in marketing, than what the farmers possess. Since the intermediary has greater advantages over the market information, he can exploit the situation to maximize benefit. Similarly, urban consumers too have less information about the procurement prices prevailing in the peri-urban areas; therefore, they end up paying a higher price fixed artificially by the actors in the retail markets.

© Gnomeandi

Changing institutions and labour migration

Labour scarcity, caused by institutional and behavioural changes in rural areas is becoming a critical issue in Indian agriculture. It emanates from various push and pull factors (Shah, 2001). The seasonality of employment and irregular income, mechanization of agriculture, the increasing level of education and improved quality of agricultural labourers are considered to 'push' people out of agriculture. On the other hand, increased employment opportunities in urban areas—especially in the booming construction industry, hotel industry, manufacturing, service sectors (e.g., security), engineering, and motor industries and household sectors—act to 'pull' the unskilled and semi-skilled labourers from the rural and peri-urban areas into Chennai City. For example, an unskilled labourer working in the construction industry can earn four to five times greater income compared to that earned through agriculture and unlike in agriculture employment is not bound by seasons. Even though migrant labourers experience problems, such as inadequate housing and poor water and sanitation facilities in the city, they are still better off with more savings, more resources to send remittances back to their villages and more opportunities to get their children well educated. Social networks established between migrants and home communities are critically important in the success of the migration experience.

The government's welfare schemes also cause increased labour scarcity in agriculture in the peri-urban region. For example, it is claimed that the 25 kg free-rice scheme being implemented under the universal public distribution system is not only ensuring food security for poor but also causing labour market distortions in rural areas around Chennai. Empirical evidence also shows that the National Rural Employment Guarantee Act (NREGA), established to create 100 days of employment for poorer households in rural areas, is also moving workers away from agriculture. In addition, rapid social changes taking place in peri-urban areas, due to the location of higher-education institutions in these areas, also contribute to intensifying labour scarcity. The increasing scarcity of labour, improvements in the bargaining power of agricultural labourers, increased agricultural wages and reduced working hours all worsen the agricultural situation.

8 Climate change and food production

Risks to agriculture associated with climate change, such as warmer temperatures and hot spells, changes in precipitation patterns, and occurrence of extreme events have the potential to cause further deterioration of the agriculture sector in the coming decades. Climate change impacts on the agricultural sector for much of India are expected to be negative (Srivastava *et al.*, 2010; Ortiz *et al.*, 2008) and could create greater incentives for out-migration.

Studies need to be done in this region to better understand how climate change may interact with the multitude of factors that are driving declining farm productivity and rural out-migration. Issues that are of particular concern include:

- How vulnerability to water supplies could change as a result of excessive groundwater depletion overlain by higher temperatures and drought that would further drive up water demand. Research is needed to understand potential thresholds and tipping points for water scarcity driven by interactions between population growth, present and future water use and demand, and the likelihood of more extreme climatic events. Increased crop water demand should be a part of such studies.
- How the risk of saline ingress into coastal aquifers will increase with the combined effects of sea level rise and the continued unsustainable rates of groundwater extraction. The impacts of increased groundwater salinity on both agricultural and non-agricultural users need to be understood in the context of both future water demand and adaptation in both agricultural and urban contexts.
- How compound factors (e.g., a heatwave corresponding with a weak monsoon period) affects agricultural and non-agricultural systems. What are the potential non-linearities of impacts?

Analysis of paddy rice production

An analysis was conducted by MSSRF in conjunction with this assessment to estimate the impact of climate change on paddy production and water use.

TABLE 8.1
Impact of near-future climate change on rice, A1B scenario

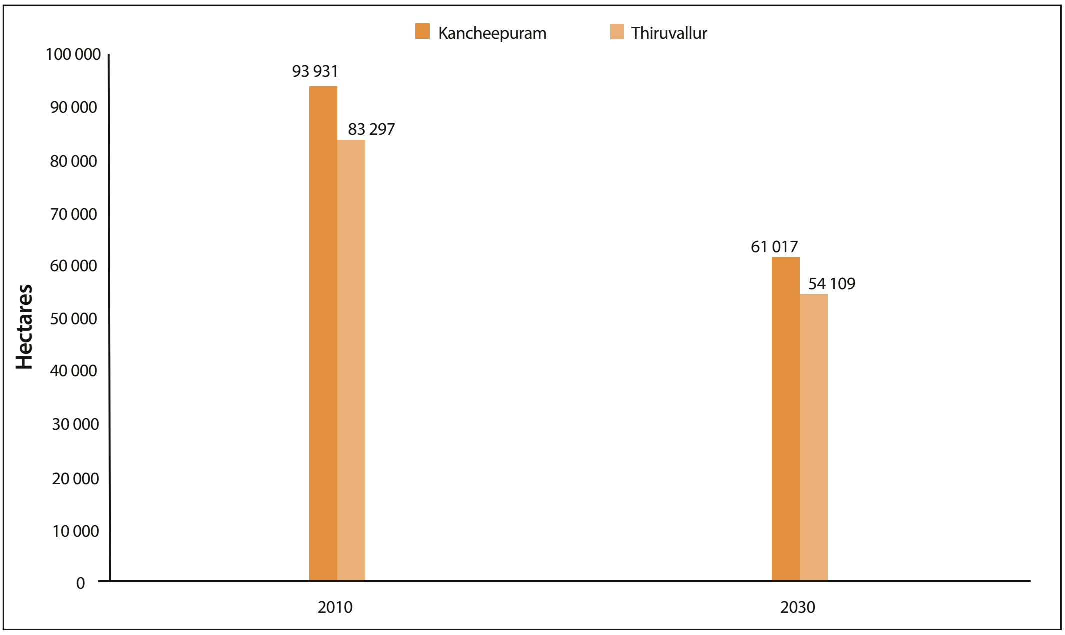
Place	Days to anthesis		Days to maturity		Yield (kg/ha)		ET (mm)	
	Current	2030	Current	2030	Current	2030	Current	2030
Thiruvallur	77	75	109	106	6 139	5 765	751	769
Kancheepuram	79	77	111	108	6 367	5 992	746	763

As Table 8.1 indicates, an increase in growing season temperatures will reduce the days to anthesis as well as days to maturity in the rice crop in Thiruvallur and Kancheepuram Districts. In 2030, days to anthesis as well as days to maturity are expected to advance by two to three days. Faster maturation of cereal crops results in more unfilled grains and lower yields. Results suggest that yields by 2030 would decrease by an average 6 per cent in Thiruvallur and Kancheepuram. Under this A1B scenario, water requirements of rice increase because of higher temperatures that increase evapotranspiration of the crop. The productivity decline during this period is accompanied by a decline in area under production (Figure 8.1)[3].

Decline in area under production is not a direct effect of climate change. It's due to a large number of non-climatic factors, which have been elaborated in the previous sections. Section 5, detailing land use change in the Chennai peri-urban area and the cropping pattern analysis of this region has clearly established the fact that area under agriculture is declining in this region. Disaggregated analysis of change in cropping pattern indicates huge decline in total food crops as well as non-food crops. Land put to non-agriculture use increased by 82 per cent during the period 1960–61 to 2009/10. Net sown area declined by 31 per cent and gross cropped area reduced by 45 per cent during 1960–61 to 2009–10. And area under paddy, which is the major food crop in the region, reduced by 79 per cent during this period.

Section 3 elaborates the impact of urbanisation, the expansion of the Chennai Metropolitan Area and the accompanying land market pressures that act as demand side factors for land growing out of agriculture. Section 6 brings out the competing demands for water and the basic inputs for agriculture and establishes the declining trend in area under irrigation in the peri-urban area.

FIGURE 8.1
Area under rice in Chennai's peri-urban area, 2010 and 2030
Source: www.agcensus.nic.in



3. Area projection for rice in the peri-urban area is derived by fitting a linear trend to the area under rice in the peri-urban area. From this, based on the proportionate share of Kancheepuram and Thiruvallur Districts in the total peri-urban areas, figures for area under rice in Kancheepuram and Thiruvallur are estimated. This methodology was followed because the current peri-urban districts, namely Kancheepuram and Thiruvallur, were formed by bifurcating erstwhile Chengapettu district in 1996.

Land-holding patterns and vulnerability

Land-holding patterns have an important bearing on risk management in the agricultural sector, and by extension on the extent of climate change adaptation that can realistically be pursued. As the size of land-holdings decreases and access to reliable water supplies becomes increasingly tenuous, so too does the risk bearing and coping capacity of peri-urban farmers. Analysis of the land-holding pattern of the peri-urban area in Chennai shows that 83 per cent are marginal holdings of less than 1 ha, which account for 40 per cent of the total operational holding area. Small holdings of 1–2 ha have the next highest share in terms of number and area (Figures 8.2 and 8.3). This indicates that the largest numbers of farmers operating in Chennai's peri-urban area are marginal and small farmers whose coping mechanisms and risk bearing abilities are low.

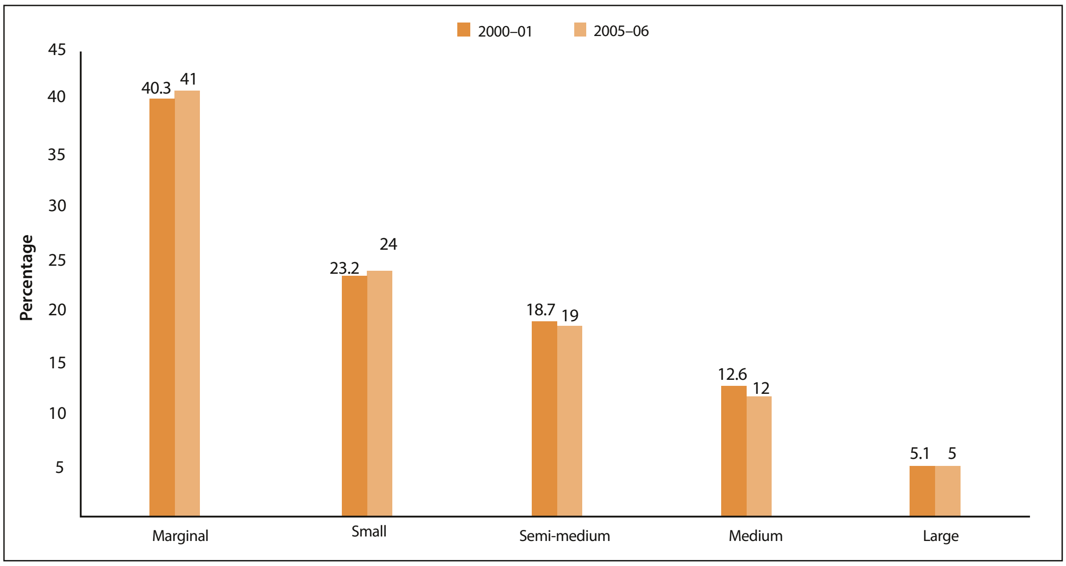


FIGURE 8.2
Share of different sized holdings in Chennai's peri-urban area, 2000–01 and 2005–06

Source: www.agcensus.nic.in

Any strategy to address the issue of climate change in the peri-urban area should take into account the extent of fragmentation in holdings in the area. With water being the critical production variable, and as a resource that is under stress from urbanization, groundwater depletion and salinization, emphasis should be placed on a watershed approach to sustainable regional development. Within such a framework, water harvesting and soil-water conservation are important responses in the peri-urban region, within which water-conserving technologies, such as systems of rice intensification and precision/conservation farming, have important implications for adaptation. Shifting to low-water intensive crops such as millets could also help to reduce reliance on climate-sensitive rice production; though recommendations for crop substitution must consider the plethora of production, economic feasibility and consumer demand factors that determine the viability of non-rice crops. Also, strategies to promote farmer collectives and other forms of farmer advocacy would help to buffer against high volatility in production regimes and thus reduce risks inherent to small-holder farming.

Irrigation tanks could potentially play a more critical role in lessening the impact of projected increases in droughts and floods (Palanisami *et al.*, 2010). Managing irrigation tanks so as to be better prepared to adapt to changing climatic conditions and in the face of rapidly changing rural economies requires innovative institutional arrangements. However, identifying and implementing such innovative institutions has become a major constraining factor.

Dairy production

The extent to which climate change may impact dairy production in India has not been well established. Increased heat associated with global climate change may stress dairy animals and adversely affect milk production (Armstrong, 1994; Bohmanova *et al.,* 2007; Vitali *et al.,* 2009) though no studies have been done in Tamil Nadu and few studies in India. The temperature-humidity index (THI) is used to relate animal stress to productivity of milk from buffaloes, cross breeds and indigenous cattle. Almost 85 per cent of India experiences moderate to high heat stress during April, May and June and THI ranges from 75-85 in the afternoon during these months (NATCOM 2012). On average, the THI exceeds 75 in Chennai and the surrounding areas throughout the year, which has a direct bearing on the production of milk.

Fisheries and climate change

Sea-surface temperatures in the Indian seas are projected to increase by about 3° C by 2100 (Vivekanandan *et al.,* 2009), which is likely to affect fish breeding, migration, and harvests. Most of the fish species that occur in the Bay of Bengal have a very limited range of optimum temperatures related to their basic metabolism and availability of food organisms. Hence even slight changes in temperature in seawater may lead to change in their distribution and life processes. A typical case is oil sardine (*Sardinella longiceps*). Off the coast of Tamil Nadu at latitude 14° N to 20° N, the catch of this species in 2006 was 185 877 t, while up until 1985, the catch of this species centered around the Malabar region, latitude 8° N to 14° N and longitude 75° E to 77° E. Further, the Indian mackerel (*Rastrelliger kanagurta*), which normally occupies surface and subsurface waters, used to be caught using pelagic gear, but the catch during 2003–07 shows that 15 per cent is now caught by bottom trawlers. This change in fishing characteristics suggests that warming of surface and subsurface waters are causing the mackerel to go deeper (CMFRI, 2008).

Vivekanandan *et al.* (2009) reported that rising sea-surface temperatures are also affecting the spawning season of threadfin breams (*Nemipteridae*), which is shifting from the warmer months of April to September to the cooler October to March. The study points out that sea-surface temperature of 28–29° C may be the optimum for spawning and when it increases above 29° C the species shifts its spawning activity to seasons when the temperature is lower. Apart from the shift in the spawning season, the depth of fish distribution has changed. The threadfin breams are normally found at 10–100 m and are fast growers. During 2006, the total catch of these species along the Indian coast from bottom trawls was 111 345 t, 4.7 per cent of the total catch (CMFRI, 2007).

The example of the threadfin breams shows a shift in distribution and may have on impact on the nature and value of fisheries (Perry *et al.*, 2005). Warming trends in the ocean have potential to alter marine ecosystem structure and functions, especially an imbalance between small, low-value fish species and large, high value species, with subsequent effects on the fishing industry. This is an important knowledge gap requiring research on potential economic and food security implications for the Chennai region.

9 Sea-level rise and the coastal environment

Climate change is expected to affect the coastal Chennai region through sea-level rise, storm surge leading to inundation, coastal erosion, saltwater intrusion, and loss of coastal biodiversity and ecosystems. Urban infrastructure, including roadways, railways, ports, power plants, airports and other infrastructural facilities are vulnerable to varying degrees. In addition to infrastructure damage, sea level rise could also make agricultural land in some parts of the peri-urban area unfit for cultivation, which could have important implications for food security. Comprehensive studies are needed to estimate the potential extent of agricultural and non-agricultural resources that are at risk.

Chennai's peri-urban coastline is some 134 km long—19 km for Chennai, 27.9 km for Thiruvallur, and 87.2 km for Chennai and Kancheepuram). Land bordering the Bay of Bengal, which forms the eastern boundary of the peri-urban region, is already vulnerable to extreme events such as storm surges and sea level rise in the Bay of Bengal is likely to have further, potentially devastating, impacts (Byravan *et al.*, 2011). For example, groundwater sources are already experiencing salinization due to rapid groundwater depletion and seawater intrusion (Rao *et al.*, 2004; Natesan and Parthasarathy, 2010), and this has resulted in making extraction infrastructure ineffective. Sea level rise may also reduce suitable nesting habitats for Ridley sea turtles (*Lepidochelys olivacea*) that come to the shores of the Chennai region every year to breed (Marcovaldi *et al.*, 2010).

Based on available secondary data and other qualitative information, Byravan *et al.* (2010) estimated the total replacement cost of infrastructure—ports, power plants and major roads—at Rs. 474–536 billion (US $7.8–8.8 billion) at 2010 prices for the entire coastal Tamil Nadu. Their study also estimated that the economic loss of ecosystem services to be between Rs. 36–146 billion (US $0.6–2.4 billion; Table 9.1). Similarly, the economic value of damage to the land at risk is estimated to be between Rs. 3 177–61 155 billion (US $52–1 000 billion). The following table provides an estimate of the total potential economic loss occurring in the three districts that comprise this study.

TABLE 9.1
Economic loss due to sea-level rise in Chennai's peri-urban region (2010 Rs. '000,000)

Districts	Ports		Power plants		Roads		Land		TOTAL	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Chennai	76 390	97 860	-	-	60	160	229 9760	4 599 510	2 376 210	4 697 530
Thiruvallur	91 060	97 940	138 140	138 140	-	-	339 390	9 241 300	568 590	9 477 380
Kancheepuram	5 000	5 000	-	-	630	1 730	78 820	14 307 490	84 450	14 314 220

Source: Byravan *et al.*, 2010

Based on the above information, we used an alternative method to estimate the total damage cost. The study by Byravan *et al.* (2010) suggests that the total damage due to sea level rise will amount to Rs. 3.43–57.5 billion (US $0.06–0.94 billion) per kilometre of coastline at 2010 prices. Using this estimate as a proxy, we estimated that our peri-urban area of Chennai would experience a total damage ranging from Rs. 459–7 706 billion (US $7.5–126 billion) at 2010 prices. When we take into account the intensity and quality of infrastructure and ecosystems, the estimated economic damage for Chennai region may vary.

Impact of sea-level rise and cyclones on storm surges

Sea-level rise, combined with an increased frequency and intensity of tropical cyclones, is expected to lead to an increase in extreme sea levels due to storm surges (Unnikrishnan *et al.*, 2006).

Flooding by storm surges is a major cause of coastal erosion, causing damage to buildings and other structures by direct wave impact (Coch, 1995). Kalsi *et al.* (2007) reported that the probable maximum storm surge (PMSS) heights along the Chennai coast vary from about 2.9 m to 3.6 m. Byravan *et al.* (2011) estimated that in the three districts, future storm surge would reach 4.19–4.96 m and areas in these districts below 5 m above sea level are at risk, with the assumption of a 1meter sea level rise (Table 9.2).

TABLE 9.2
Future storm surge heights and corresponding areas at risk in the three districts

Districts	Storm surge (m)	Future storm surge (m)*	Area at risk (m)**
Thiruvallur	3.6	4.96	< 5
Chennai	2.9	4.19	< 5
Kancheepuram	2.9	4.19	< 5

Source: Byravan *et al.*, 2011
** estimated based on Dasgupta et al. (2009) and Nicholls et al. (2008)*
*** "area at risk" corresponds to the elevation land area vulnerable to future storm surges*

TABLE 9.3
Land area at various heights above sea level, ha

Districts	Up to 1 m	Up to 2 m	Up to 3 m	Up to 4 m	Up to 5 m
Thiruvallur	5 456	11 088	18 453	33 940	64 465
Chennai	496	829	1 255	2 534	8 662
Kancheepuram	8 593	13 645	19 666	31 527	61 052

Source: Byravan *et al.*, 2011

No comprehensive assessments have been done to quantify the extent of sea-level rise on saltwater intrusion in the coastal zone, into coastal aquifers and on coastal agriculture and fisheries, and therefore on agricultural, pastoral and fishing communities, but these are expected to be significant.

10 Recommendations

Develop a system of water accounting for Chennai and its peri-urban area. The incentive structure that drives water transfer from peri-urban to urban users has created a wholly unsustainable situation that is undermining the long-term viability of the water resource base. Legal and institutional frameworks that determine policy decisions on water management and use within Chennai and its peri-urban area urgently need to be structured to ensure a more effective and dynamic water accounting system.

Comprehensive studies are needed to better understand the increasing opportunity costs of pursuing business as usual with respect to water management given the significant climate change risks and impacts that Chennai faces. Such studies would include determining the plausible range of impacts to coastal aquifers from sea-level rise and assessing how future water demand could be affected by potentially more severe drought and heat waves and mean temperature rise and the implications of this on the resource base. Vulnerability analysis is also needed for understanding how perverse incentives for water transfer are affecting the vulnerability of the peri-urban and urban poor to shocks.

Measures need to be instituted that promote community management of common pool resources like tank and other common water sources through institutional mechanisms, and that explicitly include wetlands as natural infrastructure in urban planning, including in landscape planning and all aspects of water management, such as stormwater management, water resources and water treatment. A payment for ecosystem services mechanism should be explored as an option for incentivizing such conservation. Empowerment of local communities and grassroots NGOs in the decision making process for groundwater use and conservation will be critically important, as will involvement of the private sector and other key actors who have a stake in how water resources could be better managed. Specific programmes aimed at benefiting local communities in sustainable water resource and wetland ecosystem management should be part of this engagement effort. Rainwater harvesting also shows strong potential for addressing groundwater depletion, as discussed in Section 6.

Develop and institute a rational process for agricultural land use. The reality is that Chennai is growing rapidly and will continue to do so into the foreseeable future. Current land conversion from agricultural to non-agricultural uses is haphazard, with the undervaluing of agricultural land uses relative to urban and industrial ones likely contributing to overexploitation of groundwater resources for non-agricultural use. Policy frameworks and regulations are needed that arrest the conversion of agricultural land to non-agricultural purposes. However, regulations alone will not solve the problem if the underlying factors that place agriculture at a disadvantage are not addressed. Such factors include disempowerment of small-scale farmers and agricultural labourers who cannot compete against more powerful forces for use of water resources, and lack of strong support and incentives for agriculture in the peri-urban region.

The government needs to provide more robust institutional support services such as marketing and credit and promotion of agro-industries and provide infrastructure that supports good rural-urban connectivity and transportation to incentivise farming in peri-urban areas. Creating 'farmers' markets' in urban areas, establishing communication networks among producers and consumers and strengthening transportation facilities to minimize the transaction costs could substantially reduce the differences in prices across different types of markets and provide farmers with greater decision making power. In addition, development of saline tolerant rice varieties and other technological interventions to address the increasing abiotic and biotic stresses on crops from environmental degradation and climate change are needed.

There is a dire need for promoting agriculture extension reforms in urban centres with a focus on demand and need driven agriculture extension. It is imperative to educate political leaders in local governments on the importance of urban agriculture to urban economies. Use of information and communication tools are critical to promote urban agriculture.

Better understand and protect against long-term risks to coastal infrastructure and ecosystems. Tamil Nadu and the Chennai region's coastline are highly vulnerable to sea level rise, storm surge leading to inundation, coastal erosion, saltwater intrusion, and loss of coastal biodiversity and ecosystems as well as severe infrastructure damage. A participatory coastal-vulnerability assessment needs to be initiated and from that process co-management based on climate change adaptation needs to be developed. Such efforts would likely entail the promotion of barriers—natural "bio-shields", involving saline-tolerant tree species such as the mangroves, casuarinas, and coconut trees, and man-made engineering structures—to reduce the impact of storm surges and tidal waves on coastal lives and livelihoods. The Coastal Regulation Zone (CRZ) Notification 2011 needs to be strengthened by removing the ambiguities that lead to a lax permitting process for development activities along the Chennai coastline. A provision for dynamic and locally specific advisories and early warning to serve coastal communities is needed. Fishing-dependent livelihoods need to be strengthened and supported by providing forward links in terms of storage of and value addition to fish catches, and early warning systems that can allow fishing communities to better protect boats and fishing gear from storm surges. Lastly, studies to understand how fisheries may be affected by warming ocean temperatures are needed in order to promote anticipatory planning.

11 References

Ahmed, S.A., N.S., Diffenbaugh and Thomas W.H. (2009). Climate Volatility Deepens Poverty Vulnerability in Developing Countries. *Environmental Research Letters*, 4: 1–8.

Al Gamal, S. and Abdel-Kader D. (2009). 'Impacts of Climate Changes on Water Resources in Africa with Emphasis on Groundwater', Journal of Environmental Hydrology, 17(2): 1–11.

Armstrong, D.V. (1994). Heat Stress Interaction with Shade and Cooling. *Journal of Dairy Science*, 77, 2044–2050.

Bohmanova J., Misztal I., and Cole, J.B. (2007). Temperature-Humidity indices as indicators of milk production losses due to heat stress. *Journal of Dairy Science,* 90:1947–1956.

Bounoua, Lahouari., AbdelmounaineSafia, Jeffrey Masek, Christa Peters-Lidard and Mark L. Imhoff (2009). 'Impact of Urban Growth on Surface Climate: A Case Study in Oran, Algeria', DOI: 10.1175/2008JAMC2044.1.

Brown, M.E. and C.C. Funk. (2008). Food Security under Climate Change. *Science*, 319: 580.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringer, C. (2009). Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints. *Environmental Science and Policy*, 12: 413–426.

Byravan, Sujatha, SudhirChellaRajan and Rajesh Rangarajan (2010). 'The Impact of Sea Level Rise on Infrastructure, Ecosystem and Land along the Tamil Nadu Coast', Centre for Development Finance (CDF), IFMR and Humanities and Social Sciences, IIT Madras (published online 2011).

Census of Tamil Nadu.(1991 & 2001). Primary Census Abstract, 1991 & 2001, Directorate of Census Operations, Chennai.

Central Marine Fisheries Research Institute (CMFRI) (2007). Annual Report 2006-2007. CMFRI, Cochin, 126.

Chand, Ramesh and T. Haque (1998). 'Rice-Wheat Crop System in Indo-Gangetic Region: Issues concerning Sustainability Rice-Wheat Crop System in Indo-Gangetic Region: Issues concerning Sustainability', Economic & Political Weekly, 33(26): A108–A111.

CMDA (2007). Draft Master Plan—II for Chennai Metropolitan Area—2026, Chennai Metropolitan Development Authority. Chennai Metropolitan Development Authority www.hindu.com/nic/draftmasterplanii_short.pdf

CMFRI (2008). Research Highlights 2007-2008. Central Marine Fisheries Research Institute, Cochin, India, pp. 36.

Coch, N.K. (1995). Geohazards: Natural and Human. Englewood Cliffs, NJ: Prentice Hall.

Daniel Allen Sinclair, Sarah Lynn Maxey, Graciela Tiburcio Pintos, Ernesto Acevedo Ruiz, Vidal Castillo Leggs, Pedro MárquezAlmanza, Juan Carlos Fiol, Rafael Fiol, and Katherine Santos (2010). 'Predicted Sea Level Rise Impacts on The Nesting Beaches of Olive Ridley Turtles In Los Cabos, Mexico', Thirtieth Annual Symposium on Sea Turtle Biology and Conservation, Goa.

Dasgupta, S., Laplante, B., Murray, S. and Wheeler, D. "Climate Change and the Future Impacts of Storm-Surge Disasters in Developing Countries." Center for Global Development Working Paper 182. Washington, D.C.: Center for Global Development.

De Zeeuw, H., R. Van Veenhuizen and M. Dubbeling. (2011). The role of urban agriculture in building resilient cities in developing countries. *Journal of Agricultural Science,* 149(S1): 153–163.

FAO (2012). 'Food, Agriculture and Cities: Challenges of Food and Nutrition Security, Agriculture and Ecosystem Management in an Urbanizing World, in: www.fao.org/fileadmin/templates/FCIT/PDF/FoodAgriCities_Oct2011.pdf

GoI (Government of India) (Year not known). Performance of Agriculture Sector and Policy Initiatives, NIC Planning Commission, India. Working Group 12. http://planningcommission.nic.in/aboutus/committee/wrkgrp12/agri/Crop%20Husbandry%20_WG1_Final_.pdf.

Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodhanan, M.S., Xavier, P.K. (2006). Increasing Trend of Extreme Rain Events over India in a Warming Environment. *Science* 314:1442–1445.

Government of India (2011).Population Census Reports, 2011, Registrar General, New Delhi.

Government of Tamil Nadu.Five Year Plan Reports, State Planning Commission, Chennai.

Government of Tamil Nadu.Statistical Hand Book, Various Years, Department of Economics and Statistics, Chennai.

Government of Tamil Nadu.Statistical Handbook of Tamil Nadu, Various Years, Department of Economics and Statistics, Chennai.

Hallegatte, S. and J. Corfee-Morlot. (2011). Understanding climate change impacts, vulnerability and adaptation at city scale: an introduction. *Climatic Change*. 104: 1–12.

Indian Network for Climate Change Assessment Report (INCCA). (2010). Climate Change and India: A 4X4 Assessment—A Sectoral and Regional Analysis for 2030s. Ministry of Environment and Forests, Government of India, New Delhi.

IELRCH (2003). The Tamil Nadu Groundwater (Development and Management) Act, 2003. International Environmental Law Research Centre House, Http://ielrc.org/content/e0302.pdf

IPCC SREX, (2012). Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) 2012. Intergovernmental Panel on Climate Change (IPCC). http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf

Janakarajan, S., Raman, S., Jothi, G. and Prabahar, G. (2006). Impacts of increased urban demand for water on livelihood resilience in Chennai's peri-urban areas. [online] Chennai, India: Madras Institute of Development Studies (MIDS).

Jaganathan, A. and Andimuthu. R. (2013). Temperature trends of Chennai City, India. *Theoretical & Applied Climatology,* 111(3/4): 417–425.

Kalsi, S.R., N. Jayanthi, Y.E.A. Raj, and S.K.R. Bhomik. (2007). "Probable Maximum Storm Surge Heights for the Maritime Districts of India". New Delhi: Indian Meteorological Department.

Karthikeyan, A. (2008). Chennai's groundwater hits new high. Times of India, TNN. July 30, 2008.

Krishna Kumar, K., Patwardhan, S. K., Kulkarni, A., Kamala, K., Rao, K.K., and Jones, R. (2011). Simulated projections for summer monsoon climate over India by a high-resolution regional climate model (PRECIS). *Current Science*, 101(3), 312–326.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylor, R.L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science* 319(5863): 607–610.

Marcovaldi, M.A., Lopez, G.G., Soares, L.S., Lima EHSM, Thome JCA, Almeida, A.P. (2010).Satellite-tracking of female loggerhead turtles highlights fidelity behavior in North-eastern Brazil. *Endangered Species Research*, 12:263–272.

Natesan, U. and Parthasarathy, A. (2010). The potential impacts of sea level rise along the coastal zone of Kanyakumari District in Tamilnadu, India. *Journal of Coastal Conservation,* 14(3): 207–214.

National Family Health Survey (NFHS-3) (2005-06). India: Key Findings. International Institute for Population Sciences (IIPS) and Macro International. 2007. Mumbai.

National Informatics Centre (2013). http://www.chennai.tn.nic. in/chndistprof.htm#loc

National Sample Survey Organisation (2003). Situation Assessment Survey of Farmers. Ministry of Statistics and Programme Implementation, New Delhi.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. and Kaltenborn, B. (Eds.), (2009).The Environmental Food Crisis.The Environment's Role in Averting Future Food Crises. A UNEP Rapid Response Assessment. Arendal, UNDP.

Nicholls, R.J., S. Hanson, C. Herweijer, N. Patmore, S. Hallegatte, J. Corfee—Morlot, J. Chateau and R. Muir-Wood (2007). Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes. OECD Environment Directorate, Environment Working Papers No. 1.

Ortiz, R., K.D. Sayre, B. Govaerts, R. Gupta, G.V. Subbarao, T. Ban, D. Hodson, J.M. Dixon, J. Iván Ortiz-Monasterio, and M. Reynolds (2008). Climate change: Can wheat beat the heat? *Agriculture, Ecosystems and Environment,* 126 (1–2): 46–58.

Packialakshmi, S., Ambujam, N.K., and Nelliyat, P. (2011). Groundwater market and its implications on water resources and agriculture in the southern peri-urban interface, Chennai, India. *Environment, development and sustainability,* 13(2): 423–438.

Palanisami, K., S. Rahul and M. Kadiri (2010). Andhra Pradesh State Water Sector Reforms: Current status, emerging issues and needed strategies. IWMI-Tata Water Policy Programme Study Report. IWMI, Hyderabad.

Perry, A.L., Low, P.J., Ellis, J.R. and Reynolds, J.D. (2005). Climate Change and distribution shifts in Marine Fishes. *Science*, 308(5730): 1912–1915.

Rao, S.V.N, Saheb, S.M. and Ramasastri, K.S. (2004). Aquifer Restoration from Seawater Intrusion: A Preliminary field scale study of the Minjur Aquifer System, North of Chennai, Tamilnadu, India. 8-SWIM. Cartagena, Spain. *Eds.* Araguás, Custodio and Manzano. IGME.

Season and Crop Report Tamil Nadu (Various Years). Department of Economics and Statistics, Government of Tamil Nadu, Chennai.

Shah, A. (2001). Water Scarcity Induced Migration. *Economic and Political Weekly*, 36 (35): 3405–3410.

SIPDWA (2005). South India Packaged Drinking Water Association.

Srivastava, A., S. Naresh Kumar, and P.K. Aggarwal, 2010: Assessment on vulnerability of sorghum to climatechange in India. *Agriculture, Ecosystems and Environment,* 138 (3–4), 160–169.

Tamil Nadu Groundwater (Development and Management) Act (2003). International Environmental Law Research Centre. http://www.ielrc.org/content/e0302.pdf

Thapa, S., Marshall, F. and Stagl, S. (2010). Understanding Peri-urban Sustainability: The Role of the Resilience Approach, STEPS Working Paper 38, Brighton: STEPS Centre.

The Hindu (2003). http://www.hindu.com/thehindu/mp/2003/06/05/stories/2003060500290100.htm

United Nations Framework Convention on Climate Change (2012). India's Second National Communication (NATCOM) Report. Ministry of Environment and Forests, Government of India, New Delhi.

Unnikrishnan, A.S., Rupa Kumar, K., Fernandes, S.E., Michael, G.S. and Patwardhan, S.K. (2006). Sea level changes along the Indian coast: Observations and Projections. *Current Science,* 90(3): 362–368.

Venkatesh, S. (2006). Post-tsunami rehabilitation of fishing communities and fisheries livelihoods in Tamil Nadu, Kerala and Andhra Pradesh ICSF India Tsunami Report Revised 12-01-06.pdf.

Vitali, A., M. Segnalini, L. Bertocchi, U. Bernabucci, A. Nardone, and N. Lacetera, 2009: Seasonal pattern of mortality and relationships between mortality and temperature-humidity index in dairy cows. *Journal of Dairy Science,* 92(8): 3781–3790.

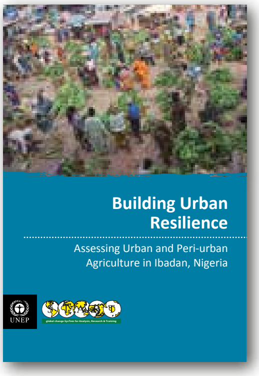
Vivekanandan, E. and D.B. James. (1986). Population dynamics of Nemipterusjaponicus (Bloch) in the trawling grounds of Madras. *Indian J. Fish*., 33: 145–54.

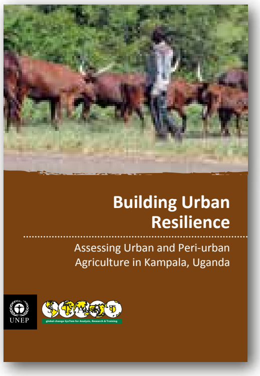
Vivekanandan, E.Rajagopalan, M. and Pillai, N.G.K. (2009). Recent Trends in Sea Surface Temperature and its Impact on Oil Sardine. In: Global Climate Change and Indian Agriculture. Aggarwal, P.K., (ed.) Indian Council of Agricultural Research, New Delhi, pp.89–92.

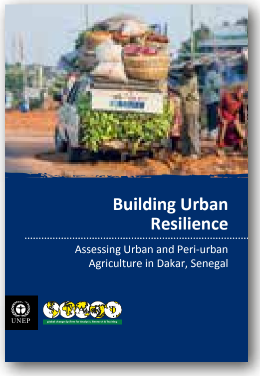
Wang, J. (2010). Food Security, Food Prices and Climate Change in China: A Dynamic Panel Data Analysis. *Agriculture and Agricultural Science Procedia*, 1: 321–324.

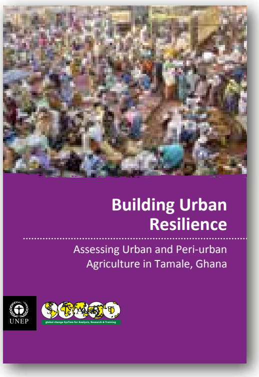
Ziervogel, G., Bharwani, S. and Downing, T.E. (2006). 'Adapting to Climate Variability: Pumpkins, People and Pumps', *Natural Resource Forum*, 30:294–305.

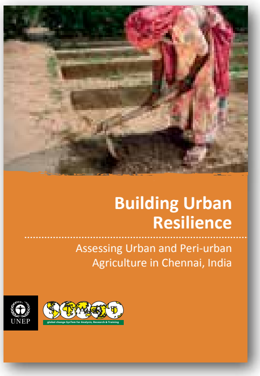
This report represents one from a series of nine city-level reports on urban and peri-urban agriculture (UPA), which together form a larger knowledge assessment. The knowledge assessment was carried out in Dakar (Senegal), Tamale (Ghana), Ibadan (Nigeria), Dar es Salaam (Tanzania), Kampala (Uganda), Addis Ababa (Ethiopia), Dhaka (Bangladesh), Kathmandu (Nepal) and Chennai (India). The nine reports and a synthesis report can be downloaded at: http://start.org/programs/upa

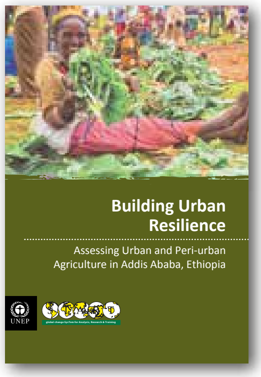


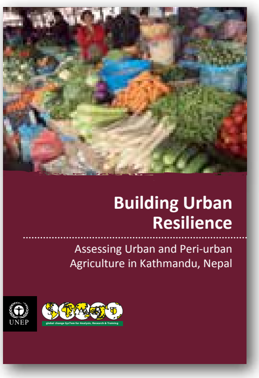


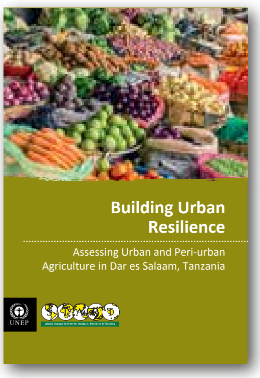












Funding Partners

European Commission
UNEP
USAID FROM THE AMERICAN PEOPLE
United States Global Change Research Program

This assessment report presents the findings of a knowledge assessment on urban and peri-urban agriculture (UPA) for the city of Chennai, India, that was conducted in 2012. The assessment examines the state of UPA in the city through the lens of intensifying urban pressures and increasing climate risks with the objective of identifying how these and other drivers potentially interact to affect the long-term sustainability of UPA, and what response options are needed to address existing and emerging challenges.

www.start.org

International START Secretariat
2000 Florida Ave NW #200
Washington, D.C. 20009, United States
Tel.: +1 202-462-2213
e-mail: start@start.org
www.start.org

www.unep.org

United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: publications@unep.org
www.unep.org

UNEP

ISBN: 978-92-807-3377-8
Job Number: DEW/1789/NA