

Review article on Indian climate change scenario and role of urban green spaces in providing ecological services

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Abstract: The Review article focuses on the global challenges to tackle the increasing emissions of GHGs, the projected sea level rise and the various impacts of global warming. The IPCC reports have been studied and included. The human activities are causing unprecedented growth of CO₂ and its impacts on overall Ecology, Social and Economic activities. According to Paris conference, the world has to limit the temperature rise below 2 degrees centigrade. In the race of urbanisation, industrialization, competitiveness and political pressure, the nations are increasing their per capita CO₂ emissions and are responsible for disastrous consequences on all countries and specifically on India. India has taken National Action Plan to tackle the issues related to energy, sustainability, forestry, Agriculture and Climate change. The article emphasizes on role of urban green spaces in biodiversity maintenance and their ecological, economical, social and psychological impacts on health of Ecosystem and on human beings. The recommendations and remedial measures for sustainable cities, the need of hour and the best possible solutions are also covered.

Keywords: GHG, IPCC, Climate Change, Sustainability, Urban green spaces

I. Introduction:

Climate change is recognized as the greatest threat to the planet and the greatest challenge facing humanity. Ever since the industrial revolution began about 150 years ago, human activities have added significant quantities of GHGs to the atmosphere. An increase in the levels of GHGs could lead to greater warming which, in turn, could have major impact on the world's climate, leading to accelerated climate change. Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased from 280 ppm to 379 ppm, 715 ppb to 1774 ppb and 270 ppb to 319 ppb respectively, between pre-industrial period and 2005 (IPCC, 2007). Eleven of the last twelve years rank among the 12 warmest years in the instrumental record of global surface temperatures since 1850. The updated 100-year linear for 1906-2005 is 0.740C. Globally, average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. The rate was higher over 1993 to 2003, about 3.1 mm per year (IPCC, 2007). The projected sea level rise by the end of this century is likely to be 0.18 to 0.59 meters. In its 2007 Report, the Intergovernmental Panel on Climate Change (IPCC) predicts global temperatures will rise by 2-4.50C by the end of this century and for the next two decades a warming of about 0.20C per decade is projected. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.10C per decade would be expected.

The Intergovernmental Panel on Climate Change, in its 2007 report, predicts that global temperatures will rise by 2-4.50 C by the end of this century "fig.1", with a 2.7-4.3⁰C increase over India by the 2080s. The panel also predicted an increase in rainfall over the Indian sub-continent by 6-8 per cent and that the sea level would rise by 88 centimeters by 2100.

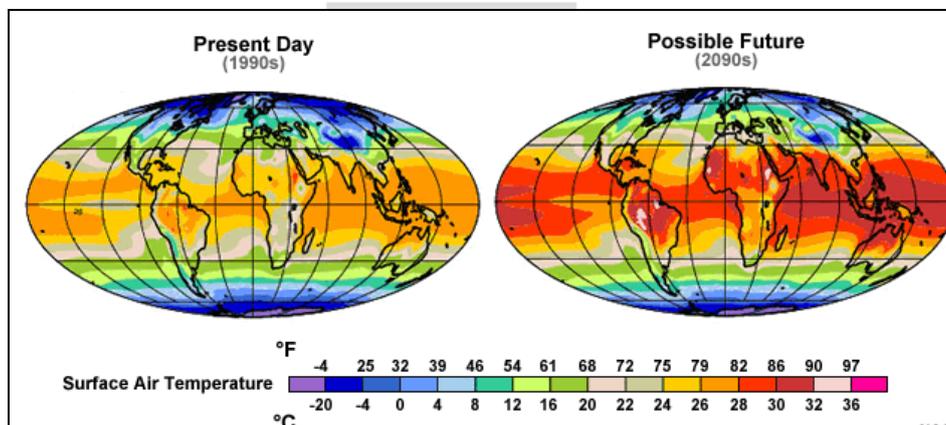


Figure 1: Global Temperature Projections Source: National Centre for Atmospheric Research

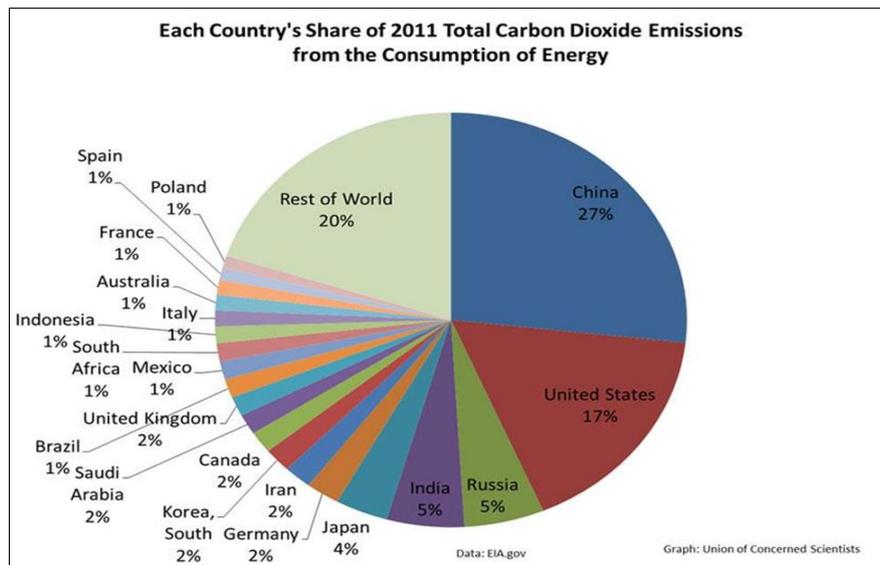


Figure 2: Country's share of 2011 in CO₂ emissions

India's contributions to CO₂ emissions have increased to 2.47 billion tones in 2015, which was 5.1% more than in 2014 "fig. 2". The G20 consists of Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom, United States and the European Union. As a whole, the G20 was responsible for 81.5% of global CO₂ emissions [2] in 2015. The remaining 194 non-G20 countries, collectively, contributed 14.6% to global CO₂ emissions in 2015 "fig.3, fig.4 and fig.5".

92% of the world breathes bad air.--- WHO terming this ' a public health emergency'—China and Malaysia(South east Asia and Western pacific region) most affected countries. 98% of cities in low- and middle-income countries with more than 1,00,000 inhabitants do not meet WHO air quality guidelines.56 % of high-income countries do not meet WHO air quality guidelines.6 lakhs deaths in India every year due to air pollution. Nine out of 10 people globally are breathing poor quality air, calling for dramatic action against pollution.

Fourth assessment report of the Inter-governmental panel on Climate Change (IPCC) has strongly recommended to limit the increase in global temperature below 2°C as compared with pre-industrial level (i.e. measured from 1750) to avoid serious ecological and economic threats to the planet. Global mean temperature rise of 0.74°C has already been recorded. Hence climate scientists and policy makers are focusing on an urgent action to curb global warming. Forests play an important role in regional and global carbon (C) cycles because they store large quantities of C in vegetation, detritus and soil. The amount of carbon stored in the biomass has gained special attention in the recent past as a result of the UN Framework Convention on Climate Change (UNFCCC) as well as its Kyoto Protocol. Under these agreements, all member countries are requested to estimate and report CO₂emissions and removals of forest, and the credited sinks may be used as emission reductions.

The year 2015 was a historic year----

- It was the hottest year since records began in 1880.
- The 16 warmest years recorded are in the 1998-2015period.
- Top emitter China started to curb its carbon dioxide (CO₂) emissions in 2015. China and the United States reduced their emissions by 0.7% and 2.6%, respectively, compared to 2014.
- Characterized by one of the strongest El Niños in history, and with record high ocean temperatures, globally (with annually averaged ocean surface temperature around the world of 0.74 °C higher than the average over the 20th century). The global land temperature for 2015 was 1.33°C above the 20th century average.
- The year closed with the adoption of the landmark Paris Agreement on Climate Change by 194 countries and the European Union. Forestry is recognized by the Kyoto Protocol as a sink measure for greenhouse gases in the atmosphere under the Clean Development Mechanism (CDM) in terms of afforestation and reforestation (Singh et al., 2011). It is increasingly being realized by the international community that the mitigation of global warming will not be achieved without the inclusion of forests in the mitigation plan. In this context, Reducing Emissions from Deforestation and Forest Degradation (REDD) is a new initiative of United Nations Frame-work Convention in Climate Change (UNFCCC), led by forest-rich developing countries that calls for economic incentives to reduce the emissions of greenhouse gases from deforestation and forest degradation in developing countries (Gibbs et al., 2007).

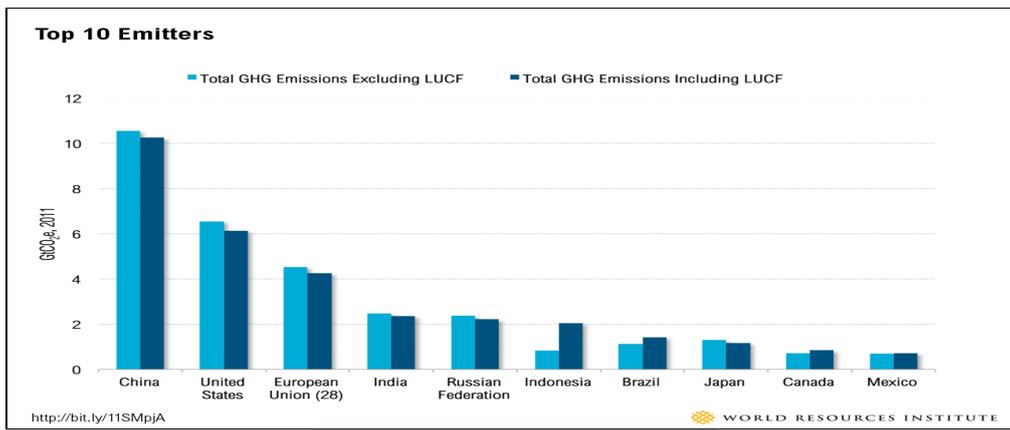
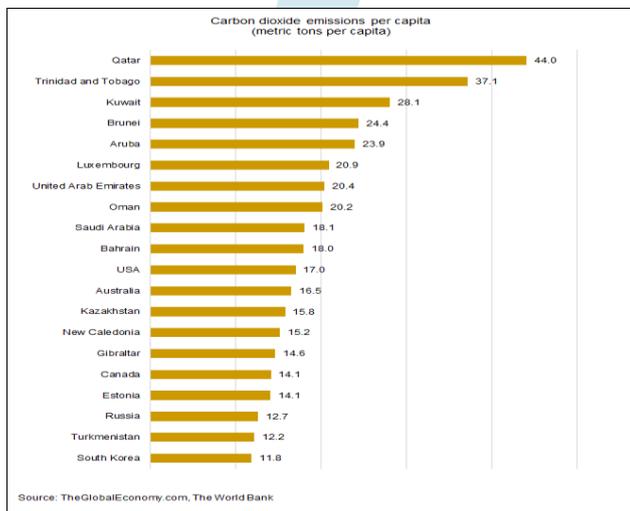
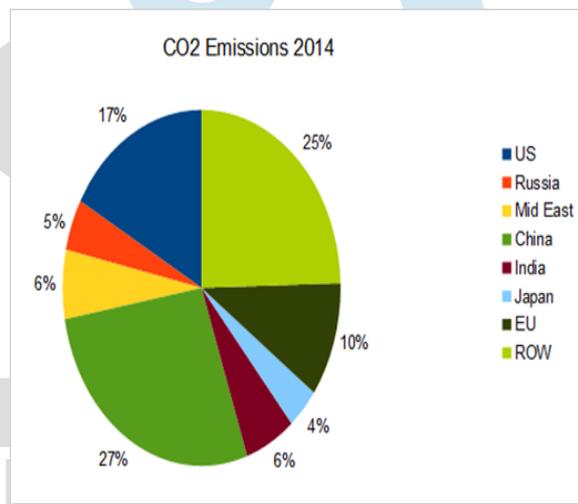


Figure 3: The top 10 emitters of GHG Source: World Resources Institute, <http://bit.ly/11SMpjA>

During the past few years, carbon sequestration and biodiversity protection have been high priorities in the scientific, governmental and civil-society agendas for mitigating climate change (Diáz et al., 2009). Developing countries are starting plantation programmes, which along with carbon credits; also generate significant income (Niles et al., 2002). The market for CDM has a large potential for reforestation and afforestation activities in developing countries beyond 2012 (De Koning et al., 2005). In 2013, the world passed the landmark of 400 ppm of CO₂, as registered at Mauna Loa. To be exact, it was 410.28 ppm according to ‘Scientific American’.



Source: The Global Economy.com, The World bank
Figure 4: Per capita CO₂ emissions



Source: Google images
Figure 5: CO₂ emissions of major countries

Indian Scenario:

India is a fast-growing economy and has many future developmental targets, several of which are directly or indirectly linked to energy and therefore increased green house gas emissions. Being a developing country with nearly 700 million rural populations directly depending on climate-sensitive sectors (agriculture, forests and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Further, the adaptive capacity of dry land farmers, forest dwellers, fisher folk and nomadic shepherds is very low. Climate change may alter the distribution and quality of India's natural resources and adversely affect the livelihoods of its people. With an economy closely linked to its natural resource base and climatically sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected change in climate [72]. With climate change, there would be increasing scarcity of water, reduction in yields of forest biomass, and increased risk to human health. The contribution of India [13] to the cumulative global CO₂ emissions is only five per cent. Thus, historically and at present, India's share in the carbon stock in the atmosphere is relatively less when compared to its distribution over the nation's population. India released its National Action Plan on Climate Change (NAPCC) on 30th June, 2008 to outline its strategy to meet the Climate Change challenge. The National Action Plan advocates a strategy that promotes, firstly, the adaptation to Climate Change and secondly, further enhancement of the ecological sustainability of India's development path.

Recent data about India:

- Heat waves ----4500 people lost their life in last 4 years. Andhra Pradesh and Telangana—increased by 92%
- Delhi Pollution—more than 3000 people died. 8 persons/ day ---So ban on use of Furnace oil and coal
- Bad air caused 80,000 premature deaths in Mumbai And Delhi in 2015. In economic terms, air pollution cost the two cities 10.66 billion dollars in 2015, or about 0.71% of the country's gross domestic product.

Table 1: Burden on Health- Mortality by bad quality of air

Mumbai	2005	2015	Delhi	2005	2015
Mortality	19,291	32,014	Mortality	19,291	48,651
Chronic bronchitis	78,293	1,07,197	Chronic bronchitis	79,636	1,61,388
Asthma(Adults)	1,84,798	2,81,935	Asthma(Adults)	1,90,706	4,36,738

- Bad air quality [82] causes 35% rise in emergency hospital visits.—Worsening quality of air in the city has led to 64,037 emergency room visits in 2015 because of respiratory ailments –a study by researchers at Indian Institute of Technology, Bombay.
- Economic cost of PM10 exposure rose by around 60% in Mumbai from 2.68 billion dollars in 1995 to 4.26 billion dollars in 2015.
- More than 1600 people died due to extreme weather conditions across the country last year, with severe heat wave claiming the largest chunk of the total deaths at 40% followed by flooding and lightening. The IMD said 2016 was the warmest year ever recorded, globally as well as in India.
- More fish species on the east coast, especially in the off Odisha and West Bengal, are highly vulnerable to climate change, according to Central Marine fisheries Research Institute. Overall, 69% of the 68 fish species studied were found to be vulnerable to climate changes.

India's National Action Plan stresses that maintaining a high growth rate is essential for increasing the living standards of the vast majority of people of India and reducing their vulnerability to the impacts of climate change. Accordingly, the Action Plan identifies measures that promote the objectives of sustainable development of India while also yielding to benefits for addressing climate change. Eight National Missions, which form the core of the National Action Plan, represent multi-pronged, long term and integrated strategies for achieving key goals in the context of climate change. The focus is on promoting understanding of Climate Change, adaptation and mitigation, energy efficiency and natural resource conservation.

Tropical forests constitute as much as 86% of the forested area in India [12], of which 53% is dry deciduous, 37% moist-deciduous and the rest is wet-evergreen on semi-green. From past few decades, these forests, however, have been strongly affected by anthropogenic activities, particularly excessive grazing, conversion of plantation, various developmental activities including hydroelectric project, trampling and overexploitation of fuel wood.

Impacts of Climate Change at Global level:

The GHGs increase the earth's temperature results in many adverse impacts such as sea level rise and inundation of coastal land, changes in weather patterns, accelerated rate of fresh water evaporation, effect on the agricultural productivity, increase in disease carrying vectors, etc. It is estimated that GHGs emissions from the Asia-Pacific region will be about half of the global emissions by the end of year 2100. The global average surface temperature increased by 0.6°C over the course of the 20th century and has caused a decline in snowfall by about 10 per cent since the 1960s, raised the global average sea level by 10 to 20 cm during the 20th century and also changed the rainfall patterns in the Northern Hemisphere, with generally more rain at high latitudes and near the equator and less in the sub-tropics.

Arctic Warming may cost trillions -- as its melting from Siberia to Alaska raising world sea levels and disrupting temperature patterns --arctic warming could have the cumulative net costs from 2010-2100 of between 7 trillion dollars and 90 trillion dollars.

Impacts of climate change on Indian subcontinent:

The IPCC reports that the effects of global warming will be mixed across regions. Developing countries are vulnerable to reduced economic growth as a result of global warming. Most of the consequences of global warming would result in----

- Heat Spells and Extreme temperatures causing deaths
- Change in Rainfall pattern which has an effect on the monsoon too. India is heavily dependent on the monsoon to meet its agricultural and water needs, and also for protecting and propagating its rich biodiversity. Climatic change and variability could also upset the spatial and temporal distribution of the rainfall patterns. Lower rainfall and increased evaporation may lower the quantity of run-offs into the watersheds, there by affecting the availability of freshwater. Subtle changes have already been noted in the monsoon rain patterns by scientists at IIT, Delhi. They also warn that by the 2050s, India will experience a decline in its summer rainfall, which accounts for almost 70 percent of the total annual rainfall and is crucial to agriculture. Changing rainfall patterns bring extreme events such as droughts, torrential rains, flashfloods, cyclones.
- Melting of Glaciers causing sea level rise and flooding --According to International Centre for Integrated Mountain Development (ICIMOD), Himalayan glaciers could disappear within 50 years because of climate change, with far reaching implications, as global warming has pushed up the temperature of the Himalayas by up to 0.60C in the past 30 years. Ice melt's share in sea level rise is increasing, accelerating the larger ice sheets crumble, mountain glaciers shrink, large regions that rely on glacial runoff for water supply could experience severe shortages. Some of the glaciers in the Himalayas are receding at an average rate of 10 to 15 meters per year. The dams can break and cause flash floods of water, rocks and gravel, destroying villages and fields downstream imitating the phenomenon termed as Glacial Lake Outburst Flood (GLOF).
- Agriculture- Food production in India is still considerably dependent on the rainfall quantity and its distribution, which is highly variable, both spatially and temporally. In the past fifty years, because of 15 major droughts the productivity of rain-fed crops was adversely affected [76] and threatened livelihood security of millions of small and marginal farmers in the rain-fed agriculture region. Food security may be at risk in the future due to the threat of climate change leading to an increase in the frequency and intensity of drought and floods, thereby affecting production and Food security and food basket. Climatic and agro-ecological zones would shift, forcing farmers to adapt, and threaten natural vegetation and fauna. The current imbalance of food production

between cool and temperate regions as well as tropical and sub-tropical regions could worsen. Further warm temperatures shorten the duration of crop cycles, which in turn result in lower crop yield per unit area.

- Addressing multiple risks due to climate change—temperature and precipitation variability, drought, flooding and extreme rainfall, cyclone and storm surge, sea level rise, and associated environmental health risk—is a serious public policy and adaptation management challenge for India (Revi 2008).
- Forests- the regional climate model projections (HadRM2) for India shows shifts in forest boundary, changes in species assemblage or forest types, changes in net primary productivity, possible forest die-back in the transient phase, and potential loss or change in biodiversity. And will have adverse socio-economic implications for forest dependent communities and the national economy. The impacts of climate change on forest ecosystems are likely to be long-term and irreversible.
- Rise in sea level-The sea level would rise, threatening valuable coastal agricultural land, particularly in low lying small islands. Distribution and quantities of fish and sea foods could change dramatically, wreaking havoc in established national fishery activities.
- Biological diversity would be reduced in some of the world's most fragile environments, such as mangroves and tropical forests. Climatic change affects the geographical distribution, composition and productivity of the forest ecosystems, which affect the survival of flora and fauna.
- Stress on the ecological and socio-economic systems that are already facing tremendous problems due to rapid urbanisation, industrialization and economic development.
- Health-- Climate change and variability increase the breeding grounds for vector-borne diseases such as malaria. Areas with warmer and wetter climate encourage faster reproduction and greater survival of disease-causing viruses, bacteria, fungi and parasites. Increased flooding may cause non-vector borne diseases like cholera, salmonellosis and leptospirosis. Additional indirect effects include respiratory and allergic disorders due increase in air pollutants, pollens and mould spores due climate change.

National Action Plan on Climate Change:

India has a robust and comprehensive National Action Plan on Climate Change (NAPCC) in place which has a mix of both mitigation and adaptation measures.

India released its National Action Plan [77] on Climate Change (NAPCC) on 30th June, 2008 to outline its strategy to meet the challenge of climate change which advocates a strategy that promotes the adaptation to climate change and enhancement of the ecological sustainability of India's development path.

It recognizes that climate change is a global challenge and should be successfully addressed through a globally collaborative and cooperative effort on the basis of the principle of equity. The Plan also expresses India's willingness to play its role as a responsible member of the international community and to make its contribution. However, it emphasizes that this requires not only sustainable production processes, but also sustainable life styles across the globe. In this effort, every citizen of the planet should have an equal share of the planetary atmospheric space. The Action Plan suggests that the long-term convergence of per capita GHG emissions is the only equitable basis for a global agreement to tackle climate change. The Action Plan assures the international community that India's per capita GHG emissions would not exceed the per capita GHG emissions of developed countries, despite India's developmental imperatives.

It stresses that maintaining a high growth rate is essential for increasing the living standards of the vast majority of people in India and reducing their vulnerability to the impacts of climate change. Accordingly, the Action Plan identified measures that promote the objectives of sustainable development while yielding to benefits for addressing climate change.

The Action Plan also contains a detailed series of sustainability goals and actions in operational areas such as, energy conservation, greenhouse gas reduction, waste management, sustainable transportation, purchasing, food and green buildings.

Eight National Missions, which form the core of the National Action Plan, represent multipronged, long term and integrated strategies for achieving key goals in the context of climate change. The focus is on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation.

National Missions

1. **National Solar Mission** aims at increasing the share of solar energy in the total energy mix through development of new solar technologies, while attempting to expand the scope of other renewable and non fossil options such as nuclear energy, wind energy and biomass.
2. **National Mission for Enhanced Energy Efficiency** comprises four new initiatives, namely - a market based mechanism for trading in certified energy savings in energy intensive large industries and facilities, accelerating the shift to energy efficient appliances in designated sectors, demand side management programmes in all sectors by capturing future energy savings, and developing fiscal instruments to promote energy efficiency.
3. **National Mission for Sustainable Habitat** attempts to promote energy efficiency in buildings, management of solid waste and nodal shift to public transport including transport options based on biodiesel and hydrogen.
4. **National Water Mission** has as its objective, the conservation of water, minimizing wastage and ensuring more equitable distribution both across and within states.
5. **National Mission for Sustaining the Himalayan Ecosystem** is aimed at evolving management measures for sustaining and safeguarding the Himalayan glacier and mountain ecosystem.
6. **National Mission for a Green India** focuses on enhancing ecosystem services and carbon sinks through afforestation on degraded forest land, in line with the national policy of expanding the forest and tree cover to 33 per cent of the total land area of the country.

7. **National Mission for Sustainable Agriculture** would develop strategies to make Indian agriculture more resilient to climate change, with new varieties of thermal resistant crops, credit and insurance mechanisms and improving productivity of rain fed agriculture.

8. **National Mission on Strategic Knowledge for Climate Change** is intended to identify the challenges of, and the responses to, climate change through research and technology development and ensure funding of high quality and focused research into various aspects of climate change.

The Missions on Solar Energy and Enhanced Energy Efficiency under the NAPCC have recently been approved by the Prime Minister's Council for Climate Change.

In addition, the Action Plan envisages effective disaster management strategies that include mainstreaming disaster risk reduction into infrastructure project design, strengthening communication networks and disaster management facilities at all levels, protection of coastal areas, provision of enhanced public health care services and assessment of increased burden of disease due to climate change. The Action Plan also highlights the role of Central Government, State Governments and local.

Green India Mission:

- ✓ GIM[70] is one of the eight missions under the NAPCC.
- ✓ The objectives of the Mission include increased forest/tree cover on 5 m ha of forest/non-forest lands and improved quality of forest cover [11] on another 5 m ha of non-forest/forest lands to improve ecosystem services including biodiversity, hydrological services, carbon sequestration from the 10 m ha of forest/non-forest lands as mentioned above, increased forest-based livelihood income of about 3 million households, predominantly tribals living in and around the forests, and additional enhanced annual CO sequestration by 50 to 60 million tons annually by year 2022.
- ✓ The total projected Mission 2cost is ` 46,000 crores spread over 10 years.
- ✓ The Mission provides funding of ` 2000 crores under 13th Plan outlay, along with ` 400 crores from 13th Finance Commission Grants towards States' share. It also spells out convergence with CAMPA to the tune of ` 6000 crores, with MNREGS to the tune of ` 4000 crores and with National Afforestation Programme for ` 600 crores. Thus, total expenditure proposed for GIM will be ` 13,000 crores during the 12th Plan and a one-year spill-over into the 13th Plan.
- ✓ Similarly, the Mission is likely to generate 1352 crores worth of skilled employment for about 28,000 community youths.
- ✓ The Mission provides key roles to Gram Sabha and the Committees mandated by it to carry out the activities of the Mission at the village level. All the plans at village level will have to be approved by the Gram Sabha, before they could be implemented. Provision of Social Audit by the Gram Sabha, as done in MGNREGS will ensure accountability of local level institutions. Similarly, planning at landscape level will be done by the revamped.

Role of Local governments:

- ✓ Local governments play an important role in implementing sustainable urban development policies. Ideally, decision-makers in city authorities should be fully aware of the latest research findings, the range of available solutions, and current legislation and best practices on this field; however, this information is not always accessible or disseminated in a timely and appropriate format. Therefore, there is a need for cross-checking the supply of information and the demand for solutions on Sustainable Urban Development (SUD) policies and practices, so city practitioners can benefit from this "knowledge and know how" and contribute to a greater urban sustainability.
- ✓ Thematic workshops should be held each year, offering transferable examples of best practice and facilitating mutual learning between city practitioners and researchers.
- ✓ The surveys and direct encounters with city administrations through the workshops allowed us to improve the dissemination of knowledge on SUD.
- ✓ Responsibility for environmental issues is not the preserve of governmental bodies; it is a responsibility shared with every member of society. Everyday decisions by individuals can contribute either to environmental degradation (biodiversity loss, pollution, waste, etc) or to its protection and enhancement. Current levels of resource use, in particular energy and water, are at unsustainable levels, and the volume of waste being generated is continuing to escalate. Individual behaviors must change if a more sustainable style of living is to be attained.
- ✓ Municipalities (state agencies) hold a key role in planning and management of urban green areas.

Role of cities [62][63]/ Impact of cities:

- ✓ Although cities occupy just 2 per cent of the Earth's surface, their inhabitants use 75 per cent of the planet's natural resources. Rapid urbanization in India is bringing complex changes to ecology, economy and society (DeFries and Pandey 2010). During the last 50 years the population of India has grown two and a half times, but the urban population has grown nearly five times (Taubenböck et al. 2009).
- ✓ Cities draw on their surrounding ecosystems for goods and services, and their products and emissions can affect regional and even global ecosystems.
- ✓ Healthy ecosystems and biological diversity are vital for cities to function properly. Ecosystems provide three main kinds of services to the city: provisioning, regulating and enriching.
- ✓ While some of these services are easily measured, such as the provision of food and fresh water, others are harder to quantify, such as the contribution an ecosystem makes to quality of life in aesthetic or spiritual terms.
- ✓ Biodiversity in cities plays an essential role in ensuring the survival of life on earth.
- ✓ Clean water, foodstuffs, medicines and quality of life are just a few of the services which biodiversity offers to cities.

- ✓ Recognizing the importance of biodiversity and healthy ecosystems for their survival, cities today undertake many initiatives to utilize and conserve their surroundings efficiently. These actions can reach far beyond the boundaries of the city, affecting biodiversity on a global scale.
- ✓ A city's ecological footprint contributes significantly to biodiversity loss, both locally and at the global level. For example, ecosystem disturbance in just one city on a migratory flight path can affect certain species of birds well beyond the confines of that city.
- ✓ Studies of the 'ecological footprint' of cities – the area of land needed to provide a city with the resources it requires to function and to remove its wastes – show that cities affect a geographic area vastly greater than their own surface area. A city's ecological footprint contributes significantly to biodiversity loss, both locally and at the global level.
- ✓ They play a key role in global efforts to protect and manage vulnerable ecosystems and biodiversity. Just as the ecological footprint of a city can have a negative impact far beyond the boundaries of the city, certain urban actions can also have a far reaching positive impact.
- ✓ The arrangement of green areas in a city and their connection with the surrounding countryside are critical to sustainability.

Benefits of Urban Green Spaces / Need of Urban Green Spaces:

Urban development should proceed its journey proceed in partnership with its green space.

Urban green spaces are public and private open spaces in urban areas, primarily covered by vegetation, which are directly (e.g. active or passive recreation) or indirectly (e.g. positive influence on the urban environment) available for the users.

- ✓ Trees are an indicator of environmental quality because of their ability to moderate the effects of urbanization on air, water, and energy. Investing in ecosystem conservation makes economic sense. It strengthens the ability of cities to adapt to climate change and make the transition to a more healthy and sustainable future. Ecosystems provide natural solutions to many challenges cities face by offering numerous services such as clean air, water filtration, flood prevention, noise reduction, recreation, as well as climate change mitigation and adaptation. This can help save money and generate economic benefits for cities.
- ✓ Urban green spaces are highly patchy and dynamic, formed by biophysical and ecological drivers on the one hand, and social and economic drivers on the other. Given the accelerating rate of urbanisation worldwide, urban green spaces are becoming increasingly important to society as nodes of interactions between humans and nature.
- ✓ Urban green spaces generate a diverse set of ecosystem services of substantial significance for human well-being.
- ✓ Their dynamics are shaped by human activities in what we refer to as a coupled social ecological system. Many green spaces in cities that have become disconnected from the wider environment tend to lose biodiversity and erode. Hence, protecting green spaces in isolation will often fail to sustain the capacity of urban ecosystems to generate services.

Why do we need Urban Green spaces?

Cities occupy less than 3% of the global terrestrial surface, but account for 78% of carbon emissions, 60% of residential water use, and 76% of wood used for industrial purposes.

Urban green spaces generate a diverse set of ecosystem services [32]of substantial significance for human well-being (Bolund and Hunhammar 1999).

About half of Earth's human population today lives in cities, and the proportion is increasing (United Nations 2005). This generates a tremendous pressure to develop urban green areas for alternative land-uses. However, there are strong arguments for their preservation. Urban green areas generate many ecosystem services that contribute to human well-being (Daily 1997, Chiesura 2004) and provide habitat for many organisms (see, e.g., Saure 1996, Tommasi et al. 2004). These services could also potentially help mitigate the growing disconnection of urban residents from nature (Pyle 1978, 1993).

Urban green spaces are highly patchy and dynamic, formed by biophysical and ecological drivers on the one hand, and social and economic drivers on the other (Pickett et al. 2001).

Services range from providing shade and space for recreation, filtering of aerosols and absorbing CO₂ emissions, to pollination, pest regulation and seed dispersal processes that support biodiversity and the ability to maintain ecological function[29][[30] (Alberti 2005; Andersson et al. 2007).

Ecological Benefits [64]:

- Absorb pollutants; moderate the impact of human activities by, for example, absorbing pollutants and releasing oxygen.
- Contribute to the maintenance of a healthy urban environment by providing clean air, water and soil.
- Lower wall surface temperatures by 17°C, which led to a reduced air conditioner use by an average of 50%.
- Improve the urban climate and maintain the balance of the city's natural urban environment.
- Preserve the local natural and cultural heritage by providing habitats for a diversity of urban wildlife and conserve a diversity of urban resources.
- Urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality by reducing smog.

Despite the enormous benefits that urban green spaces provide there is a serious lack of information about the quantity and quality of urban green spaces. However, with the new integrated approaches to combine strategic planning for green spaces with innovative design and delivery and the active involvement of the community at all stages, urban green spaces can be part of an 'urban renaissance'.

Social Benefits

- Provide a refreshing contrast to the harsh shape, colour, and texture of buildings, and stimulate the senses with their simple colour, sound, smell, and motions.

- Offer a bigger diversity of land uses and opportunities for a wide range of activities, help to foster active lifestyles, and can be of real benefit to health.
- Well-managed and maintained green spaces contribute to social justice by creating opportunities for people [27] of all ages to interact.
- Emphasize the diversity of urban areas by reflecting the different communities they serve and meeting their varying needs.
- Enhance cultural life by providing venues for local festivals, civic celebrations and theatrical performances.
- Provide safe play space for children, contribute to children's physical, mental and social development and play an important role in the basic education of schoolchildren with regard to the environment and nature.
- Urban open green spaces play an important role in offering town-dwellers a more stress free environment, irrespective of sex, age or socio-economic background.
- The more time people spend outdoors in urban open green spaces, the less they are affected by stress and related complaints (Grahn and Stigsdotter 2003).
- Tree planting and management activities also cause strengthening of community bonds and keeping crime rates low (Kuo 2003).

Planning Perspective [61]

- From the planning perspective, a network of highquality green spaces linking residential areas with business, retail and leisure developments can help to improve the accessibility and attractiveness of local facilities and employment centers.
- Well-designed networks of green spaces help to encourage people to travel safely by foot or by bicycle for recreation or commuting.
- Furthermore, they provide a barrier to noise and can function as a visual screen.

Economic Benefits

- Research from around the world indicates that property owners value the urban forest by the premium they pay to live in neighbourhood urban green spaces and public parks. For instance, according to the most influential study on the subject, just one kilometer increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling.
- Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics. In densely populated areas this effect is even more pronounced. For example, view of green spaces and proximity to water bodies raised housing price in China, contributing notably at 7.1% and 13.2%, respectively.
- Urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality by reducing smog. The savings associated with these benefits vary by climate region and can be up to \$200 per tree. The cost of planting trees and maintaining them can vary from \$10 to \$500 per tree. Studies on benefit-cost ratios suggest residents may receive back \$1.85 and \$1.52 in annual benefits for every \$1 invested in management through aesthetic and other benefits[26][34].
- Further, a five-city study in USA suggests that although these cities spent \$13–65 annually per tree, benefits ranged from \$31 to \$89 per tree. For every dollar invested in management, benefits returned annually ranged from \$1.37 to \$3.09

Among the **reasons** of the shortage of open and green are [73]:

rapid urbanization associated with immigration, legal gaps, insufficient planning approaches, management problems, etc.

Urban open and green spaces have many physical, ecological and social functions.

- Provision of circulation between different urban land uses,
- Contribution to the physical comfort of city dwellers,
- Increasing aesthetical value of the environment,
- Provision of recreation opportunities,
- Formation of habitats for plant and animal species,
- Reduction of noise and air pollution and so on.

To be able to provide all these contributions, they need to be planned with a system approach in urban planning process (Ortacesme et al, 2000)

Social planners and sociologists have stressed the importance of public open spaces in daily life. Provision of urban open spaces is a central issue in urban planning and development. Green spaces have been regarded as least important aspects of land use in urban planning on one hand, but have received significant attention from the public (Melasutra, 2004). Provision of urban green spaces has to be planned and realised together with the planning of other urban functions like housing, transport, infrastructure, etc. The process of urban green planning must be seen as one part of an integrated overall city planning process where the implementation of the strategy becomes easier because it is accepted both by the municipality administration and the citizens.

- Because of its symbolic and cultural aspects and emphasize the difference between life-cycles (age, family structure, employment) and social groups (income, education, profession). For young people especially, public open spaces open up a much wider range of social and communicational experiences than is possible in private and institutionalized places (Grimm-Pretner, 2004).
- Open and green spaces like community gardens affect not only the lived experience of their participants but also have an undeniable effect on city's politics. The gardens are much more than the sum of their soil and vegetation. They are sites through which many social, economic, cultural and political concerns, especially of underprivileged urban residents, are channeled, articulated and brought forth to the public sphere (Eizenberg, 2004).

- The challenges cities will face in the near future are likely to place greater emphasis on the multiple roles of green spaces, especially regarding the expectations of citizens regarding the quality of life.
- The provision of an urban green structure consisting of green spaces, greenways, natural valleys, streams, planted boulevards, and other linear corridors is an important target in urban green space planning. Many authors have already stated the contributions of a green structure to urban environments and there are very good examples of it in various countries (Nyhuus, 1992; Ahern, 1995; Searns, 1995; Jensen et al., 2000).
- Most of the problems concerning urban green spaces in the country come from the lack of a comprehensive legal Framework, Organizational and financial weaknesses are other negative factors affecting the provision of green spaces. In Problems concerning good quality open and green spaces in the country are also related with the existence of professionals trained on this field.

Effects of Urban Pattern on Ecosystem Functioning:

Urban ecological systems are characterized by complex interactions among social, economic, institutional, and environmental variables. These interactions generate complex human-dominated landscapes, which significantly influence the functioning of local and global earth ecosystems and the services they provide to humans and other life on earth.

- Urban development fragments, isolates, and degrades natural habitats; simplifies and homogenizes species composition; disrupts hydrological systems; and modifies energy flow and nutrient cycling.
- Urban areas also appropriate a large share of earth's carrying capacity from other regions in terms of resource input and waste sinks.
- Change in ecological conditions[41] that result from human actions in urban areas ultimately affect human health and well-being.
- Also affects the spatial heterogeneity of the landscape (i.e., pattern of variation in land cover) and spread of disturbance (i.e., invasive species).

The future of earth ecosystems is increasingly dependent on the patterns of urban growth. Cities are growing rapidly worldwide. The world's urban population has multiplied more than tenfold during the past century, from 224 million in 1900 to 2.9 billion in 1999 (United Nations [UN] 1999). It has also risen from 14 to 50 percent of total world population. In 1900, only sixteen cities had a population exceeding 1 million; by 2000, more than four hundred did. By the year 2030, more than 60 percent (4.9 billion) of the estimated world population (8.1 billion) will live in cities:

Pune--Facts:

- Pune is among the top seven cities in India, and after Mumbai, it is the second largest city in the State of Maharashtra. Spread across about 5 sq. km in 1818, Pune has now grown into a metropolitan city covering more than 243.84 sq. km [87].
- Pune has always been regarded as a pro-active and forward-looking city as far as pro-environment related initiatives are concerned. Pune Municipal Corporation (PMC) has been documenting and publishing an annual Environmental Status Report (ESR) for the last 15 years [3]. The PMC has also implemented many eco-friendly and innovative projects for managing their resources effectively and responsibly. It is reflected from initiatives like implementation of energy-efficient street lights, installation of bio-methanation plants to treat bio-degradable municipal waste, promoting use of Compressed Natural Gas (CNG) fuel within the public transport system, and so on.
- Pune is one of the first cities in India to document a detailed carbon emission inventory at the municipal level and by estimating its cumulative and per capita carbon footprint, it has set a unique example.
- Pune ranks 5th in Carbon emissions [1] in India with 6 MT emissions per year as per 2007-08 study of Pune city's Carbon Inventory "fig. 6".

Land use:

- ✓ Comprises of five major habitats, the grasslands /scrub lands, the hills and forested lands, the agricultural lands, the river basins and the settlement areas.
- ✓ As seen from the table below from 1967 to 1998 there has been an increase of 24% in the area under settlement.1 this increase is directly proportional to the decrease in the agriculture and grassland/scrubland areas [39].

Table 2: L and use change at Pune Metropolitan Region Area under Each Category (%)

Land use Category	1967	1998
Settlements	17.33	41.00
Agriculture	61.26	42.11
Water sheets	02.25	02.25
Hills and Forest	07.64	07.64
Grassland and scrub	11.52	07.00
Total	100.00	100.00

✓ It can therefore be concluded that the habitats that are most impacted are the agricultural and grassland habitats. These habitats support a wide variety of faunal species such as insects, amphibians, butterflies that are impacted by the change of land use.

Table: 3: PunesCO2emissions

Sector	Pune tCo2 emission (2010-2011)
Residential	1,470,788.96
Transport	869,565.25
Commercial	440,870.94
Industrial	367,844.71

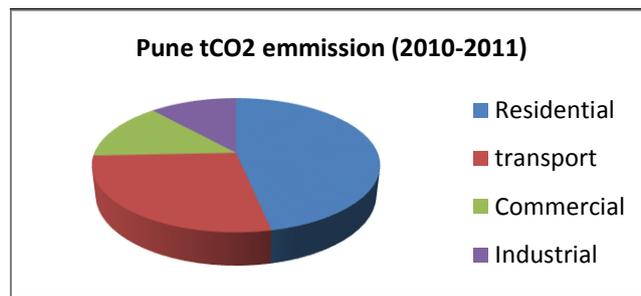


Figure 6: Pie-chart of CO2 emissions by various sectors

Source of data: Carbon Inventory of Pune City—Final report, project code 2010WR02 Prepared for Pune Municipal Corporation, teri-The Energy and Resources Institute.

Biodiversity Habitats in Pune city:

Pune city has various areas that are rich in biodiversity[22]. These areas because of their thick tree cover not only act as the lungs of the city but also provide a haven for a large number of floral and faunal species.

These areas can be categorized as a. Natural Resources and b. manmade resources.

Natural Resources

✓ **Hills:** The city is surrounded by hills such as NDA hills, Katraj, Sinhagad, Vetar tekdi, Bhamburda, Hanuman tekdi, Taljai and Parvati- Pachgaon hills.

These hill forests support nearly a fifth of the butterfly species and also exclusively host over a sixth of the bird species, seldom seen elsewhere in the city campus.

✓ **Water bodies:** The Mula and Mutha rivers provide habitat to a large number of reptiles, amphibians, birds and above all it supports the aquatic ecosystem in the city harbouring large number of fish population.

The hills and the water bodies of the city are the natural habitats to many of the faunal community. There has been habitat loss and habitat change due to which there has been a decline in the number of amphibians, reptiles, mammals, butterflies, birds and even insects. Amphibians are on the verge of decline and extinction because of habitat loss along the riverbed due to constructional activities. These areas therefore need to be conserved and impacts of any kind of human activities should be avoided.

The deterioration of fish population from Mula River is due to industrial effluent poured into it. The Mutha River is also much polluted because of the domestic waste and can support only few hardy varieties of fishes. Tree snakes are affected due to fuel wood collection activity on the hills. Many of the snakes are also killed by the people visiting these area, hence certain areas on the hills should be restricted so that quiet spots can be developed which do not have any human interference.

Due to the removal of grass and shrubs and destruction of natural grassland there has been a decline in the number of insects. This has also resulted in the number of insectivorous species of birds to decline over the years. Hence in the city few areas of grassland and shrubs should be developed and the weeds that grow in the rainy season should be allowed to grow until their breeding season is over.

Manmade Resources:

✓ **Parks:** Peshwe Park, Sarus Baug, Rajiv Gandhi Zoo, Sambhaji Park, Kamla Nehru Park have been able to sustain a certain amount of birds, insects, reptiles and mammals as these parks have matured trees. These landscaped areas host some rare species of flora, which attract various faunal species too.

✓ **Manmade Lakes:** The Katraj Lake and Pashan lake, which have been formed by damming the rivers, and the Lakaki Lake formed from an excavated quarry, provide a habitat for a large number of birds and aquatic species.

✓ **Institutions and Public areas:** Law College, Fergusson College, University of Pune, Shaniwar Wada, Cantonment areas and certain areas such as temples and churches have been supporting nesting, feeding and roosting sites to many of the birds, butterflies, insects, mammals and even reptiles.

✓ **Sensitive Microhabitats:** In and around built-up areas, habitat conservation is more challenging. If such micro habitats are conserved, many species can be conserved.

✓ **Within the city exist certain specific areas** that either have a rare or endangered tree located or form an important habitat area for certain faunal species.

✓ **Residential areas** have tree avenues along roadsides, these are matured trees and provide feeding, nesting and roosting sites for many birds, mammals, and insects.

✓ **Historical structures**, old wadas, temples, churches, and mosques tend to have matured trees and also some water bodies in their building complexes, these too provide a large number of insects, birds and mammals with nesting and roosting sites. These areas are considered as sensitive habitats and need to be conserved to sustain the biodiversity of the city.

List of sensitive habitats of faunal importance:

1. The important roosting sites for the birds are Peshwe Park, Sarus Baug, Vaikuntha Crematorium, Police Parade Ground, Agriculture College, Pune University campus, Fergusson College Campus and Bund Garden – Koregaon Park, Empress Garden, Empress Garden Belt, Fruit Research Station (Aundh – Khadki) .

2. All the hill slopes and hilltops especially the Bhamburda Vanvihar, Parvati Panchgaon and Mhatoba Shrine hill are rich in biodiversity and are a part of the faunal movement corridor.
3. The CME campus has a huge natural patch of babul plantation with marshy area. This area is favoured by a large number of insects, birds, reptiles and amphibians.
4. The Naik Island at the Mula and Mutha confluence has few trees, which support the largest number of bats. The campus of the District Magistrates bungalow near the Sangam Bridge is also a sensitive habitat for various avifauna species.
5. River courses downstream of Khadakwasla Dam and Vittalwadi area are rich in biodiversity.
6. The various lakes in and around the city, Khadakwasla Lake, Pashan lake, Katraj Lake, Lakaki Lake are habitats for various migratory and local bird species.
7. The Bird Sanctuary on the Mula Mutha River.
8. Roosting habitat for crows and egrets at K.T. Weir near Nand on the way to Pirangut from Baner.
9. Presence of rare fish species have been found in Bund Garden Yerawada area which are found to be declining in number because of introduction of exotic species which are of commercial importance. Thus this area needs to be protected and conserved.
10. Few genera of ants have been found restricted to Bhamburda and Pachgaon hills and thus should be conserved.

Roosting sites of Flying Foxes that are sensitive:

- a) The largest colony is near Sangam Bridge in the campus of the District Magistrates bungalow.
- b) Fruit Research Station (Aundh – Khadki)
- c) On Karve Road near Mrutyunjay Temple.
- d) At Khadakwala dam.

Recommendations for conservation at city levels:

As People, society and ecosystems are embedded in social-ecological systems, and societal development ultimately is dependent on the generation of ecosystem services (ES) to sustain it.

1. A builder should check whether any of the above mentioned sites are in the near proximity of his/her construction site and should ensure that these sites are not impacted by the activities on his/her building site.
2. PMC needs to take efforts to identify and conserve the sensitive microhabitats on public lands.
3. Plantation along public roadways and nallahs should be done with native vegetation with the intent to conserve the biodiversity of the city.
4. Certain damaged areas may be suitable for restoration. It is important to strategically conserve undeveloped lands in urbanizing areas to provide important connectivity between surrounding less developed landscapes.
5. There is a need to develop urban forest and urban farmlands as parts of cities. These will provide breathing areas for the city as well as maintain the biodiversity of the city.
6. The impacts of activities such as excavation for aggregate, soil for bricks, and digging of sand from dry river beds should be monitored and measures taken to mitigate them.
7. Urban administrations should respond positively to citizens' environmental concerns, by declaring protected areas, enacting legislation like Urban Tree Acts.
8. Develop alternative urban patterns that generate differential ecological effects.
9. The interactions between urban development patterns and ecosystem dynamics should be properly understood.
10. The need is to investigate how actors and actor groups, as well as their governance context, shape the generation of Ecosystem Services complex adaptive systems theory and resilience thinking for the interdisciplinary approach. Methods should include ecological inventories of birds and bees and studies of maps, field observations, questionnaires, deep interviews, literature analysis, ground management of biodiversity and ecosystem services in urban landscapes, with a focus on social ecological features behind management practice.
11. Analyze effects of past land use and of local current management practice on the generation of urban ecosystem services.
12. To explore how management practices, which are linked to ecosystem services, are retained and stored among a group people, and modified and transmitted through time.
13. Suggest an organizational structure of governance that enables management of ecosystem services in the larger urban landscape.
14. Need to identify and conserve the less urbanised and a biodiversity rich fragment for town-planners.
15. Creation and management of green spaces (including urban forests) should gain importance as Urban Green Spaces [89][90][91] provide town and city dwellers with significant environmental, recreational and material benefits and are also home to a vast diversity of flora and fauna and are recognized as important repositories of biodiversity.
16. Urban Green Spaces are critical for keeping our cities habitable and make them healthy and energy efficient. However, for Urban Green Spaces to contribute to the their fullest to the quality of our cities they have to be thoughtfully planned, diligently created and inclusively managed.
17. Urban forests provide shade, beauty, and habitat for urban wildlife [10][18]. Properly planted trees and other urban vegetation can reduce heating and cooling costs, intercept and store rainwater, improve air quality, and increase property values and local tax bases.
18. Properly cared for and well-managed urban forests can provide benefits that far exceed their management costs.
19. Urban forests can also bring communities of people together and form connections between humans and the urban flora and fauna.

20. Similar to Urban forest, it would be beneficial to have areas as urban farmlands within the city as green spaces. In new development zones, especially in the 23 additional villages recently included in the city limits, certain plots of lands that were originally farmlands should be preserved by providing incentives to the owner to maintain the farms and develop the area as an eco-tourism and agricultural tourism spot. This would help to create open breathing spaces in the city and enrich the biodiversity of the area.

On site biodiversity conservation:

Changes of landuse from non-residential to a residential use or even a low-density use to a high-density use impacts the ecology of the area. Biodiversity conservation is site specific and the needs for conservation on each site would be different.

Biodiversity conservation for eco-housing has to be done before the site is built upon and not as a remedial action after the natural system has been destroyed.

Thus, site-specific conservation should be considered in a two-prong method:

- a) Conservation of the existing natural habitats
- b) Remedial measures to restore and promote the natural biodiversity of the area.

a) Conservation of the existing natural habitats

1. The first step is to inventorise the naturally occurring flora and fauna on the site with the involvement of taxonomy experts and other experts. Conduct a detailed ecological survey of the site to identify floral species of trees, shrubs and even weeds. Identify the faunal species present and survey their habits in the area.

2. The natural drainage pattern on the site, its topography and slopes are also an important component of its biodiversity. These should be studied and taken into consideration during design stage. The first, second and third order streams should be maintained and not filled for leveling.

3. Based on the site inventory report identify pockets of microhabitats that need to be left undisturbed. The building layout should be designed with the aim of conserving these areas.

4. It is important to do a study of the movements of fauna in the area. A corridor study of the site and immediate surrounding area to understand the movements of fauna and the impact of construction activity on the path should be conducted, especially for those sites closer to hills forest patches.

5. The destruction of natural habitat could be because of absence of co-ordination between the various activities in the construction process. Developing a logical framework that provides a sequence of activities that ensures protection of the biodiversity of the area should be prepared. Measures should be identified to conserve the biodiversity at every stage of the design and construction activity.

6. Transplantation of trees – Not all trees require to be transplanted. Sometimes the cost of transplantation may be exorbitant, compared to the cost of planting a sapling of that species.

7. Based on the site inventory trees that need to be conserved at its present location, and trees that can be transplanted should be prioritized.

8. It should be noted that although the emphasis is on conserving and developing native vegetation trees. If existing non-native trees/exotic species exist on the site, these should not be cut to be replaced by native vegetation.

b) Remedial measures to restore and promote the natural biodiversity of the area.

Once the site has altered it is impossible to regain the original natural biodiversity of the area. Remedial actions are therefore focused towards creating a conducive urban niche for the flora and fauna that have been displaced from the site.

1. Plant only native species in the landscaped area[37]. Plant trees of species that existed naturally on the site before development.

2. Alternate paths should be identified and developed for the fauna movement wherever old paths have been altered.

3. Landscape for the building should be designed to integrate the conserved pockets of microhabitats.

4. Create urban niches to form environments conducive for fauna. Refer to Need for Creating Urban niches in Report on Native Fauna of Pune.

5. Landscape of the building should be designed to recreate the natural connections of the site with the surrounding area and not in isolation.

6. Provide for areas of natural growth in the landscape design that would allow weeds and seasonal plants to grow, as these would attract insects and consequently other fauna.

7. Buildings[47][48] should not only have landscaped areas but also provide for children playgrounds where games such as cricket can be played.

8. Sustainable use of plant and animal species by rural people can play an important role in conservation of particular ecosystems. In India, as elsewhere in many parts of the world, a number of communities traditionally prohibit harvests from patches of forests termed as 'sacred groves' and dedicated to deities or ancestral spirits.

Future Measures:

To promote biodiversity conservation for eco-housing there are various measure that need to be taken. These measures would create a resource base that can assist individual builders to access the impacts of the project on the biodiversity of the region.

1. Damage to biodiversity and impacts from construction are many a times mainly because of absence of knowledge and awareness. Builders, civil engineers and architects need to be educated on ways to conserve the biodiversity during development stages.

2. A training Programme for Architects, Landscape architects and civil engineers.

3. There exists a need to generate a larger awareness regarding the impacts of the construction activity on the environment. Public awareness needs to be created to educate the buyer of residential properties of the importance of eco-friendly construction.

4. Need to prepare a detailed study of movements of fauna in Pune city from surrounding areas.

5. Need to prepare a GIS based biodiversity map of Pune, which displays the various Biodiversity habitats and sensitive microhabitats of Pune.
6. Prepare Gardens of Pune GIS based database, with information about the various species of flora and fauna present in each garden.
7. PMC should develop a list of trees that are recommended for transplantation. This list should be flexible enough, to permit changes depending upon the site inventory for selecting trees for transplantation.
8. One exercise that requires to be undertaken would be for experts to visit four sites that are under construction and record the various activities undertaken that are changing/destroying the biodiversity of the area.
9. Approximately 30,000 acres of Defense Land (Cantonment Board) exists in and around Pune City, much of this land is barren. These lands if planted with trees and preserved would provide the City of Pune with the much-needed green cover.

Native Plant Species for Landscaping

- ✓ The native trees and plants of region evolve over long periods of time and adapt themselves to the local climatic conditions, water availability, pest resistance etc.
- ✓ Native plant species do not require watering other than during the initial years of establishment.
- ✓ They also play a major role in supporting a large number of birds, insects, animals etc. for food and habitat requirements.
- ✓ When native trees and plants get increasingly replaced by exotic, introduced species, the ecological balance will shift in unfavorable directions for the existence of other dependent species and can result in ecological damages that cannot be repaired.
- ✓ Exotic plants alter soil nutrient dynamics by differing from native species in biomass and productivity.

Fauna of Pune:

The fauna of Pune shows species diversity [57] and richness, “fig.7”, this is because of the fact that the city has diversified natural habitats such as forests, plantations, grassland, water bodies and wetlands and public garden established many decades ago. Over the years there has been a change in the native fauna of Pune because of urbanization and introduction of exotic species. Development of the city has resulted in the habitat loss and posed a threat on the faunal community. The current faunal diversity of urban Pune [50] is as given below.

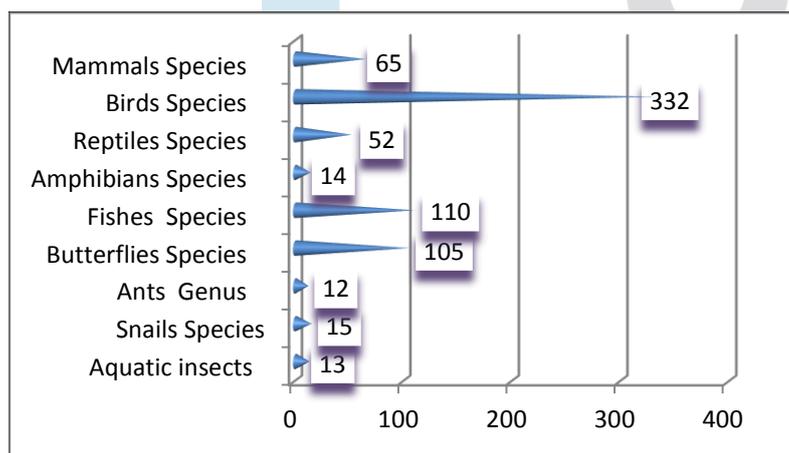


Figure 7: Fauna richness in Pune

Need for creating ‘urban niches’:

Reasons:

- Since man has been clearing land to build cities, towns, and farms, a great deal of native flora and fauna has been altered or destroyed.
- Many of the native species of fauna that once thrived in certain areas have had to find other places to live or they eventually disappeared [43].
- Not all species have been affected in a negative way. Species of wildlife that are highly adaptable, have benefited from the habitat alteration that have taken place in developed areas.
- Some species are not so adaptable to man's habitat alteration, and have suffered severe declines in their numbers.
- There are many species of wildlife, especially birds that can thrive in urban and suburban areas, but need a little help.

Need/ Importance:

In an era of global climate change and rapid urbanization, innovations on governance of urban systems are critically required as 50% people are now living in less than 3% of the earth's urbanized terrestrial surface. Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Both policy and science now emphasize the critical necessity of green areas thin urban social-ecological systems.

Many residential areas have a great deal of potential for restoring or enhancing wildlife habitat.

Due to undergoing urbanization trend worldwide, distance between city inhabitants and nature is increasing.

- Creating small pockets of urban niches[42] – environments conducive for fauna can help to conserve the biodiversity of the area.

- These would be cultivated habitats that provide certain adaptable fauna with conducive environments.
- Creating and maintaining such urban niches would not only help the native fauna of the areas but also provide children with an opportunity to see butterflies, birds and other fauna in their backyard, than having to travel outside the urban limits to see them.
- Urban forestry is the art, science and technology of managing trees and forest resources in and around urban community ecosystems for physiological, sociological, economic and aesthetic benefits trees provide for society.
- Urban parks, gardens and natural landscapes are better known for their non-market or intangible benefits than market or tangible benefits.
- As per the study, green spaces[53] of cities also provide ample opportunity for recreation. In a study on the response of persons put under stress, it was shown that when subjects of the experiment were exposed to natural environments the stress level decreased, whereas during exposure to built up urban environments the stress levels remained high or even increased.

Steps to be followed:

With the aim of conserving or recreating a pocket of natural habitat on the site, the first step has to be done before any site activity is initiated, a baseline ecological inventory of the site should be undertaken to identify the following:

- **Different environments:** It is often useful to record existing habitat diversity and associated flora and fauna. Record those areas that receive sunshine and shade during the day. Record the various environmental gradients such as temperature, moisture, wind etc. Also, the areas that are wet most of the time and those that are dry. This provides valuable information about which types of trees and shrubs would be best to plant in each area, and about the kinds of animals that they are likely to be able to attract.
- **Existing vegetation:** Record the trees, shrubs, flowers, grasses and other plants naturally occurring on the site
- **Existing wildlife:** Record fauna species seen and the time of observation. Record information such as whether certain areas are more populated than others and the type of plant animal association seen.
- **Develop a comprehensive plan** to conserve as much as feasible. Refer to measures given in biodiversity conservation for measures to be taken to conserve the biodiversity.
- **Planning for developing conducive environment:** The next step is to plan for developing such urban niche. Faunal species prefer areas undisturbed by humans, thus these pockets of natural habitats should be planned in secluded corners of the site. The spots should be developed such that it is not easily accessible and can grow on its own. Another important factor to be considered is that urban niches cannot be developed in isolation, they need to be connected in some nature to surrounding natural habitat areas. Thus during the site planning process, consideration should be given to demarcate areas near existing natural areas.

Plants:

- Plants provide food for insects, birds, mammals etc. the more diverse the vegetation, the more diverse the animal population will be.
- Select plants that bear fruit at different times of the year so that food is available throughout the season.
- Native plant species are more preferred over the exotic species. In addition to the wildlife benefits, native plants are well adapted to the local climate, soil and water conditions and hence they require very little maintenance[6].
- Planting native trees and shrubs will also help restore some of the habitat that was destroyed when the area was developed.
- Restoring the natural habitat, will attract some of the native species of wildlife that have had to look elsewhere for their food, water, and shelter.
- The trees and shrubs provide shelter for the animals for resting, escaping into when alarmed, protection from severe weather and nesting sites.
- Creating small thickets of 3-5 trees and 3-6 shrubs provide a better habitat.
- Different animals favor different plants. Bees prefer flowers that produce a peculiar fruity smell of the nectar. Butterflies like bright coloured flowers mostly red and yellow. They also prefer puddles because of the dissolved nutrients. The nutrients gained from the puddles also help in producing pheromone; the chemical, which is a sexual attractant, released by the males to attract the females. Moths feed at night and are therefore attracted to white or pale coloured flowers that have a strong, sweet smell. Birds also prefer red and other bright coloured flowers.
- The plants should provide them with food, cover and nesting area. The birds favor trees and shrubs with multistem and forming thick canopy. Fruit trees such as *Ficus racemosa* (Umbar), *Terminalia catapa* (Wild almond) etc attract birds as they provide food. Insects such as wasps, flies bees and even mammal such as bat prefer bell shaped flowers, while brush and tube shaped flowers are preferred by bees, moths, butterflies and birds for sucking nectar.
- Although many of the exotic, ornamental shrubs that are frequently used for landscaping will provide some benefit to native species of wildlife, they are not highly recommended.
- Many of the ornamentals do not produce food for wildlife, nor do they serve as host for the invertebrates that many birds feed on.
- Sometimes artificial source of food can also be provided in the garden to attract certain species.
- Artificial feeder such as grain tub attract many birds.

Measures to be taken for developing natural habitats:

Urban forests are fundamentally a human dominated ecosystem i.e. the role played by human beings in the urban forestry environment is critical.

- Do not use any pesticides and herbicides, as they will kill most of the butterflies and insects species.
- Protect the urban niche from human predators.

- Selection of native plant species to exotic ones as they are more preferred by the animals.
- Selecting plants that form a dense canopy, as it will satisfy the needs for nesting and cover.
- Have a variety of plant species in the garden so that a diverse faunal group will be attracted.
- Birdbaths should be no more than 3" deep, with gently sloping sides, and a rough surface to provide good footing. Change the water every few days to keep it fresh.
- Provide water sites; let plants around the water body to grow as they provide a good aquatic habitat.
- Provide nesting materials and sites; leave small twigs and grass growing nearby undisturbed as they are used as construction material of making nest. Add birdhouses hanging in the garden and even balcony as a landscape feature.
- Try and have a layering effect in the garden with taller trees towards the back and smaller shrubs in front of them this will create an 'edge' effect.
- Allow grass and weeds to grow in the garden as they provide the fauna with food, cover and nesting site.
- Leave rock piles and log piles undisturbed as they form smaller pockets of habitat attracting certain fauna.
- Maintain quiet spots or areas with less human interference in the garden.
- In lines with the old English gardens with natural landscaping, such urban niches should be planned that allow seasonal weeds to grow too. These weeds will attract the seasonal fauna of insects, bees and butterflies.
- Plant trees that flower and fruit at different times such that food is available for the fauna year round.
- Plant trees with brightly coloured flowers such as orange, magenta etc. so as to attract birds and butterflies.
- The educational level and environmental awareness of urban residents play a crucial role in determining species composition, management and overall demand for urban forests. Urban greenery development relies not only on investment and technology, but largely on the attitude and involvement of urban residents.

- ❖ **The need of the hour in India** is to educate people and policy makers about the utility of urban green spaces, because public knowledge of the connection between human well being and ecosystem services is limited.
- ❖ Urban greenery plays a significant role in developing countries towards development of tourism sector, thereby contributing in city's economy.
- ❖ Urban green spaces attract better prices for residential and commercial properties in developing and developed countries equally.
- ❖ Residents in the cities of developing countries have also shown willingness to pay for developing and maintaining urban forests. It is win-win situation for all concerned in creating and maintaining urban greenery in the Indian cities.
- ❖ Therefore, all concerned state governments should pay more attention in developing urban green spaces by involving City residents, NGOs and Resident welfare organizations.
- ❖ Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Foremost among these challenges is maintaining human wellbeing by provisioning for clean air and healthy living through conservation and restoration of urban green spaces and urban forests.
- ❖ Enhancing the management effectiveness of existing green spaces, financial innovations to generate resources for sustainable management of green spaces, and local monitoring and local enforcement for effective governance of urban forests.
- ❖ India's Emission Target--20-25% reduction in emissions per unit of GDP (excluding agriculture sector) from 2005 level by 2020.
- ❖ The Finance Bill proposes to levy a tax of 10% on income earned on transfer of carbon credits.. Such a tax will be levied on the gross income, without allowing for any deductions.
- ❖ Direct taxes code had recommended that income from sale of carbon credits be treated as business income.
- ❖ In Environment and Union Budget 2017, The Environment Ministry got an increase of nearly 19 % in its budgetary allocation for the next fiscal even as environmental bodies said that the Union Budget has failed to acknowledge the problem of pollution. The Union Budget proposed an allocation of Rs. 2675.42 crores for the Environment Ministry for 2017-18.
- ❖ Jaitley announced that around 7,000 railway stations will get power from solar panels in the medium term and 2017 will see the initiation of second phase of solar park development for creating additional generation capacity of 20,000 MW.
- ❖ Prime Minister Narendra Modi had launched the Global Solar Alliance at Paris Climate Conference in 2015, with around 30 countries. The plan was to create India as a manufacturing and Research hub for Solar technologies that can feed power to the developing world.
- ❖ Strengthening of existing conservation initiatives/traditional practice
- ❖ Additional economic gains to the people
- ❖ Conservation model through villagers' participation
- ❖ Legal provisions for conservation of biodiversity

Possible Solutions:

Climate change is one of the most pressing issues of this era.

- ✓ The international community should come together in order to implement short-term and long-term solutions to mitigate the effects of climate change.
- ✓ Through cooperation and innovation, it could be able to solve this important problem.
- ✓ One of the most comprehensive frameworks to combat climate change is still the Kyoto Protocol, despite ongoing difficulties with its ratification.

✓ The Protocol outlines three specific mechanisms that signatory nations must comply with in order to mitigate the effects of climate change:

• **Emissions Trading:**

This mechanism allows nations with excess carbon credits to sell those credits to nations who have not yet met their emissions targets. While the so-called carbon market is indeed a valuable and innovative approach toward reducing greenhouse gas emissions, there are still issues with the mechanism that must be solved.

• **Clean Development:**

This mechanism involves the creation of emissions -reduction projects in developing countries, which can earn certified emission reduction (CER) credits. These CER credits can then be used on the carbon market.

• **Joint Implementation:**

This mechanism allows countries to work together in order to create sustainable projects in return for emission reduction units. Together, these three mechanisms of the Kyoto Protocol have allowed most nations to cut carbon emissions by a total average of 5%. These three mechanisms represent three areas in which the United Nations and the international community can come together to develop possible solutions.

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