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DIRECTOR'S MESSAGE

Due to its unique geographical and geological conditions, India is vulnerable to various natural disasters. In India, the incidents of flood, drought and other natural disasters are on the rise and pose a tremendous challenge to the society in general and administration in particular. Each disaster heightens the sense of urgency to equip ourselves better in coping and managing them. In this context, the training of civil servant in Disaster Management assumes critical significance.

There is a need to move from the paradigm of responding to disasters to one of building in resilience against disasters in all aspects of decision making. A key challenge to administrators would be raise the level of awareness in the society regarding the cost of allowing disasters to affect it and to build resilience in infrastructure and in the community.

It gives me immense pleasure to note that Centre for Disaster Management, LBSNAA is bringing out the edited journal "Disaster-Response and Management" Volume 5, Issue 1 for the year 2017-18 under the project "Capacity Building on Disaster Management for IAS/Central Civil Services Officers" sponsored by National Disaster Management Authority (NDMA). This is the compilation of research articles providing insights in the recent trends in disaster management. I hope this volume will add to the knowledge base for disaster management in the country and will be useful for both the trainees and the administrators in the field.

Sanjeev Chopra, IAS
Director,
LBSNAA, Mussoorie.

PREFACE

The Centre for Disaster Management (CDM), Lal Bahadur Shastri National Academy of Administration (LBSNAA), Mussoorie is a training and research centre working under the aegis of LBSNAA, Mussoorie. The centre is involved in training IAS and other Group-A civil service officers at induction as well as at in-service level in various aspects of disaster management, besides undertaking, action research projects, documentation of best practices, development of case studies, etc.

The magnitude and frequency of disasters has increased drastically in terms of human, economic and environmental losses. Under the conventions on SDGs, Paris agreement, Sendai framework for Disaster Risk Reduction, there is a need to document the research carried by individuals in the field of Disaster management to achieve the committed goals of India as a signatory. Disaster Response and Management in recent times, received increased attention, both within the country and abroad. In a caring and civilized society, it is essential to deal effectively with the devastating impact of disasters.

In continuation to the successful publication of the fourth volume of the journal Disaster-Response and Management" from Centre for Disaster Management, it is our pleasure to publish Volume 5, Issue 1 of the journal "Disaster-Response and Management" for the year 2017-2018. The journal will provide an insight to administrators about the recent trends in response, planning and scientific interventions towards Disaster Risk Reduction. I would like to place on record the contribution made by faculty and staff of CDM who have contributed in various capacities for bringing out this Journal.

Raghuraj Rajendran, IAS
Deputy Director (Sr.) & Director
CDM, LBSNAA

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Drought Management Strategies in Rajasthan: Best Practices

Bijender Singh

Background

Rajasthan is the largest state in India. It covers 10% of the country's land area and 5.67% of population, but has only 1% of water resource. 12 out of the 33 districts, which comprise 60% of the area of the State, fall within the Thar Desert. Thar is the most populous desert in the world. Despite scanty rainfall with all its variation, timing, intensity and irregularity, 64% of its population lives in this area. The rural economy of Rajasthan is governed by agriculture and livestock. Agriculture is mostly rain dependent. Pattern of rainfall is very much skewed in the State. Behavior of monsoon commands over the livelihood of people. Except for the Chambal, the 13 other rivers of the state are non-perennial. Only 30% cultivable land is under irrigation, 68% out of it is irrigated from ground water. Ground water is highly exploited and the average ground water exploitation is 138%. 198 out of the 249 Blocks of the State are in dark zone. The per capita water availability in Rajasthan is 780 cum as against a minimum requirement of 1000 cum. Significant quantity of rain water is also lost through surface run off and evaporation. Hence, it has been experienced that there is no assured irrigation and people have to resort to dry farming techniques.

Rajasthan has approx 12% of the country's cattle population which contributes significantly to the State GDP by providing major share to the rural employment. However, this sector also faces a lot of stress owing to less availability of feed and fodder due to scanty/ no rains. This also leads to increased number of stray animals as the farmers are not able to conserve their live stocks due to scarcity conditions. This increase of stray animals also causes considerable destruction to the standing crops.

In the six decades since the country's independence, Rajasthan has shown steady progress in many economic and human development indicators. Diversification of crop varieties and a price policy which supported crops suitable for the agro-climatic conditions helped improving the agricultural performances. The poverty proportions reduced substantially, literacy rates improved, consumption inequalities declined, and regional disparities in economic growth decreased.

Rajasthan sought to broad base the economy by diversifying into non-agricultural sectors, especially the industrial and service sectors. Given Rajasthan's vast mineral resources and subsistence of majority of rural population on agriculture, the industrial development in Rajasthan focused on mineral-based and agro-based industries. The State industrial policies have progressively sought to exploit the mineral reserves of metallic and non-metallic minerals like zinc, lead, copper, limestone, marble, granite, gypsum, lignite, petroleum and natural gas resources. The small- scale industries have shown significant growth primarily on textile printing and dyeing, small mining leases, stone crushers, cement kilns and agro-processing units. Tourism has immense potential for employment generation in Rajasthan. Major focus has been given in promotion and development of tourism due to State's rich cultural heritage, forts and palaces, vast desert, wildlife sanctuaries, religious sanctity, traditional fairs and festivals, and folk performances. The State has also started exploring its considerable lignite, oil and gas reserves.

Drought history

Drought is almost an annual feature in Rajasthan. It's slow and quite steady. After the formation of Rajasthan State, except the years of 1959-60, 1973-74, 1975-76, 1976-77, 1990-91 & 1994-95, Rajasthan has experienced drought in some part or other with its impacts on a very large population for a much longer period.

The rainfall pattern in south and western Rajasthan districts has been varying from time to time but western Rajasthan in variably experiences scanty rainfall. Also 5 Districts: Banswara, in Udaipur Division and 4 others in Kota division have been receiving more than 550 MM of rainfall. Despite this, wide spread scarce conditions are prevalent in all these districts. Whereas Ganganagar & Hanumangarh receive less than 300 mm of annual rainfall but are not under the impact of drought because of alternate and additional sources of irrigation through the canal system. Inadequate rainfall at the critical time of crop growth and flowering stage has been experienced, in Rajasthan in 3 out of every 5 years. The rainy days are generally uneven across the State. The average total number of rainy days are just 34.3 in eastern Rajasthan and 16.8 in western Rajasthan.

Drought management strategies adopted

Government of Rajasthan has a very well defined objectively verifiable drought assessment mechanism. The declaration of scarcity and drought situation is announced by considering the agro-climatic indicators (rainfall and hydrological situation), detection of early warning signs, review and observations of the weather watch group, Girdawari (assessment of crop status) of the Kharif crops and District Governments detail report. Based on all these reports, the state government declares scarcity of areas having 50% damage to crop or more.

The State has a Disaster Management policy in place. It has a detailed Drought Management manual for ready reference for all the stakeholders and field functionaries. It has Emergency Operation Centers (EOCs) at the State as well as in all 33 districts. It updates the data regularly in the India Disaster Response Network (IDRN). It has established the State Disaster Management Authority (SDMA) and the District Disaster Management Authorities (DDMAs) and follows the guidelines of the National Disaster Management Authority (NDMA).

Government of Rajasthan adopts a multi–sector multi-dimensional and multi-stakeholders approach in managing the drought in the State. It focuses on employment generation (both short term and long term) for ensuring sustainable livelihood opportunities (with special care for vulnerable groups) by converging various development schemes, cattle conservation through fodder depots, fodder transport subsidy, cattle camps, medical aid to cattle population, etc. It also focuses on provision of drinking water by hiring private wells, repairing and installation of hand pumps, reviving traditional water sources, transporting water through rails and tankers. It also leads to draw the crop contingency plans by adopting soil moisture conservation practices, making field crops free from weeds, adopting recommended plant protection measures, providing agriculture inputs like short duration seeds, extending training to farmers, supporting through minimum support prices to arrest distress sale. It suspends the recovery of land revenue and irrigation case in the drought notified areas. It converts the short term cooperative agricultural loan to medium term for the benefit of the farmers. It adopts the mitigation strategy by developing community based drought preparedness and mitigation plans by integrating the concerns of women and converging the same with various other existing schemes. A lot of emphasis is given to effective water management which include rainwater harvesting, watershed management for recharge of ground water, appropriate cropping pattern, early completion of existing projects, agro-climatic regional plans, maintenance of irrigation system, sprinkle and drip irrigation, conjunctive use of surface and ground water, reduction in evaporation, renovation of tanks, creating water consciousness in public, etc.

Government of Rajasthan also gives very high priority in the monitoring of drought management activities. High level task forces are constituted, ministers and secretaries are nominated as in-charge for relief supervisions, detailed instructions are given to the district collectors, government officials are made in-charge of activity at the village level. Public representatives at all level (even at the community level) are involved, social audits and web applications are being done for better transparency, on-line placement of budget demand and timely allotments are made for enhancing effectiveness of the programme.

Outcome of earlier efforts: MJSA

Based on the agro climatic conditions, different schemes have been initiated by state Government through different departments for improvement in water availability and land productivity. However, all these departments were independently implementing these schemes and there was a lack of convergence of efforts and resources which was not giving the desired results. Therefore, it was felt that all these efforts should be synchronized to produce better and effective results.

Hence, it was decided to launch "Mukhya Mantri Jal Swavlamban Abhiyaan" (Chief Minister Water Self-reliance mission) (MJSA) in the State with a view to converge various schemes and to bring them on a single platform to conserve the four waters i.e. Rainfall, Runoff, Ground water and Soil moisture up to maximum potential.

MJSA is a mission started by State Govt. on direction of Hon'ble CM to make villages self-reliant in terms of water needs, a vision to find permanent solution of drinking water scarcity in Rajasthan with help of people participation.

Objectives of "Mukhya Mantri Jal Swavlamban Abhiyaan (MJSA)"

1. to ensure effective implementation of water conservation and water harvesting related activities in rural areas from available financial resources (Centre, State, Corporate, Trusts and People's participation) through effective convergence,
2. to undertake implementation of works through people's participation and to generate awareness among villagers and beneficiaries about judicious utilization of water resources,
3. to prepare water budget after estimation of water availability from various available resources and requirement of water for drinking, irrigation, livestock and commercial purposes,
4. to identify works and proposals in consultation with local people so as to harness their traditional knowledge/practices and seek due approval of action plan in Gram Sabha (village council),
5. to harvest available runoff (rain water, ground water and in situ soil moisture) in rural areas through treatment of catchments, proper utilization of available water harvesting structures, renovation of the non-functional traditional water harvesting structures and creation of new water harvesting structures,
6. to develop land, water, forest and fauna, keeping watershed/cluster/index as a work unit for natural resource management,
7. to find permanent solution of drinking water scarcity by making the Village self-reliant in terms of water, and
8. to increase the Irrigated area through water harvesting and conservation.

A. Scope of campaign:

Water harvesting and conservation works are being implemented from the funds available with State Government Departments and the shortfall is being mobilized from Non-Government Organizations, from Corporate Social Responsibility commitments (CSR), Peoples Participation, Non Residents Villagers Clubs (NRV Club) etc. to safeguard the villages from frequent droughts by doing watershed wise water budgeting and attempt to find a permanent solution to the chronic drinking water shortage problem.

In the first phase, 3529, villages (islands of excellence) on the basis of defined priority criteria had been identified and the phase-II covered 4213 villages. In 3rd year Phase-III is covering 4240 more vulnerable villages. In all, 21000 villages of the State are likely to be benefitted under the mission. The state government shall strive to find a permanent solution to the water scarcity problem by making them self-reliant in terms of water.

B. Duration of work:

The duration of "Mukhya Mantri Jal Swavlamban Abhiyaan (MJSA)" is of 4 years commencing from Financial Year 2015-16. The aim is to complete the works of Action Plan of every year by 30th June of next year i.e. before the monsoon (rainy season), so that benefits of these watershed works start flowing to the community from the same year. Only in special conditions works are allowed to be implemented in next year after the approval of District Committee. Generally, works are being executed as per Gramin Karya Nirdeshika (GKN) or as determined by the District Committee.

C. Mukhya Mantri Jal Swavlamban Abhiyan (Rajasthan water self-reliant mission):

In order to achieve the objectives of "Mukhya Mantri Jal Swavlamban Abhiyaan (MJSA)", a high level Mission has been setup under the chairmanship of Hon'ble Chief Minister at the State Level. Further, to ensure smooth implementation of the activities, a Directional Committee under the chairmanship of Chairperson, Rajasthan River Basin and Water Resources Planning Authority and a Task force under the chairmanship of Chief Secretary have also been constituted. At district level, a supervisory committee under the chairmanship of Hon'ble Minister –in charge of the respective district and an executive committee under the chairmanship of District Collector have been constituted. Similarly, at Block Level, a review committee under the Chairmanship of Sub Divisional Magistrate has also been set up.

D. Sanction of district action plans:

The District Mission Plan is issued by the District Collector after approval from the District Level Committee.

E. Preparation of priority list of villages: criteria

- Villages where IWMP/ other watershed Project e.g. "Four Water Concept" etc. are sanctioned
- Villages where drinking water is not potable or fluoride quantity is in excess
- Villages where drinking water was supplied by tankers during last five years
- Villages declared as famine/ drought effected during last five years
- Villages where 70 % of agriculture land is rainfed
- Adarsh villages under Chief Minister, MP, MLA & other schemes
- Villages falling under sanctioned cluster of forest department scheme
- Villages where villagers are willing to participate/contribute in this scheme

Keeping in view above criteria, the priority of villages in Gram Sabha is fixed as per marks mentioned in the table below:

Sl. No.	Details	Total marks	Marks obtained	Marks obtained	Marks obtained
1	Villages sanctioned under IWMP (09-10)	20	Sanctioned Area more than 50% of the Total Area of the Village under IWMP (20 Marks)	Up to 25 to 50 % (15 Marks)	Up to 25 % (10 Marks)
	Villages sanctioned under IWMP (10-11 & 11-12)	15	Area more than 50% (15 Marks)	Up to 25 to 50% (10 Marks)	Up to 25% (5 Marks)
2	Villages sanctioned under Four Water Concept	15	Area more than 50% (15 Marks)	Up to 25 to 50% (10 Marks)	Up to 25% (5 Marks)
3	Villages under tanker water supply for drinking water	15	Continuous for 5 years (15 Marks)	Last 3 years (10 Marks)	From last year (5 Marks)
4	Famine affected villages	10	3Years of Famine out of last 5years, specially having Famine last year (10 Marks)	3 out of last 5 years (5 Marks)	Famine in last year (3 Marks)

Sl. No.	Details	Total marks	Marks obtained	Marks obtained	Marks obtained
5	Fluoride affected villages	5	Affected villages (5 Marks)	-	-
6	Rainfed agriculture land	5	More than 70% (5 Marks)	50 to 70% (3 Marks)	-
7	Villages Sanctioned by forest department	10	Cluster on-going work from 3 years (10 Marks)	Cluster in progress current year (5 Marks)	Proposed villages (3 Marks)
8	SANSAD ADARSH Village	10	Sanctioned ADARSH Village (10 Marks)	-	-
9	Villagers willing to contribute for the works of village development plan	10	For each 1.00 lac (1 mark)		

Note: *All the villages of the clusters of Micro watershed (Approx 5000 ha. area) in which first priority village exist being taken on priority & after that the whole Micro watershed /cluster having village of second priority. In similar manner, clusters are selected till approximate 10 villages are covered. It is ensured that at least one Micro watershed / cluster get sanctioned in each block.*

F. Fund management:

The estimate of every work is prepared after the village action plan is approved by district level committee. Then an assessment is made as to how many works can be completed from funds available under different ongoing schemes and how much funds need to be raised for other sources. Details of activities and probable schemes from which funds are being accessed as under:

Sl. No.	Name of activity	Availability of fund	Implementing agency
1	Watershed development works such as water harvesting structures, farm ponds, contour / field bunds, CCT, deep CCT, gabion, sunken gully pit, MPT, Tanka, Johad etc.	PMKSY, IWMP, Mahatma Gandhi NREGA, National horticulture mission, Rashtriya Krishi Vikas Yojana, state fund etc.	Watershed development department, Panchayati Raj Intuitions, Forest department, Agriculture department

Sl. No.	Name of activity	Availability of fund	Implementing agency
2	River Basin Micro Irrigation tank, Check dam & Construction of New Structures for Watershed development works based on Four-Water Concept	Schemes of Irrigation, Ground-water, Watershed & Forest Department	Water Resource department, Panchayati Raj Institutions, Watershed development department, Forest Department
3	Deepening of Nalas/ widening of banks and construction of series of cement check dams and Other Nala bundh	PMKSY, The State Fund, MP/MLA development fund, Zilla parishad schemes, voluntary organizations, CSR and institutional support	Water Resource department , Watershed development department, Panchayati Raj Institutions
4	Renovation/Rejuvenation of old water harvesting structures	PMKSY, IWMP, Mahatma Gandhi NREGA, schemes of water resource department, State fund, MP/MLA development fund, schemes of Zilla parishad, Voluntary organizations , CSR and institutional supports	Water resource department, Watershed department, Panchayati Raj Institutions
5	Preparation of New Micro Irrigation Schemes & Repair, Renovation& Reinforcement of minor irrigation works	PMKSY, schemes of water resource department, the state fund, MP/MLA development fund schemes of Zilla parishad, voluntary organizations, CSR and institutional supports	Water Resource department, Watershed department, Panchayati Raj Institutions

Sl. No.	Name of activity	Availability of fund	Implementing agency
6	Desilting/deepening of water conservation structures like village ponds, Nadis, water tanks, Water storage structures, Percolation tanks etc.	PMKSY, the state fund, MP/MLA development fund, schemes of Zilla parishad, voluntary organizations, CSR and institutional supports	Water Resource department, Watershed Department, Panchayati Raj Institutions
7	Works to take maximum use of irrigation potential of created large and medium irrigation projects in region	PMKSY, State fund, MP/MLA development fund, Schemes of Zilla parishad, Voluntary organizations, CSR and institutional supports	Water Resource department, Panchayati Raj Institutions
8	Linkages of water sources/structures to Nalas	PMKSY, Mahatma Gandhi NREGA, Public Participation, Voluntary Organizations	Water Resource department, Gram Panchayat, Watershed department
9	Construction of Artificial structures for Ground-water recharging	PMKSY, Mahatma Gandhi NREGA, Water Resource department schemes, Ground water & Watershed, Schemes of central water resource department	Ground water, Local bodies, Water Resource department, Panchayati Raj Institutions
10	Reinforcement of drinking water sources	PMKSY, Schemes of Zilla parishad, PHED, Own income of gram panchayat and grants received	PHED, Panchayati Raj Institutions
11	Development works in command area of Large, medium & Minor Irrigation projects	Schemes of Command area development department	Water Resource department, Panchayati Raj Institutions, Command Area Development Department

Sl. No.	Name of activity	Availability of fund	Implementing agency
12	Pasture development and plantation	PMKSY, Schemes operated by Forest Department	Forest department
13	Water drainage & Sanitation works in Rural Area	Panchayati Raj Institutions schemes operated by Water Resource Department	Panchayati Raj Institutions, Water Resource Department

G. Strategy:

1. Initially, for the first phase in year 2015, approximately 3,000 villages were planned. A total of 3,529 villages were taken up with completion of 95,793 works. Plantation work of a total of 28 lakh trees was completed.
2. Village action plan for these selected villages was prepared keeping in view the model plans for selected micro watersheds / clusters and accordingly works were executed.
3. Funds available in Central & State schemes were earmarked as per prevailing Guidelines.

On the basis of encouraging results of MJSA Phase-I and involvement of people of State at large in its activities, Government decided to launch this mission in urban area too in year 2016.

H. Project implementing agency:

Agriculture department, Rural development & Panchayati Raj department, Forest department, Water Resource department, Mahatma Gandhi NREGA scheme, Watershed development & Soil Conservation department, P.H.E.D., National Horticulture Mission, NGO's, Cooperatives, Water & Sanitation Committees, Gram Vikas Mandal (registered organizations), Ground Water Department & Department /Institutions /Organizations/Experts authorized by the District Collector.

I. Works being undertaken in the campaign:

1. Watershed (catchment) area treatment: Deep Continuous Contour Trenches (deep CCT), Continuous Contour Trenches (CCT), Staggered Trenches, Farm Ponds, Mini Percolation Tank (MPT), Sunken Gully Pit (SGPT), Earthen bund with stone pitching, Khadin, Johar, Tanka construction, Water harvesting structures, Gabion Structures, Compartment/Contour/Field Bund etc.
2. Drainage line treatment: Small Anicuts in series, Earthen check dams and Water storage structures, Mini Percolation Tank (MPT), Sunken Gully Pit (SGPT), Minor Irrigation tank etc.

3. Repair of minor irrigation work, renovation, reinforcement work, works to take maximum use of large and medium irrigation projects constructed in the region and works for linkage of water sources/ structures.
4. Increasing the capacity of water storage structures: by Repair and Revitalization/ Restoration, Rejuvenation, Deepening of Nallas by desilting and widening as per requirement, bank stabilizations and peripheral bund.
5. Reinforcement of water sources, Recharging of wells & Tube wells.
6. Pasture development & plantation.
7. To Increase Agricultural Productivity by promoting advanced methods of cropping & horticulture (Drip, Solar pump etc.) & to promote commercial farming by crop rotation to take maximum output of Rabi, Kharif & Ziad crops.

J. Special powers to district collector for implementation of mission:

1. To formulate action plan for "Mukhya Mantri Jal Swavlamban Abhiyan" in the district and effect convergence of different schemes for implementation, monitoring & evaluation.
2. To mobilise the shortfall in resources and generate support from NGO's, CSR, NRV & other Bhamashah's (donors).
3. Competent Authority for Sanctions (Technical, Administrative and Financial sanction) of works.

K. Steps for preparation of district plan of "Mukhya Mantri Jal Swavlamban Abhiyan":

1. Village Work Plan is approved by the Gram Sabha & submitted to Block level committee by the Departmental representatives.
2. Block level Plan duly scrutinized by the Block Committee under the chairmanship of Sub Divisional Officer/Block Development Officer forwards the Plan to District level.
3. After approval of District Plan & issuance of Administrative sanction, concerned department issues Technical sanction.
4. Financial Sanction at district level is issued within 15 days and directions are issued to executing agency for commencement of work immediately.
5. Apart from executive agency, District Collector appoints responsible officers at Gram Panchayat level/Cluster level for supervision and monitoring of execution works within time. These officers are responsible for uploading progress reports regularly on the online portal.

6. A meeting at least once in a month at District Level for monitoring of progress under the chairmanship of Collector is organised. All Sub Divisional Officers and concerned Departmental officers have to participate in this meeting.
7. Review of works and timely payment of executed works is ensured along with adjustment of funds and financial progress.

Department wise & Gram Panchayat wise progress, problems & solutions are submitted to District level monitoring & evaluation committee under Chairmanship of Minister in-charge of District.

L. Participation of CSR/NGO/TRUST:

The Mission envisages a very significant contribution from the civil society to fulfill the likely gap in available financial resources particularly from the Corporate Sector, Non-Governmental Organizations, Religious Trusts, and Individual Groups. These contributions can be in the following forms:

1. Corporate Sector, Non- Governmental Organizations & Religious Trusts have full freedom to adopt any village as a whole or works of a particular village or execute works themselves under technical guidance of department.
2. In addition to above, Corporate Sector can contribute resources to fund the gaps in the proposed village plan.

M. Preparation of water budget

1. Estimation of availability of Run-off Water depending upon the type of soil, slope of land and utilization of land surface.
2. Assessment of demand of village (for Human, Livestock, Industries & agriculture use).
3. Assessment of Capacity of existing Water Harvesting Structures in village and proposed Water Harvesting Structures.

After the above exercise, estimation of surplus/shortfall of water of villages of the catchment/ watershed in respect of run- off water coming from other catchment or going out of village to other catchment is to be done and detailed water flow network is to be prepared at village, Block and District level.

N. Public awareness for mission

- State level orientation workshop: Orientation of Ministers, Chief Secretary, Principal Secretary, Divisional Commissioner, Head of the departments, MLA's, District Collector's & Superintendent of Police, Project Manager's (Watershed) etc. under the Chairmanship of Hon'ble Chief minister.
- Divisional level orientation workshop

- District level orientation workshop
- Block level orientation workshop
- Orientation of CSR, Industrialists, NRI, NRV, NGO's etc.
- Orientation of owners of JCB, Pockland, Tractor & other Earth Moving Machines.
- Orientation of Village level/Gram Panchayat level workshop.
- Nukkad Natak/Puppet Show
- JAL Pad – Yatra
- Religious Saints & Gurus to convey the messages related to water conservation
- Advertisements through different media like Doordarshan & newspaper for publicity
- To encourage non-resident people of state & NRV who works in other District/State for funding in the Mission by using techniques like Twitter, Facebook, Whatsapp

A Public awareness campaign in Gram Sabha is to be conducted by Gram Panchayat & Watershed department. Funding for this campaign is to be met out from available funds under IEC in Schemes of Swatch Bharat Abhiyan (SBA), IWMP, Agriculture, Water Resources and Panchayati Raj department. In this Campaign, villagers are to be sensitized about the objectives of the mission.

O. Evaluation and progress review

Monitoring is based on GIS technique on real time basis in "Mukhya Mantri Jal Swavlamban Abhiyan". For this, GIS Portal of Information & technology is used. Latitude & longitude of all water conservation works executed are taken in the smart mobile phone and the same are uploaded on Bhuvan portal (Srishti-Drishti) on real time basis.

Along with all other information, Village Work Plan, Base Line survey, Cost of Work, Present Condition, Working Agency & Department, Progress Report are being uploaded on website. This work is being done with the help of Information & technology department. Separate website has been created for "Mukhya Mantri Jal Swavlamban Abhiyan" where monitoring of works is being done online.

Nodal department prepares the progress report by getting the information from block/district level through MIS System and compilation is done at district level.

P. Impact indicators

- Increase in irrigated area under agriculture (Agriculture & Revenue Department).
- Changes in the cropping pattern (Agriculture & Revenue Department).
- Reduction in the water supply from external water sources to the village (Public Health & Engineering Department).
- Reduction in occurrence of Famine (Revenue Department).
- Increase in number of Agro forestry, Horticulture plants (Agriculture & Horticulture Department).
- Timely Payment of Agriculture Loan/Kisan card (Cooperative Department).
- Improvement in quality of under-ground water (Public Health & Engineering Department).
- Reduction in seasonal migration of Cattle (Animal Husbandry department/ Sheep & wool).

Q. Expected outcome

- Availability of surface flow in the main stream of watershed & presence of surface flow up to April-May in small streams.
- At least 40 % Rain-fed area would be irrigated.
- Reduction in suspended sediments in flowing water of main streams.
- Drinking water needs are fulfilled by the groundwater & water would be available for irrigation of perennial plants in summer also.
- Emergence of self-water reliant village (free from tanker supply/ free from Famine & permanent solution of water)
- Increase in ground water level and reduction in depletion of ground water level
- Increase in irrigated areas
- Change in the cropping pattern
- Stability in availability of drinking water
- "Mukhya Mantri Jal Swavlamban Abhiyan" is a time bound mission and a time-line has been set for timely execution of the proposed works.

R. Works taken up and progress so far

The details of MJSA Rural, Phase I to III are as under:

Phase	Year	Works
Phase-I	2015-16	No of villages approached: 3529 No of works completed: 95793 Plantation: 28 lakh trees
Phase-II	2016-17	No of villages approached: 4213 No of works completed: 129484 Plantation: 60 lakh trees
Phase-III	2017-18	No of villages planned: 4240 No of works planned: 1.50 lakh approx. Phase III campaign inaugurated on 9th, 15th Dec. 2017 & 20th Jan. 2018

Mukhya Mantri Jal Swavlamban Abhiyaan (MJSA)- Urban

Works taken in MJSA (Urban) Phase-I (Nov. 2016) **

Works taken up in Phase-I (66 towns, 2 from each district).

- Repair and restoration of Bawaris and step wells.
- Productive use of rain water by enhancing ground water recharge through Roof Top Rain Water Harvesting Structures (RTWHS) over all Government buildings with roof top area 300 sq. m & more.
- Afforestation in the city area as an eco-friendly measure for improved and green landscape of the town.

Works taken in MJSA (Urban) Phase-II (Jan. 2018)

Works in Phase-II taken in all the 191 towns of the State

- In addition to works taken in MJSA (Urban) Phase-I, following one more activity was added in Phase-II
- Identification of areas prone to storm water stagnation in municipal area and action plan for remedial measures in the cities.

Progress of works of both phases of MJSA (Urban)

Work name	Phase-I	Phase-II	Total
RTWHS	1452	1482	2934
Bawaris	259	214	473
Afforestation	71	70	141
Grand Total	**1782**	**1766**	**3548**
Cost of Work	95 Cr.	120 Cr.	215 Cr.

Total plantation done under MJSA(U) Phase I

- By forest department - 304599 (O & M by forest dept.)
- By ULBs - 217143 (O & M by ULBs)

  Total - 521742 Plants

Total plantation done under MJSA(U) Phase I:

2.5 lacs {1.5 Lacs (Forest Dept.) + 1.0 Lacs (ULB)}

Preparation and proposals of water logged areas:

- Prefeasibility reports of 60 towns (having 196 spots) having waterlogged area identified- costing approx. 413.62 Cr.

Funds from various departments and MPLAD / MLALAD and public contribution were arranged for MJSA Phase-I & II. Approx. 1710 Crores were available for Phase-I with major contributions from MGNREGS (411 Cr.), MJSA Untied Fund (540 Cr.), Crowd Funding (26 Cr.) and Watershed Department (565 Cr.). For Phase-II a total of approx. 1614 Crores were arranged with major stakeholders as MJSA Untied Fund (668 Cr.), IWMP (185 Cr.), MGNREGS (224 Cr.), PMKSY (102 Cr.), Crowd Funding (51 Cr.) and MLALAD contributed more than 32 Crores.

S. Impact assessment:

The targeted results of the village work plan under the mission is being reviewed keeping in view the following indicators:

Main indicators for evaluation (and responsible departments) and results from MJSA Phase-I are as under:

- Supply - Side Indicators
  1. Additional Sustainable Storage Creation - 4,516 MCFT
  2. Additional Interception of Precipitation - 11,170 MCFT.
  3. Positive impact on Groundwater
     - Average rise in non-Desert Districts - 4.66 FT
     - Nowhere negative trend observed
- Demand- Side Indicators
  1. Reduction in Tanker Trips - 56.13 %.
  2. Defunct Hand Pumps Revival - 63.64 %
  3. Lean Season Crop Area Enhancement - 46,879 ha
  4. Lean Season Orchard Area Enhancement - 323 ha
  5. Enhancement in Tube & Open Wells Functioning - 22%.
  6. Increase in Green Cover- 3678 ha

OSD, Disaster Management & Relief Deptt., Govt. of Rajasthan

Global Warming and the Sixth Mass Extinction of Species The Decades Ahead

Brig. Kuldip Singh

Global warming and climate change, and its implications for Earth and humans, is a much talked about issue. However, another associated threat, that had started to manifest after the Industrial Age began, is now raising concern, i.e. the accelerated decline in populations of a huge number of plant and animal species, and the extinction of large numbers of such species on account of human overpopulation, industrialization and overconsumption, especially by the rich (1). Many scientists are opining that Planet Earth is now in the midst of the 'Sixth Mass Extinction' of non-human species (2). Paleontologists define 'mass extinction' as the loss of at least 75 per cent of Earth's species in a geologic short interval. The loss of such biodiversity is therefore a critical environmental problem, which will also have consequences for humans.

Previous five mass extinctions

Extinction is inevitable in evolution and is a natural, on-going phenomenon. Paleontologists estimate that most species "last" 1-10 million years, with about 01 to 10 species going extinct each year, i.e. at a natural background rate of 0.00001% to 0.0001% per year (3). Nevertheless, the past half-billion years have witnessed five mass extinctions. Often referred to as the 'Big 5' (4), these are as follows:

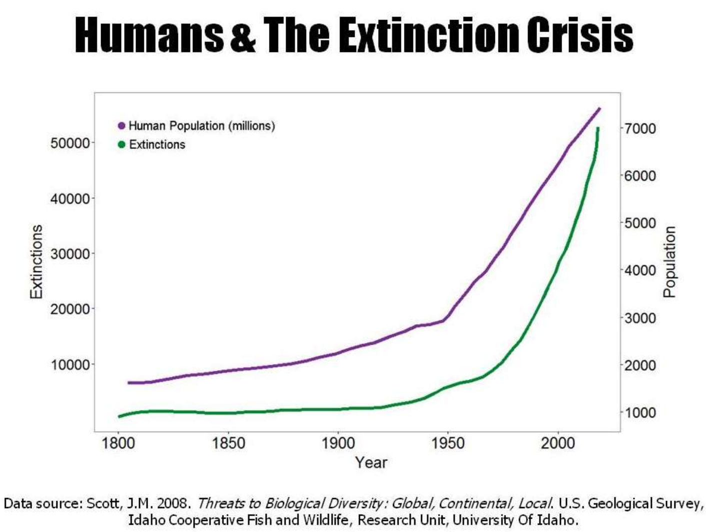
1. 23 May 2017 Report by the USA's National Academy of Sciences entitled "Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and decline".
2. The Earth has already witnessed five mass extinction events. The last, during the Cretaceous–Paleogene period, ended the dinosaurs.
3. http://labs.russell.wisc.edu/peery/files/2011/12/7.-Extinction-a-Natural-and-Human-caused-Process.pdf
4. http://www.worldatlas.com/articles/the-timeline-of-the-mass-extinction-events-on-earth.html
5. International Union for the Conservation of Nature (2009): Worldwide, 12 percent of mammals, 12 percent of birds, 31 percent of reptiles, 30 percent of amphibians, and 37 percent of fish are threatened with extinction.

Event	Approximate Period	What Happened
Cretaceous–Paleogene extinction event	65 million years ago	Perhaps the most well-known and recent of the 'Big 5'. A combination of volcanic activity, asteroid impact, and climate change effectively ended 76% of life on Earth. It however paved the way for the evolution of mammals on land and sharks in the sea.
Triassic–Jurassic extinction event	199 million to 214 million years ago	This phased loss of species is attributed to asteroid impact, climate change, and flood basalt eruptions. The end of this era laid the foundation for the evolution of dinosaurs, which later existed for around 135 million years.
Permian–Triassic extinction event	251 million years ago	This mass extinction, in which around 96% of the species were lost, is considered the worst in all history. "The Great Dying" was caused by an enormous volcanic eruption that filled the air with carbon dioxide, which fed different bacteria that began emitting large amounts of methane. The Earth warmed, and the oceans became acidic. Life as we know today has descended from the 04% of the surviving species.
Late Devonian extinction	364 million years ago	Although it is not clear whether this extinction happened in one event or was spread over thousands of years, it led to a loss of about 75% of species. It is thought that giant land plants with deep roots released nutrients into the oceans. The nutrient rich waters spawned massive algal blooms which depleted the seas of oxygen; this killed animal life. Volcanic ash is also presumed to have cooled the Earth's surface, killing off many species. Importantly, if the late Devonian extinction had not occurred, humans might not exist today.
Ordovician–Silurian extinction events	439 million years ago	This had wiped out around 86% of life on Earth. Scientists believe two major events caused this extinction: glaciation and falling sea levels.

Sixth mass extinction

There is however, an important difference between what caused the 'Big 5" and the ongoing cataclysmic, sixth 'mass extinction' event (5). The previous five extinctions were caused by climatic or planetary or galactic physical processes (e.g. climate change, an intense ice age, severe volcanic eruptions, or an asteroid crashing into the Earth). In contrast, the ongoing wave is exclusively being driven by a single species - mankind – with the current extinction rate of animals and plants being up to at least a hundred times higher than the normal 'background' rate.

As per the 2016 Living Planet Index, in just 42 years (1970 to 2012), the global populations of fish, birds, mammals, amphibians and reptiles have declined by about 58 per cent. Since population reductions are a prelude to species extinctions, at the current rate of decline, 30 to 50 percent of all species may be extinct within the next few decades (6) - and that's taking into account only the kinds of animals and plants that we know about. A recent report by the US' National Academy of Sciences states (7) that "in the last few decades, habitat loss, over-exploitation, invasive organisms, pollution, toxification, and more recently climate disruption, as well as the interactions among these factors, have led to the catastrophic declines in both the numbers and sizes of populations of both common and rare vertebrate species .... the loss of biological diversity is one of the most severe human caused global environmental problems". It adds that "by losing populations (and species) of vertebrates, we are losing intricate ecological networks involving animals, plants, and microorganisms .... [and] pools of genetic information that may prove vital to species' evolutionary adjustment and survival in a rapidly changing global environment".



A recent study in the 'Proceedings of the National Academy of Sciences' notes that although humans represent just 0.01 percent of the total biomass on Earth (82 percent - plants; 13 percent– bacteria; 5 percent – everything else including humans) they are responsible for the loss of 83 percent of all wild animals and half of all plants, with nearly half the Earth's animals being lost in the last 50 years. This study further outlines that farmed poultry today makes up 70 percent of all birds on the planet, with just 30 percent being wild; and 60% of all mammals on Earth are livestock, mostly cattle and pigs (of the balance 40 percent: 4 percent - wild animals; 36 percent human).

Sadly, there is little realization that all species on Earth – including humans – need to exist within the physical limits of the geosphere. Instead, we continue to treat the Earth as merely a source of resources as well as a huge garbage dump for our pollution. The 'Ecological Footprint' – which measures our use of goods and services generated by nature – indicates that we are consuming as if we had 1.6 Earths at our disposal and that out of the nine "Planetary Boundaries" (i.e. safe thresholds for critical Earth system processes that maintain life on this planet), we have already crossed four (human-driven climate change; loss of biosphere integrity; land system change; and the high level of phosphorus and nitrogen flowing into the oceans due to fertiliser use) (8). Evidently, there is little realization that humans are but one in the estimated 30 to 100 million species that form the complex biosphere.

Human population and the increasing pressure on Earth's resources

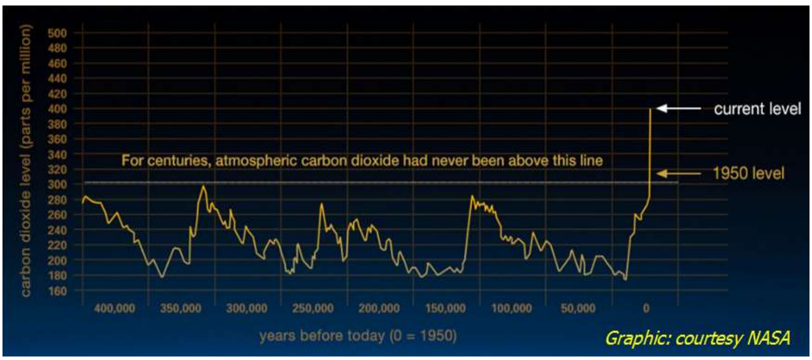
Humans evolved on Earth by chance, and not by design, after about 4.5 billion years of Earth history (9). Modern humans evolved about 200,000 years ago and had started migrating about 100,000 years back. Around that time, the total human population was less than one (01) million. Humanity has expanded

Growth of Human Population

Year	Global population (estimated) (in billions)
8000 B.C.	0.2
1	0.3
1000 A.D.	0.5
1500	0.5
1830	1.0
1930	2.0
1960	3.0
1975	4.0
1987	5.0
1999	6.0
2060	10-11

Credit: United Nations Population Reference Bureau, 1994; courtesy of Piotr Kowalski, Montrouge, France exponentially since then. Population growth picked up with the advent of farming and by 1 A.D, the world population had reached 170 million. By 1800 A.D, it increased to about one billion; in 1930 it touched two billion and in 1960, three billion. In mid-2017, it reached 7.6 billion (10). In sum: it took about 200,000 years for our population to reach one billion - and just around 200 years to reach 7.6 billion. As our population grew, our exploitation of Earth's resources increased exponentially. It is assessed that overall:

- Humans are consuming over 50% of the total net biological productivity on land and 50% of the available supply of freshwater (11).
- 50% of the planet's land mass has been transformed for human use, with 37-40% of the planet's land being devoted to human food production or pastures, up from 06-07 percent in 1700 AD (12).
- More atmospheric nitrogen is now fixed by humans than all other natural processes combined (13).
- Humans have emitted 1,540 billion tonnes of CO_2 since the Industrial Revolution. Half of this has remained in the atmosphere, causing a rise in CO_2 levels at least 10 times faster than any known natural increase during Earth's long history. Most of the other half has dissolved into the ocean, causing acidification.



The growing population and the increasing scale of the human enterprise, particularly industrialization and the quest for greater Gross Domestic Product (GDP) is thus putting immense pressure on Earth. In turn, this is having a number of direct as well as second-order effects. These effects include climate change, a reduction in the populations of species as well as their extinction. The report by the US's National Academy of Sciences assesses that "the ultimate drivers of these immediate causes of biotic destruction ... trace to the fiction that perpetual growth can occur on a finite planet. [and these drivers] are increasing rapidly. A study by Prof. Will Steffen of the Australian National University and the Stockholm Resilience Centre concludes that "all of these changes are shifting Earth into a "new state" that is becoming less hospitable to human life".

Temperature and climate change, and biodiversity loss are in fact feeding into each other. A September 2016 study by the USA's Director of National Intelligence entitled "Implications for US National Security of Anticipated Climate Change", which also draws from the report by the Intergovernmental Panel on Climate Change, concludes that:

- Extreme weather events, such as heavy rainfall, floods, droughts, cyclones, and heat-waves, the frequency and magnitude of which is increasing, will disrupt critical human and natural systems.
- Heat-waves threaten livestock directly, reduce fertility, decrease milk production, and make them more vulnerable to disease. Droughts, wildfires, and extended periods of reduced precipitation threaten pasture and food supplies, indirectly threatening livestock.
- Increasing heat stress is likely to adversely affect agriculture, manufacturing, and other sectors requiring physical labour and could significantly contribute to GDP loss.
- Increased ocean temperatures and more frequent and more intense storms will increasingly threaten fisheries, many of which are already under stress from overfishing and pollution.
- Low-income countries are less equipped to rebound from the economic setbacks caused by extreme weather events, and an increase in the frequency of these events could contribute to, or even push some people into poverty.
- Such dynamics will (i) pose a threat to the stability of countries; (ii) heighten social and political tensions; (iii) adversely affect food prices and availability; (iv) increase risks to human health; and (v) have a negative impact on investments and economic competitiveness.

Implications

There are both direct and indirect effects of such population declines and extinctions. For example: in the USA, 25% of bumblebees are at risk of extinction (bees help pollinate 35% of the world's food); at the ongoing rate of pollution, by 2050, the oceans may contain more plastic than fish by weight, which will impinge on food availability. Indirectly, species diversity helps ensure that our ecosystem remains resilience and is able to withstand stress. This is because most species are linked to each other in a complex ecological web. Some species even serve as buffers between humans and some dangerous pathogens (14). Therefore, whether it's pollinating crops, purifying water, harvesting fish for food, weaving fibres or sourcing medicines, humans are deeply dependent on biodiversity - and if we want ecosystems to continue to provide things for us, then they must be allowed to function in approximately the same way as hitherto fore.

But with human populations increasing; dietary requirements and preferences improving; with lifestyles seeking more "style and entertainment'; humans wanting greater luxury, comfort, and using more and more resources; and polluting resources at a rate faster than they can be replenished, our existence is in jeopardy unless we re-think our consumption patterns and implement widespread sustainable initiatives, particularly in countries with large populations. The 'Science Advances' (June 2015) assesses that thwarting the ongoing sixth mass extinction will require rapid, vastly intensified and widespread efforts to conserve already threatened species and to alleviate pressures on their populations from habitat loss, overexploitation for economic gain and climate change (15).

The US's National Academy of Sciences has a similar but stark message - that "the window for effective action is very short, probably two or three decades at most. All signs point to ever more powerful assaults on biodiversity in the next two decades, painting a dismal picture of the future of life, including human life. The resulting biological annihilation obviously will have serious ecological, economic and social consequences. Humanity will eventually pay a very high price for the decimation of the only assemblage of life that we know of in the universe." While "two or three decades" may seem like a long time, the fact is that conservation efforts have a very long gestation period and 20-30 years are not even a blip in the evolutionary timescale.

India and Its Biosphere

In geopolitical terms, India is usually thought of as an "island" - it has seas on its south-east, south and south-west; to the North and East are mountains; it also has hostile neighbours to its West and East. In other words, it has to accommodate all the needs of an increasing population within a finite landmass. The rising aspirations of the population include industrialization to increase per capita GDP, improvement in life styles, development of infrastructure (of all types), as well as food security. The problem is that industrialization, infrastructure-building and agriculture are all land-use intensive, and compete in demands for land.

Data from various sources indicates (16) that presently, India holds the second largest agricultural land globally (after the USA) and that 60.3% of India's land area is taken by agriculture (all types) (17). The mid-20th century Green Revolution had improved food security in India by expanding farming areas, double-cropping farmlands, and improving land yields. However, with our population growing, the demand for food is increasing – and India is expected to have 144 crore people by 2024, and 150 crores by 2030. With land yields having peaked, more food production can therefore be achieved through two main routes, i.e. by bringing more land under the till - and/or through radically new seed and farming technologies. The World Economic Forum has noted that by 2050, with the global population expected to reach 9.8 billion, demand for food will be 60% higher - even as climate change, urbanization and soil degradation shrink the availability of arable land.

An associated factor is the vulnerability of mankind's limited number of food sources - currently, 75% of all human calories come from just 12 types of plants. On account of a lack of genetic variability within these plants, a new pest or a pathogen, or changing climate can destroy an entire crop (18). A study by the University of Exeter, United Kingdom, examining how climate change could affect the vulnerability of different countries to food insecurity, opines that India is among the countries which are at the greatest risk of food insecurity due to weather extremes caused by climate change. Additionally, global warming-linked rise in sea-levels could inundate population areas and farming centres in low coastal zones, even as higher temperatures force humans to seek higher latitudes and altitudes to survive. Unlike Russia (largest land area - 16,376,870 sq. kms; population - 14.4 crores) or the USA (land are - 9,147,420 sq. kms; population – 33 crores), how would our large population adjust (population ~134 crores; landmass - 2,973,190 sq. kms).

Hence, there is a body of opinion which suggests that "environmental sustainability could become the next major challenge as India surges along its projected growth trajectory"., with the competition between land for agriculture use and that required for infrastructure, development as well as for industrialization leading to severe encroachments on existing biospheres". Although the government is doing a good amount in terms of inducting "green" and renewable technologies, the biosphere challenge in India may only be beginning. This is perhaps what should occupy thinkers and planners in the coming months and years.

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Studies for Quantifying Urban Heat Island effects over changing climate, Assessment of Urban Land Use and Environmental Risks and Adaptation Measures – A Review

Sumanta Das*, Malini Roy Choudhury and K. P. Raptan

Abstract

In this study, we have made an attempt to present our understanding of quantifying Urban Heat Island effects over changing climate which shall be used to monitor and assess the Urban land use and Environment risks. The study also focused on some adaptation measures towards urban resilience. The foremost objective of the study lies in the thorough understanding of the Urban Heat Islands (UHI), knowing its adverse impacts over urban communities, land use, and environment over changing climate, quantification process of UHI in the Geo-Spatial platform which further leads to monitoring, assessing and predicting the environmental risks and finally, taking some adaptation measures to build resilient urban community. The study demonstrated the advantages of earth observation data and Geo-Spatial technologies to detect and monitor the UHI over the temporal scale and a clear understanding of spatial data processing for quantification of UHI.

Key Words: *Urban Heat Islands, LULC, LST, Environmental Risks, Adaptation*

1. Introduction

Rapid and unplanned urbanization and a concomitant reduction in vegetation results in an increased rise in temperature compared to non-urban areas. Rapid urbanization combined with changes in land use pattern during several decades led to about 1.8°C warming of major metropolitan cities [0] in India compared with surrounding non-urban areas (called the urban heat island effect), Studies [1] revealed that, increase in urbanisation has been rapid at 83% in the last 15 years. This has led to about 89% decrease in dense vegetation, about 2% decrease in water bodies and nearly 83% decrease in crop fields during the same period. The decrease in crop areas could either be due to urbanization or fields remaining fallow. These changes have led to an increase in the urban heat island effect. The major metropolitan cities and adjoining areas in India have witnessed major changes due to the expansion of the city, leading to the warming of the city. Rapid urbanization and subsequent encroachment of natural vegetation negatively impact the thermal and radiative properties of the surface and make cities hotter than surrounding non-urban areas. With heavily built-up areas and concrete structures, most cities in India and in the world are warmer than surrounding non-urban areas due to the urban heat island effect [1].

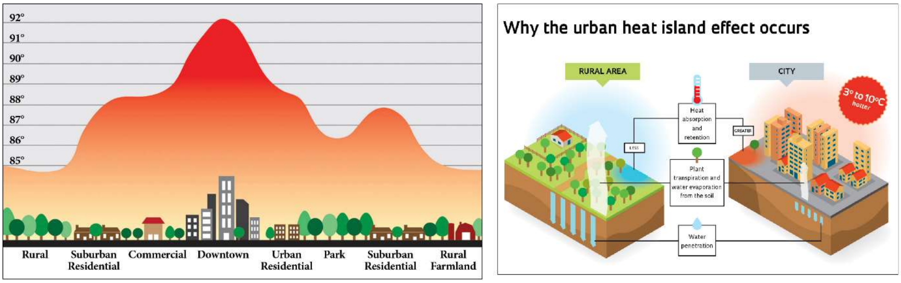
Urban Heat Islands (UHI) are parts of a metropolitan area which is significantly warmer than its surrounding areas [2]. Rapid urban shift often results in a series of urban environmental problems. Urbanization includes removal of vegetation cover to construct new highly reflective surfaces (parking lots, rooftops, roads etc). This results in high thermal radiation at the surface producing “Urban Heat Island”. The main cause of this UHI is the faster rate of cooling of the open spaces around cities when compared with the rate of nocturnal cooling of the densely built-up areas. The larger and denser the city, the greater is the difference in air temperature between the city center and the surrounding rural areas. The urban heat island grows with time. These thermal changes contribute to the change in flora and fauna, increased cooling load requirements (air-conditioning), that hampers the GHG emissions and increased discomfort to human health (heat stroke).

As population centers grow in size from village to town to city, they tend to have a corresponding increase in average temperature [3]. This consequently increases building energy demand for air-conditioning in warmer countries like that of tropical regions. This increase in energy demand could result in not only an additional generation of anthropogenic heat but also further intensification of heat islands themselves [4]. Urban heat island intensity (UHI) estimations are therefore important in urban planning as well as emission reduction strategies. Studies, [5,6] have shown the emergence of urban heat island phenomenon in the past decade. Changes in Urban land use and land cover (LULC), due to increasing population and infrastructure pressures for rapidly growing megacities, play an important role in the development of urban heat islands. Such a rapidly increasing population in megacities is associated with somewhat similar growth rates in vehicular population, residential and commercial complexes, industries and other infrastructure resulting in significant changes in LULC and increase in anthropogenic heat emissions. All these changes accounts for generating several UHI pockets and shift in dynamics of urban heat island phenomenon. In general, the heat island effect is maximized on clear days, when incoming solar radiation is high and night time cooling proceeds most slowly [7]. This complex problem can be solved through sound decision making system where the amalgamation of Remote Sensing data and GIS technique solely stands as the sound analyzer with a futuristic approach. The orbital remote sensing technique with its repetitive and synoptic coverage with high resolution data helps to identify and monitor the environmental degradation which is the combined effects of UHI. Over the past few years, remotely sensed data have been widely used to study the land use and land cover changes and assess environmental risks associated with urban growth, and to retrieve land surface biophysical parameters, such as vegetation abundances, built-up indices, and land surface temperatures, those are good indicators of conditions of urban eco-system. Greenness or vegetation abundance to study eco-environment plays a crucial role in the exchange of material and energy over land surface [8]. Accurate mapping and monitoring of spatio-temporal dynamics of vegetation in the urban area is essential to understand urban ecosystems, including its role in mitigating air pollution and reducing the urban heat island effect. Impervious land surface, as one of the most important land cover types and characteristics of urban/suburban environments, is known to affect urban surface temperatures. However, this may not produce satisfactory accuracy in mapped data, due to the high incidence of mixture pixel in an urban area. To quantify the UHI effect, retrieval of Land Surface Temperature (LST) is very important from earth observation data over a period of time. Near surface soil moisture (SM) index is also an important parameter for UHI quantification and can be measured by remote sensing satellite data. Finally, the correlations can be computed between land surface temperatures, vegetation abundance and surface wetness with the impervious surface to determine the training sets. Based on the observation and studies, several adaptation measures shall be taken towards urban resilience.

2. Urban Heat Islands – Effects

Urban heat island (UHI) effect is widely recognized as a heat accumulation phenomenon, which is the most obvious characteristic of urban climate caused by urban construction and human being activities [9,10]. In the early 19th century, scholar Lake Howard measured and discussed UHI effect when studying urban climate in London. Since then, many scholars around the world conducted deeply research on the characteristics of UHI effect [11,12], reaching that UHI effect has a close relationship with urban heat release, properties, and structure of the underlying surface, vegetation coverage, population density and weather conditions. Meanwhile, the scale and intensity of the UHI effect will be increasingly serious with the on-going urbanization. Urban temperature, especially surface temperature, is the energy balance center of the urban surface and one of the most important factors affecting urban climate, regulating and controlling various ecological processes [13,14]. However, the increasingly intensive urbanization has led to the constant increase of surface temperature, definitely resulting in altering of urban resource and energy flow. More importantly, the structure and function of the urban ecological system will also be changed, affecting urban residents' health. In addition, the UHI effect has received great attention from urban meteorologists. Figure 1 (a) & (b) shows the UHI profile and causes respectively.

Cities with variable landscapes and climates can exhibit temperatures several degrees higher than their rural surroundings (i.e. UHI effect), a phenomenon which if it increases in the future, may result in a doubling of the urban to the rural thermal ratio in the following decades. Hence, assessment of the UHI and strategies to implement its mitigation are becoming increasingly important for government agencies and researchers of many affected countries.



(a) (b)

Figure 1: Urban Heat Island Profile in Rural to Urban areas (a) and causes of UHI (b)

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated inner spaces or outdoor spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulphur dioxide, carbon monoxide, and particulate matter. Furthermore, the increased energy demand means more costs to citizens and governments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to the formation of ozone precursors, which combined photo chemically produce ground level ozone.

A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. During extreme weather events such as heat waves, the urban heat island has the potential to prevent the city from cooling down, maintaining night-time temperatures at a level that affects human health and comfort. Heatstroke, heat exhaustion, heat syncope, and heat cramps are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events. Studies [14,15] carried out in several cities of the United States such as Atlanta, New York, Chicago, and Washington, have shown that urban-induced precipitation and thunderstorm events are mainly initiated by the UHI. Other meteorological impacts of the UHI are associated with reductions in snowfall frequencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phonological disturbances on ornamental plants and urban forests.

2.1 Climate change and heat island effects on human health and mortality

Climate change and changes in land use have similar impacts on society health and living. Both changes focus on the deterioration of ecosystem dynamics and its stabilization. The global climate change may affect human health and nutrition resources. Human health is affected by climate change through biogeochemical interactions and the presence of biological responses towards the climate and the atmospheric composition. The formation of heat stress through the heat wave amongst humans may lead to more serious illnesses, such as heat stroke. Increased temperature can also amplify air pollution concentrations which lead to the formation of major cardio respiratory allergies. Pollution also influences the climate of the city. Pollution particles reflect solar radiation, leading to a decrease in solar energy reaching the surface. Heat islands have been recorded as major urbanization effects.

3. In Situ Observation for Analyses of Urban Heat Islands – Perspectives from India:

The main purpose of the in situ temperature, as well as humidity observation, is to detect the diurnal variation of vertical air temperature and surface temperature with an urban concrete surface and suburban open surface, so as to get the relationship between them. On the basis of relationship, the daily surface temperatures can be approximated by air temperature at peak 14:00 hrs and daily lowest temperatures. These data and the relationship are used to determine the top boundary temperatures in numerical simulation. Meanwhile, the air temperature, surface temperature, vertical temperatures and air moisture of two sites were recorded every day during the study period in order to compare with simulation results [15].

The month of June is characterized by falling daily high temperatures, with daily highs ranging from36 to 33°C over the course of the month, exceeding 38°C or dropping below 30°C only one day in ten. Daily low temperatures are around 27°C, falling below 24°C or exceeding 29 °C only one day in ten in Figure 2.

The relative humidity typically ranges from 58 % (mildly humid) to 96 % (very humid) over the course of a typical June, rarely dropping below 48 % (comfortable) and reaching as high as 100 % (very humid). The air is driest around June 1, at which time the relative humidity drops below 62 % (mildly humid) three days out of four; it is most humid around June 27, rising above 94 % (very humid) 3 days out of four in Figure 3.

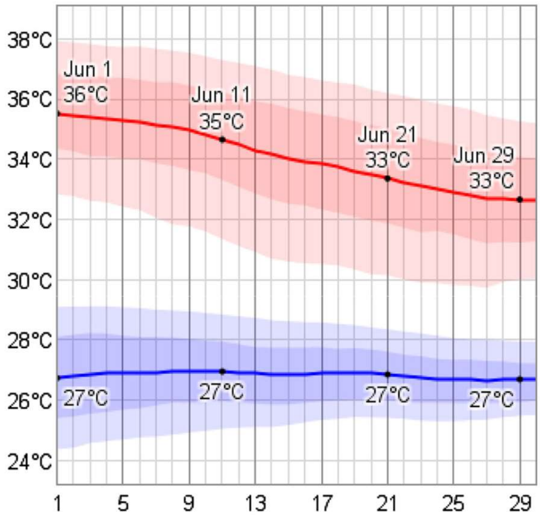


Figure 2 : The daily average low (blue) and high (red) temperature

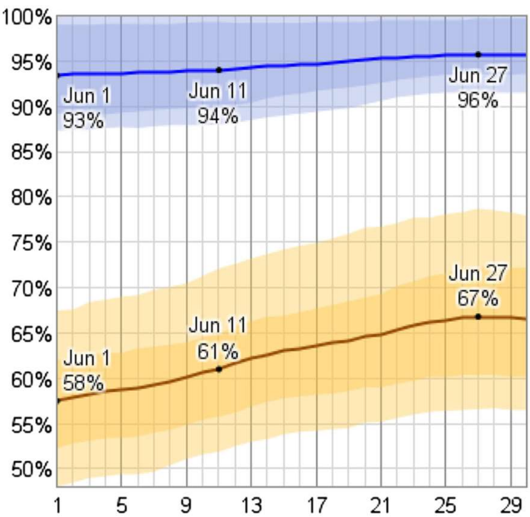


Figure 3 : The average daily high (blue) and low (brown) relative humidity.

The probability that precipitation observed at this location varies throughout the month. Precipitation is most likely around June 30, occurring in 74% of days. Precipitation is least likely around June 1, occurring in 56 % of days. Throughout

June, the most common forms of precipitation are thunderstorms, light rain, and moderate rain. Thunderstorms are the most severe precipitation observed during 58% of those days with precipitation. They are most likely around June 1, when it is observed during 39% of all days. Light rain is the most severe precipitation observed during 24% of those days with precipitation. It is most likely around June 30, when it is observed during 20% of all days. Moderate rain is the most severe precipitation observed during 17% of those days with precipitation. It is most likely around June 30, when it is observed during 16% of all days in Figure 4.

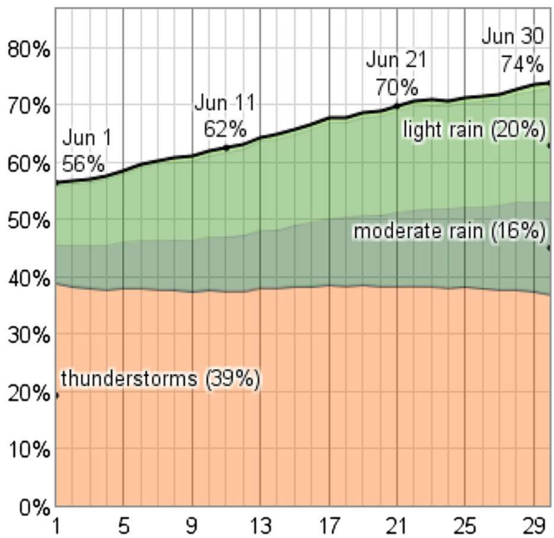


Figure 4 : The average daily Precipitation.

Vertical air temperatures are influenced by solar radiation, air moisture, wind speed, and environmental shelter, etc. Essentially, these factors act on the ground surface and then affect the vertical temperature field. In order to simulate the vertical temperature variations, we made three assumptions [16]: a) the air is homogeneous, and as a result, heat only flows in a vertical direction; b) no surface heat source; c) air moisture is not considered. Therefore, the corresponding heat conduction equation is one-dimensional. In the Cartesian coordinates, the one-dimensional transient heat conduction differential equations are as follows (1,2):

$$\begin{cases} \dfrac{\partial T}{\partial t} = \alpha \dfrac{\partial^2 T}{\partial Z^2} \qquad (0 < z < L) \qquad (1) \\ T(0,1) = \mu_1 = \mu_2(t); T(L,t) = \mu_2(t) \end{cases}$$

$$\alpha = \frac{k}{\rho c} \quad (2)$$

Where, T is temperature (°C), t is time (s), z is height (m), α is thermal diffusivity (ms^{-2}), k is thermal conductivity (w/mK), ρ is density (g/cm^3), c is heat capacity (J/kg K), and L is the height of bottom boundary (8 m). The related physical properties of urban open surface sand mixed soil and urban concrete surface are shown in Table 1. Therefore, the differential equation can be solved when the top boundary temperature and bottom boundary temperature are given. Since the surface temperature is influenced by many factors, it changes between different measured points on the same ground surface. The difference may be significant, especially on concrete surfaces. Although the problem is assumed to be one-dimensional, the Vertical temperatures are actually influenced by the whole ground surface.

Table 1: Physical properties of the urban concrete surface and urban open surface (sand).

Surface	Dry Density (g/cm^3)	Thermal conductivity (w/mK)	Heat capacity (kJ/kg C)	Thermal diffusivity ($*10^{-6}$ m^2/s)	Relative humidity (%)
Urban open surface (sand)	1.52	0.71	0.8	0.81	85
Urban concrete surface	2.4	1.7	1.3	1.45	70

4. Data Preparation, Processing, and Quantification techniques

To analyze Urban Heat Islands effectively, satellite Remote Sensing and GIS data play a crucial role. The datasets can be acquired from the electronic library (CLASS) of the National Oceanic and Atmospheric Administration (NOAA). LANDSAT, AVHRR data from NOAA-18 and NOAA-19 satellites are used for daytime because the satellites time of overpass is near noon time when the highest daily air temperatures occur. For night time, AVHRR data from MetOp-A satellite can be used as the overpass time is around 22.30 local time (19.30 UTC).

4.1 Satellite data processing

Temporal Landsat ETM+, OLI or AVHRR data can be used to quantify the UHI and its impact assessment over Land use and environment. Landsat ETM+ or OLI data can be accessed freely from Earth explorer (USGS) with a spatial resolution of 30 mts. AVHRR thermal images (spatial resolution at 1.1 km) is used in order to map the thermal urban environment. All the Images should be geometrically corrected and radiometrically calibrated; radiometric calibration of the images involved the conversion of the raw digital number (*DN*) values [17].

4.2 *Urban Atlas data processing*

The Urban Atlas dataset is used in order to identify the urban, suburban and rural regions. The aggregate land Use and Land cover type allows the spatial discrimination between the different urban land covers and also favors the spatially accurate assignment of the surface emissivity that corresponds to these urban land covers.

4.3 *Land surface temperature (LST)*

Estimation of LST using AVHRR thermal infrared data is developed by Coll et al., 1994[18]. It requires the brightness temperatures in AVHRR channels 4 and 5, the mean emissivities and the spectral emissivity difference in these channels. It also uses coefficients which depend on atmospheric moisture and the surface temperature. These coefficients can be optimized according to the characteristics of a given area. The algorithm is described by the relation:

$$LST = T4 + [1 + 0.58 \cdot (T4 - T5)] \cdot (T4 - T5) + 0.51 + \alpha \cdot (1 - E) - \beta \cdot (\Delta\varepsilon) \quad ...(3)$$

Where,

T4 is the radiance temperature for channel 4 of AVHRR,

T5 is the radiance temperature for channel 5 of AVHRR,

E is the mean spectral emission coefficient for channels 4 and 5:

$$E = (\varepsilon 4 + \varepsilon 5)/2 \quad ...(4)$$

Where, $\varepsilon 4$ is the surface emission coefficient for channel 4,

$\varepsilon 5$ is the surface emission coefficient for channel 5,

and $\Delta\varepsilon$ is the difference between the emission coefficients for channels 4 and 5

Values for E and $\Delta\varepsilon$ are taken from Stathopoulou et al., 2004[19] and are shown in Table 2. Coefficients α and β depend on the amount of atmospheric water vapour in the area of the satellite image and from the temperature of the surface under observation. They may be described as a function of the brightness temperature (T4) which is recorded in channel 4 of the AVHRR and the precipitable water (PW) in the area [20].

Table 2: Emissivity values by land cover type.

Land Cover Type	Mean Emissivity	Emissivity Difference
Urban	0.97	-0.007
Sub-urban	0.98	-0.003
Rural	0.989	0

4.4 *Air temperature*

Air temperatures shall be derived from AVHRR surface temperatures using a simple empirical relation with coefficients determined from the comparison of air temperatures observed at meteorological stations with coincident surface temperatures of the AVHRR pixels where the stations are located. Air temperature values at each station that are coincident with the satellite overpass time can be collected The relation is derived while applying to the AVHRR images in order to convert AVHRR surface temperatures into estimated air temperatures (5,6).

$$\text{Day : Tair} = 0.3896 \cdot Ts + 15.313 \quad ...(5)$$

$$\text{Night : Tair} = 0.8246 \cdot Ts + 6.2324 \quad ...(6)$$

4.5 Precipitable water (PW)

Studies [21], revealed the relationship between the AVHRR temperature difference *ΔT=T4 -T5* (K) and the atmospheric precipitable water *PW* (cm) using daytime satellite data. They found this relationship is to be essentially linear and approximated by the following equation (8).

$$PW=0.719 \cdot \Delta T+0.362 \quad ...(7)$$

For night-time images a relation was found more suitable [22], and for urban surfaces is expressed as (9):

$$PW=1.265 \cdot \Delta T+ 1.493 \quad ...(8)$$

4.6 Relative humidity (RH)

Relative humidity (*RH* %) is defined as the ratio of vapour pressure (*e*) to saturated vapour pressure (e_s) at the air temperature (T_a) expressed as a percent (9):

$$RH = 100 \left[\frac{e}{e_s T_a} \right] \quad ...(9)$$

4.7 Discomfort index (DI)

Thom's discomfort index (DI) is expressed by a simple linear equation based on dry-bulb (T_{dry}) and wet-bulb (T_{wet}) temperatures. Its original form is given as (10):

$$DI(°F) =0.4 \, (T_{dry}+T_{wet}) + 15 \quad ...(10)$$

If air temperature (*Ta*) as measured in degrees Celsius and relative humidity (*RH)* in % is given, DI can be computed by using the following equation (11):

$$DI(°C) = Ta – 0.55 \, (1 - 0.01RH) \, (Ta -14.5) \quad ...(11)$$

The classes of DI are presented in Table 3 where it can be seen that the human discomfort increases as the Di values increases.

Table 3. Classes of discomfort index (DI)

Class No.	DI (°C)	Discomfort conditions
1	DI < 21	No discomfort
2	21 ≤ DI < 24	Less than 50% feels discomfort
3	24 ≤ Di < 27	More than 50% feels discomfort
4	27 ≤ DI < 29	Most of the population feels discomfort
5	29 ≤ DI < 32	Everyone feels severe stress
6	DI ≥ 32	State of medical emergency

Besides, the quantification process comprises the basic remote sensing image analyses for extraction of producing maps of Normalized Difference Built-up Index (NDBI) to measure the built-up index and Normalized Difference Vegetation Index, to measure the vegetation index, which is used to attune the land surface temperatures.

4.8 Measuring vegetation and built-up areas

Two main equations were used to quantify the values of vegetation and built-up conditions in the study area. These equations are as follows:

4.8.1 Normalized different built-up index (NDBI)

The NDBI enhances the built-up features of the earth surface. It is an automated mapping of urban built-up areas. Using the same rationing technique as NDVI, the building and urban area reflectivity are more concentrated at the middle-infrared (MIR) band compared to near-infrared (NIR) [23]. Thus, the built-up land can be calculated using this equation (12):

$$NDBI = MIR-NIR / MIR+NIR \quad ...(12)$$

4.8.2 Normalised different vegetation index (NDVI)

The simplest form of vegetation index is a ratio of near infrared (NIR) and red (R) reflectance, known as Simple Ratio (SR). For healthy living vegetation, this ratio will be high, due to the inverse relationship between vegetation brightness in the red and infrared regions of the spectrum. Based on geometrically corrected Landsat ETM+ or OLI images, the SR can be calculated using the reflectance of the near infrared band (NIR) and is the reflectance of the red band (R). The Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation index. It can be calculated by using this equation (13):

$$NDVI = NIR-R / NIR+R \quad ...(13)$$

4.9 Comparison of land use changes and Reports on Climate Change:

Temporal satellite data shall be used to segregate several land use classes as urban, sub-urban and rural classes and assessment can be made on the basis of long term land use changes over the changing climate and environment. Topographical evaluation can also be performed by observing the elevation conditions of the study area to their neighbourhood area, temporal development, and urbanization process (pre, during, and post), and was conducted by comparative analyses of land use changes, land surface temperatures, Vegetation Index (NDVI), and Built-up Index (NDBI), and finally, a historical climate data comparison (rising sea levels and El Niño Southern Oscillation (ENSO) incidents) can be done to assess environmental risks.

5. Discussions:

5.1 Evaluation of Urban Landscape and Ecology:

Landscape pattern is the spatial arrangement of landscape elements in different sizes and shapes. Analyzing landscape pattern is essential to monitor urban landscape spatial structure changes. Landscape pattern is a measure of an ecosystem's ability to prove habitat, prevent environmental degradation, and support other natural processes. In order to study the pattern change, different landscape metrics, including diversity index, shape index, patch density, mean of patch area distribution, and the landscape fractal dimension, are often adopted [24].

5.2 Urban Environmental Risk Assessment and Mapping:

Urban Environmental risk assessment has become one of the primary contents of urban and rural ecological planning [24]. The risk assessment is done through a correlation process and a thorough decision making on the results of quantification process viz., the periodical increment of land surface temperature, urban agglomeration rate, Land use changing rate with a total urban population under risk zone. The detail data quantification and analyses help to classify urban ecological unit from high to low risk zone in local to regional scale.

5.3 Developing an effective Urban Land use and Environment-Software System:

Based on the aforementioned UHI quantification process and analyses, a software system can be developed for monitoring urban land use and environment effectively, including the basic modules and advanced modules for urban land use and environment details (Figure 5). The software routines can be developed through Interactive Data Language(IDL). The system works with a collection of IDL source files and input of data and analytical results. In order to run these scripts, installation of a virtual machine of IDL 8.x or later shall be required.

Output binary data are saved as Tagged Image File Format (TIFF) images, which are easy to open using professional Remote Sensing software or universal image processing software [24].

Figure 5 : GUI of Urban Land use and Environment-Software System

5.4 Adaptations and Mitigation Measures of UHI effect:

Mitigating and reducing the impacts contributed by Urban Heat islands and anthropogenic activities is a significant challenge to urban planners, designers, architects and the local industry especially in the context of population and urban growth and the associated urban infrastructure. By implementing the following measures, it is possible to improve the urban environment [25]. The importance of having urban green campaigns and infrastructures was suggested to influence the urban community environment. Outdoor participation leads to healthier lifestyles and helps to resolve the adverse effects of climate change, thus transforming the well-being of urban society and its environment. A major mitigation strategy, which has received global recognition and attention, is the escalation of surface cooling properties, which is the land surface albedo. Land surface albedo has a direct relationship with surface heat.

5.4.1 Actions to be followed

5.4.1.1 Recognising the issue

Built-up areas in cities create unique micro-climates as natural surfaces are replaced by artificial ones, affecting among other local air temperatures. This makes cities particularly vulnerable to the impact of heat waves. The phenomenon is called ‘urban heat island effect’ and describes the increased temperature of the urban air compared to its rural surroundings.

5.4.1.2 Analysing the drivers

Rapid urban growth and high population density coupled with sealed surfaces, and a lack of green areas in combination with projected climate-induced changes exacerbate the risk of urban heat islands in cities. Built surfaces are composed of a high percentage of non-reflective construction materials. As a consequence, they tend to absorb a significant proportion of the incident radiation, which is released as heat. Additional causes of urban heat islands come from the residual heat of, for example, air conditioning and refrigeration systems, industrial processes, motorized traffic and the obstruction of airflows. Climate change essentially increases the number of hot days for both urban and rural situations to a similar extent. However, the number of additional hot nights is larger in cities. Urban areas store more heat during the day than greener rural areas and release this heat during the night.

5.4.1.3 Understanding the consequences

Climate projections show a substantial increase in periods of extreme heat in the region of South Asia. This, in turn, may reinforce the urban heat island effect in many urban agglomerations. Urban heat island effects go well beyond simple comfort issues for the population. Extreme heat waves endanger human health and greatly affect everyday life, social activities, economic endeavors and ecological systems.

A direct relationship has been established between peaks of urban heat island effects and heat-related illnesses and fatalities. Heatstroke's, heat exhaustion and heat cramps are some of the main stress incidents, while a large number of diseases may become worse – particularly for the elderly, chronically sick, very young and socially isolated. This is mainly due to the lack of electricity and cooling systems – especially in many informal settlements – and lack of or damage to sanitation and water facilities.

Consequences include increasing stress on water resources from rising water demands and energy shocks as well as disruptions due to increased electricity demands caused by growing use of air cooling systems. High temperatures can put infrastructures at risk by, for example, deforming roads and rail tracks, which in turn impede on the supply of goods and the mobility of commuters into and out of the city.

5.4.1.4 Taking appropriate actions

Local authorities should work towards mainstreaming measures against urban heat island effects in urban development plans, land use plans, and policies. To this end it is recommended to take a cross-sectoral approach, involving sectors like housing, public health, private sector building industry, transportation, and energy to be able to address the overarching nature of the challenge. Local authorities can initiate several actions to minimize a city's vulnerability to the effects of urban heat islands. First of all, local authorities should engage all relevant stakeholders in the planning and implementation of activities – also beyond the usual governance and management circles. It is also strongly recommended to engage those who are most vulnerable to heat waves and urban heat island effects in the planning and policy making processes, thereby identifying the most appropriate solutions and at the same time building capacity and increasing public awareness.

Early warning systems and educational campaigns to teach the general public to take precautionary actions during heat peaks are critical. Green infrastructure including improved vegetation and green building investments for natural cooling can play a crucial role to prepare the city on a long-term basis. This could include increasing the vegetation cover through reforestation as well as the number of parks and implementing vertical gardening to maximize the multiple vegetation benefits to alleviate temperature rises. Local authorities may consider other measures such as retrofitting public transport with ventilation as well as with white roofs to reduce solar heat gain; retrofitting buildings by adding light-coloured roofs that provide a cooling effect; and increasing surface reflectivity to reduce radiation absorption of urban surfaces by using light-coloured or white paint on the surface of construction materials. The following actions are summarized as a part of adaptations measures of UHI [26].

- Reducing emissions by decongesting the roads.
- Use of passive techniques in designs for heating and cooling thereby reducing the anthropogenic heat generated.
- Increasing the vegetation cover by providing more trees to provide shelter and shade.
- Increased use of light colored surfaces thereby reducing the absorption of radiation.
- A cool environment will provide less demand for energy, and thus, reduce pollution from power plants
- Trees and vegetation help to improve the transportation of air pollutants, such as oxides of sulfur and nitrogen; thus reducing air pollution.
- With cooler air temperatures, the formation of fog is less.
- Mainstream adaptation actions towards urban heat island effects across all sector departments.
- Maintain and extend the green infrastructure networks.
- Create awareness and provide guidance on how to behave during periods of extreme heat.

- Learn about best practices from your stakeholders and the most vulnerable.
- Use light colored or white paint for sealed surfaces, buildings, and public transport vehicles.

Conclusion

The study gives a scientific approach to quantify and simulate the UHI effects over changing climate. It also gives a clear view to mitigate and respond to the climatic change and UHI for over urban land use and environment. Statistics shows, there is a substantial increase in the urban air temperatures from the past, especially in all metropolitan and mega cities. Increase in population, density, reduction in open spaces and green cover, increase in built-up spaces have proved to increase the air temperature. These thermal changes deteriorate the urban environment causing health problems. Therefore, Urban planners, designers, architects need to consider this urban climate while designing and planning cities.

This present study gives a clear view of the trend of temperature variation by deriving Land Surface Temperature (LST) and simulating Urban Land use, Environment and LST. The correlation between different land uses / environment with LST shows positive or negative trend by showing the direction of development pattern of urban development in near future and conversion into UHI by analyzing the trend from the past to present and present to the future development of settlement and impervious surface. A compact-town like decentralization of urban areas (e.g., satellite-towns) is, therefore, a possible way forward in order to prevent the formation of large-scale urban heat island effect in the future.

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Analysis of Change in wheat yield, phenology and physiology under varying climate parameters using InfoCrop v 2.1

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Abstract

InfoCrop v 2.1 is a generic model which simulates the effect of weather, soil, agronomic management on crop growth and yield. The model was calibrated and validated using the field experiment data obtained from agriculture farm, BHU, Varanasi for the wheat cultivars HUW 234, HUW 468 and HUW 510. The model was used to study the effect of CO_2 and temperature on wheat yield, phenology and physiology at timely sowing. On increasing the CO_2 concentration by 700 ppm, the grain yield, water use efficiency and number of grains per m^2 increased by 32.4 to 35.4 %, 86.6 to 88.6 %, 32.4 to 35.2 % respectively with respect to baseline for all cultivars. The evapotranspiration was found to decline by 28.2 to 29.5% with respect to baseline for all cultivars. On increasing the maximum and minimum temperature, the days to anthesis and maturity decreased by 5.6 to 10 % and 4.9 to 8.7 % respectively while on decreasing the maximum and minimum temperature, the days to anthesis and maturity increased by 6.7 to 9.7 % and 4.9 to 7.9 % respectively. On increasing the temperature by 0.5°C, the water use efficiency of all the cultivars improved and evapotranspiration declined. On further increasing the temperature by 1°C, the water use efficiency of cultivars HUW 468 and HUW 510 showed increasing trend, maximum increase was observed in case of HUW 510. On decreasing the maximum and minimum temperature, the water use efficiency for all cultivars increased and evapotranspiration decreased. Thus, HUW 510 showed a better adaptation for heat stress when sown timely as compared to other two cultivars.

Key Words : *InfoCrop v 2.1, water use efficiency, evapotranspiration, days to anthesis, days to maturity*

1. Introduction

The wheat production, harvested land and yield would decline to 0.87 % p.a., 0.01 % p.a. and 0.86 % p.a. respectively in 2005/2007 – 2050 as compared to 3.62% p.a., 0.68% p.a. and 2.92 % p.a. from the year 1961-2007. India would require 140 million tonnes of wheat to meet the demand of 1614 million people by the year 2050 [1]. It is an important crop which is needed to be studied for the climate change effect like temperature, CO_2 concentration, precipitation and altered frequencies of extreme weather and climate events since the Intergovernmental

Panel on climate change (IPCC) AR5 reported that the global mean surface temperature change is projected to increase by 1°C to 3.7°C and CO_2 emission by 421 ppm to 936 ppm by the end of this century [2].

The relative importance of climate change for crop productivity can be assessed using models, which vary according to the criteria used for assessment [3]. Crop simulation models are useful tools to study the effect of climate change on crops under present and future scenario and formulate adaptive and mitigation measures in India [4]. The objective of the present study is to study the effect of CO_2 and temperature on wheat phenology, yield and growth parameters and physiology using crop simulation model InfoCrop v 2.1.

2. Materials and methods

2.1 Location and Climate data

The study was performed at Varanasi lies in the transect 4 of the Indo Gangetic Plains. The 35 years (1980-2014) meteorological data for Varanasi has been obtained from India Meteorological Department [5]. The maximum temperature ranges from 22.8°C to 40.1°C, minimum temperature range from 10.6 °C to 28.6°C. The maximum and minimum temperatures showed increasing trend with an average of 31.7 °C and 19.6 °C respectively. The average rainfall from 1980-2014 was 984.9 mm.

2.2 Crop simulation model Info Crop v 2.1

The model InfoCrop 2.1 is the process -based dynamic simulation model which simulates the effects of weather, soil, agronomic managements and major pests on crop growth and yield. The model inputs are based on thermal time and temperature thresholds of phenology, growth and source-sink balance [6,7]. The input data like crop management practices, daily weather and physical and chemical properties of soil are prerequisite for simulation of model. The model uses the function of radiation-use efficiency (RUE), photosynthetically active radiation, total leaf area index, and a crop/cultivar specific light interception coefficient for dry matter production. The model depicts the net dry matter available each day for crop growth as a function of the development stage. The rate of the storage organ filling is dependent upon temperature, potential filling rate and the level of available dry matter [8].

2.3 Database for model calibration and validation

The database for calibration and validation of Info Crop v 2.1 were obtained at five different dates of sowing viz. November 25, 2007, November 23, 2008, December 4, 2009, December 31, 2010 and November 17, 2011 using PhD thesis from Institute of Agricultural Science, BHU, Varanasi. Table 1 shows the observed and simulated for the crop parameters.

The gross plot area of sowing was 4.5 m x 4 m and net plot area was 3.5 m x 3 m with row spacing of 20-25 cm depending on the dates of sowing. Field experiments were laid out with main plots with three replicates in random block design. The amount of fertilizers provided to the field was 120 kg N, 60 kg P and 60 kg K per hectare at basal, crown root initiation (CRI) and tillering stages. The half of the total amount was given at the basal stage while other halves were given at CRI and tillering stage. The amount of irrigation was 50 mm and given at five different stages viz. time of sowing, crown root initiation, tillering, flowering and grain filling stages. The number of seeds per m^2 was at 100/m^2 and sown at a depth of 5cm. The layer wise soil details from "Soil Master" inbuilt in the Info Crop v 2.1 model was used which was then validated with the existing soil data of Varanasi which included % sand, % silt and % clay, saturation fraction, field capacity fraction, wilting point fraction, saturation hydraulic conductivity (mm/day), bulk density (Mg/m^3), % organic carbon, including initial conditions soil moisture fraction at sowing, soil ammonium and soil nitrate. Since the prominent soil type of the Indo Gangetic Plains is alluvial and sandy clay loam soil texture was used for model simulation. The depth of the soil was 1000 mm which was separated into three layers, namely, layer 1(200 mm), layer 2 (400 mm) and layer 3 (400 mm). The % sand, silt and clay ranged between 56-60 %, 17-19 % and 23-25 % for the three layers of soil. The range of bulk density was between 1.40-1.50 Mg/m^3, % organic carbon between 0.12-0.4 depth wise and saturation hydraulic conductivity between 1-8 mm/day. The range of fraction of saturation lies between 0.32-0.52, field capacity fraction between 0.16-0.25 and initial soil moisture fraction at sowing was 0.1 and wilting point between 0.05-0.11 depth wise. The electrical conductivity of soil is 0.4 ds/m and pH of soil is 8.2. The initial soil ammonium is 1-2 kg/ha for all depths and soil nitrate ranged between 1.8-6 kg/ha depth wise.

2.4 Methods of simulation

The simulation process used for study used the net radiation use efficiency approach for calculation of crop growth. The potential evapotranspiration was calculated using Priestley-Taylor method. The model based study on temperature and CO_2 variability was performed using "climate change" option at project window where "fixed change every day" option was selected to study the effect of change on maximum temperature, minimum temperature at fixed or different concentrations of CO_2.

2.5 Determination of simulated results with respect to baseline

The study on effect on wheat crop was performed by changing the climate parameters and then observing it against baseline. The changes on yield, phenology and physiology of wheat was observed at normal date of sowing (November 15) using normal weather data (long term average from 1980-

2014). The effect of change in CO_2 was observed at different concentrations and comparing it with baseline concentration (380 ppm). The change in temperature was observed by increasing or decreasing the temperature which got added up from day of sowing to harvesting at 380 ppm and then compared with no change in temperature at 380 ppm.

3. Results

3.1 Model evaluation

The model validation was done using statistical methods like mean absolute error (MAE), mean biased error (MBE), root mean square error (RMSE), index of association (d). The errors were calculated for the crop parameters. The observed and simulated results matched well and the errors calculated were found to be less than +/- 10 % (Table 2). The genetic coefficients which are the characteristic features of the cultivars were determined (Table 3).

3.2 Study on crop parameters under carbon dioxide fertilization:

The effect of change of temperature and concentration of CO_2 on the yield and number of grains per m^2 showed similar behavior. The grain yield ranged between 4582 to 4706 kg ha^{-1} for the baseline and increased by 5934 to 6295 kg ha^{-1} with increase in the CO_2 concentration by 700 ppm for the three cultivars. The number of grains per m^2 ranged between 12160 to 13182 for the baseline and increased by 16188 to 17036 with increase in CO_2 concentration by 700 ppm for all the cultivars. As compared to baseline concentration of CO_2 (380 ppm), when the concentration of CO_2 was raised to 700 ppm the evapotranspiration declined between 168 and 177 mm from 242 and 264 mm at baseline for different cultivars. The water use efficiency was shown to range between 17.4 and 19.1 kg $ha^{-1}mm^{-1}$ for baseline and increased by 29.7 to 31.2 kg $ha^{-1}mm^{-1}$ on increasing the CO_2 concentration to 700 ppm for the three cultivars. The percent increase of yield, number of grains per m^2, water use efficiency and decrease in evapotranspiration was found with respect to baseline concentration of CO_2 (Fig. 1).

3.3 Study on crop parameters under change in temperature:

At 380 ppm of CO_2 concentration (baseline), the maximum temperature when increased by 2.5°C, the number of days to anthesis decreased by 8, 5 and 5 days in case of HUW 234, HUW 468 and HUW 510 respectively. The number of days to maturity decreased by 7, 6 and 6 days for HUW 234, HUW 468 and HUW 510 respectively. Further, when the maximum temperature decreased by 2.5°C with respect to baseline the days to anthesis and maturity increased by 7, 5 and 7 days for HUW 234, HUW 468 and HUW 510 respectively. The number of days to maturity increased by 6, 5 and 7 days for HUW 234, HUW 468 and HUW 510 respectively.

The effect of minimum temperature on days to anthesis and maturity was similar to that of maximum temperature. The minimum temperature when increased by 2.5°C at baseline concentration of CO_2, the number of days to anthesis and maturity decreased by 7 and 9 days respectively for HUW 234, 7 days each for HUW 468 and 4 and 5 days respectively for HUW 510. On decreasing the temperature by 2.5°C, the days to anthesis and maturity increased by 5 and 6 days respectively for HUW 234 and 5 and 7 days respectively for HUW 468 and 5 and 8 days respectively for HUW 510. Fig. 2 showed the percent change in days to anthesis and days to maturity with increase and decrease in maximum and minimum temperature.

The temperature when increased to certain level showed positive change in yield which decreased after further increase in temperature. For HUW 234, the yield increased by 2.5 and 1.2 % for increase in maximum and minimum temperature by 0.5°C (Fig. 3). When both the temperatures increased further by 2.5°C the yield declined by 7.5 % (Fig. 3). As compared to baseline, the increase in yield was observed for 1°C rise in temperature for cultivar HUW 468 and HUW 510. The yield increased by 1.3 and 0.8 % for HUW 468 and 2.7 and 2.6 % for HUW 510 when maximum and minimum temperatures was raised by 1°C (Fig. 3). On further increasing the maximum and minimum temperature by 2.5°C, the yield declined by 7.5 and 7.1 % for HUW 468 and 5.5 and 4.5 % for HUW 510 respectively (Fig. 3). The decrease in temperature had positive effect on yield. The yield increased by 11.3 and 11.2 % for HUW 234, 11.5 and 10.2 % for HUW 468 and 14 and 12.1 % for HUW 510 when temperature was decreased by 2.5°C.

At baseline concentration of CO_2, the temperature variability on number of grains per m^2 showed similar pattern of change to that of yield. The number of grains per m^2 showed positive change when temperature was raised by 0.5°C for HUW 234. For HUW 468 and HUW 510, the increase in number of grains per m^2 was observed even at 1°C increase in temperature. The number of grains per m^2 increased by 2.4 and 1.2 % for HUW 234 when maximum and minimum temperature by 0.5°C (Fig. 3). In case of HUW 468 the increase in number of grains per m^2 by 1.3 and 0.8 % and 2.7 and 2.6 % for HUW 510 (Fig. 3). On increasing the maximum and minimum temperature further by 2.5°C, the number of grains per m^2 decreased by 7.5 and 7.6 % for HUW 234, 7.5 and 7 % for HUW 468 and 5.5 and 4.5 % for HUW 510 (Fig. 3). On decreasing the maximum and minimum temperature by 2.5°C, the number of grains per m^2 increased by 11.3 and 11.2 % for HUW 234, 11.5 and 10.2 % for HUW 468 and 14.1 and 12.1 % for HUW 510 (Fig. 3).

The study for HUW 234 showed evapotranspiration to decline by 2.8 and 3.8 % and water use efficiency increased by 5.4 and 5.2 % at baseline CO_2 when maximum and minimum temperature was increased by 0.5°C respectively (Fig. 4). However further increase in maximum and minimum temperature by 2.5°C increased evapotranspiration by 10.1 and 10.5 % respectively and water use efficiency decreased by 16 and 16.3 % respectively (Fig. 4). On decreasing the temperature, the evapotranspiration decreased and water use efficiency increased. When the maximum temperature decreased by 2.5°C the evapotranspiration declined by 14.7 and 14 % and water use efficiency increased by 30.5 and 29.3 % for maximum and minimum temperature respectively (Fig. 4).

For HUW 468 and HUW 510, the decrease in evapotranspiration and increase in water use efficiency compared to baseline was observed for increase in temperature by 1°C. The evapotranspiration decreased by 2.2 % and water use efficiency increased by 3.4 and 3 % on increasing the maximum and minimum temperature by 1°C respectively for HUW 468 (Fig. 4). When the temperature increased by 2.5°C, the evapotranspiration increased by 7.6 and 7.9 % and water use efficiency decreased by 15.7 and 15.9 % on increasing the maximum and minimum temperature by 2.5°C (Fig. 4). On decreasing the maximum and minimum temperature by 2.5°C the evapotranspiration decreased by 13 and 10.4 % and water use efficiency increased by 28.1 and 23 % respectively (Fig. 4). In case of HUW 510, the evapotranspiration decreased by 1.7 and 1.4 % and water use efficiency increased by 4.4 and 4.1 % as compared to baseline for 1°C increase in maximum and minimum temperature. On increasing the maximum and minimum temperature by 2.5°C, the evapotranspiration increased by 9.2 and 8.8 % and water use efficiency decreased by 13.4 and 12.3 % (Fig. 4). When the maximum and minimum temperature was reduced by 2.5 °C the evapotranspiration decreased by 13.3 and 14.3 % and water use efficiency increased by 31.5 and 30.8 % respectively (Fig. 4).

Table 1 : Observed and simulated data for crop parameters obtained for the cultivars

Simulation details	Cultivars					
	HUW 234		HUW468		HUW510	
	Observed	Simulated	Observed	Simulated	Observed	Simulated
Anthesis days	62-75	65-75	63-77	65-80	62-76	67-78
Maturity days	101-115	101-120	100-119	101-126	99-115	100-121
Grain yield (t h^{-1})	4.02-5.01	3.98-4.95	3.94-4.91	3.91-5.92	4.28-5.52	4.02-5.12
Straw yield (t h^{-1})	3.98-5.02	4.05-5.21	4.52-6.42	4.94-6.24	4.95-5.23	5.25-6.12
Harvest index	0.44-0.47	0.46-0.50	0.35-0.40	0.38-0.43	0.41-0.43	0.41-0.46

Table 2 : Model validation obtained on calculation of errors

`Parameters	MAE	MBE	RMSE	d
Days to anthesis	3.13	-0.73	3.96	0.84
Days to anthesis	3.40	-2.30	4.50	0.82

`Parameters	MAE	MBE	RMSE	d
Grain yield	0.29	-0.10	0.34	0.59
Straw yield	0.36	-0.26	0.42	0.65
Harvest index	2.31	-2.24	2.53	0.77

Table 3: Genetic Coefficient of cultivars used in the Info Crop model simulation

Parameters	HUW 234		HUW 510		HUW 468	
	Base temp (^{0}C)	Thermal time (^{0}C days)	Base temp (^{0}C)	Thermal time (^{0}C days)	Base temp (^{0}C)	Thermal time (^{0}C days)
A. Phenology						
Sowing to germination	3.6	70	3.6	65	3.6	72
Germination to 50% flowering	4.5	750	4.5	725	4.5	780
50% flowering to physiological maturity	7.5	393	7.5	400	7.5	420
Optimal temperature (^{0}C)	25.0		25.0		25.0	
Maximum temperature (^{0}C)	40.0		40.0		40.0	
Sensitivity to photoperiod (scale 0.5-1.5)	1.0		1.0		1.0	
B. Growth						
Relative growth rate of leaf area (mg/g/day)	0.0075		0.0075		0.0075	
Specific leaf area (dm^2/mg)	0.0022		0.0023		0.0027	
Index of greenness of leaves	1.0		1.0		1.0	
Extinction coefficient of leaves at flowering	0.6		0.8		0.5	
Radiation use efficiency (g/MJ/day)	2.8		2.4		2.6	
Potential Root growth rate (mm/day)	30.0		31.0		30.0	
Sensitivity of crop to flooding scale	1.0		1.0		1.0	
Index of N fixation	1.0		1.0		1.0	
C. Source: Sink Balance						
Slope of storage organ number/m^2 to dry matter during storage organ formation (storage organ/kg/day)	28000		28000		28000	
Potential storage organ weight (mg/grain)	42		45		40	

Parameters	**HUW 234**		**HUW 510**		**HUW 468**	
	Base temp (^{0}C)	**Thermal time (^{0}C days)**	**Base temp (^{0}C)**	**Thermal time (^{0}C days)**	**Base temp (^{0}C)**	**Thermal time (^{0}C days)**
Nitrogen content of storage organ (fraction)	0.02		0.02		0.02	
Sensitivity of storage organ setting to low temperature	1.0		1.0		1.0	
Sensitivity of storage organ setting to high temperature	1.0		1.0		1.0	

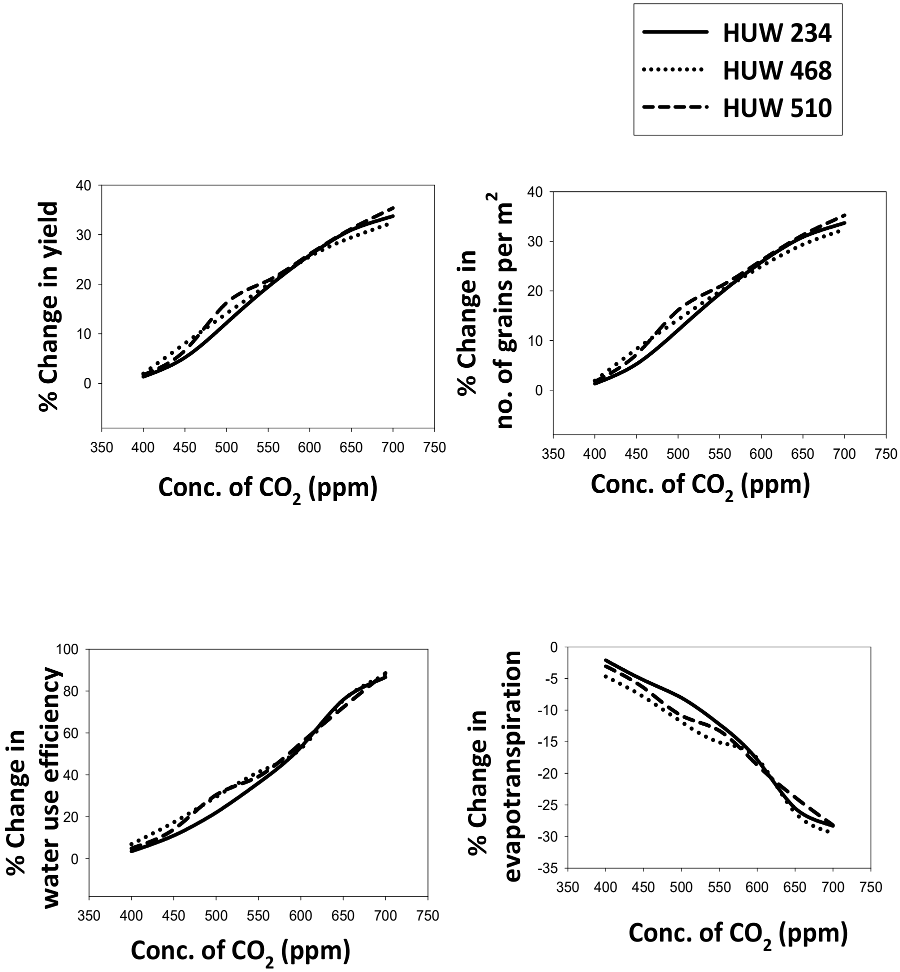

Fig. 1 : Percent change in yield, number of grains per m2, water use efficiency and evapotranspiration with increase in CO2 concentration w. r. t. baseline.

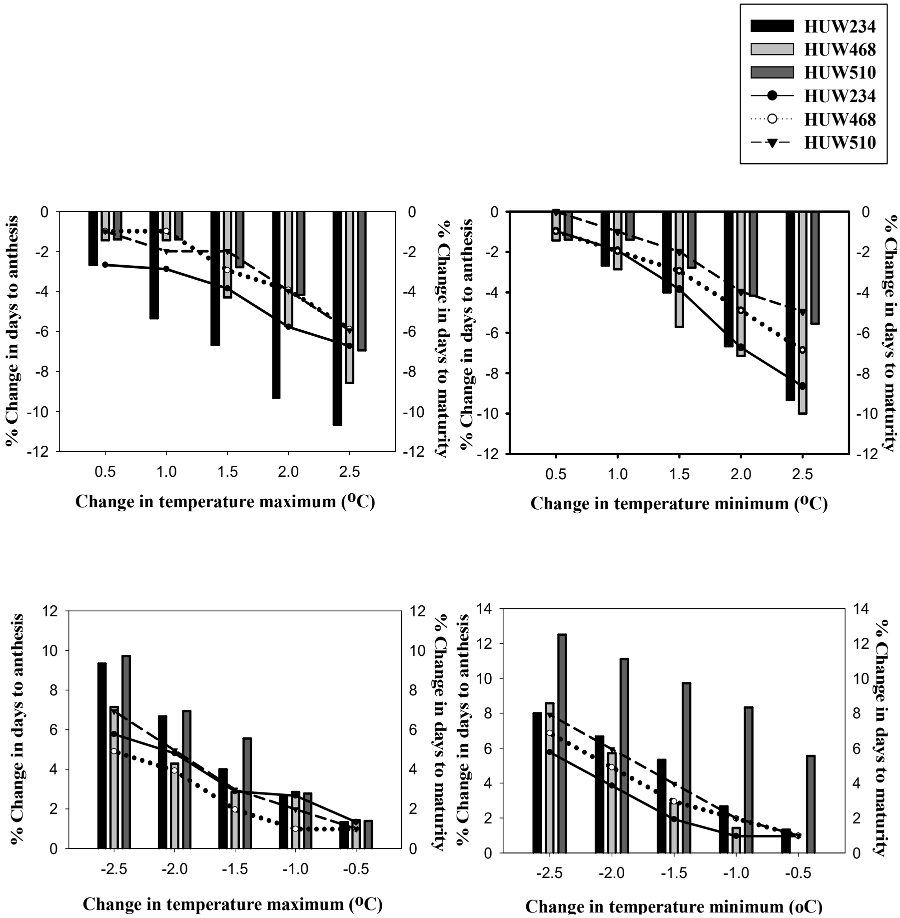

Fig. 2: Percent change in phenology (days to anthesis and days to maturity) with increase and decrease in maximum and minimum temperature w. r. t. temperature at baseline concentration of CO_2.

4. Conclusion

Crop simulations using crop model Info Crop v 2.1 showed that the cultivar HUW 510 showed greater increase in yield when maximum and minimum temperatures were decreased as compared to HUW 234 and HUW 468. The increase in yield of HUW510 is due to increase in days to anthesis and maturity and decline in evapotranspiration and increase in water use efficiency on decreasing temperature which was more pronounced than other two cultivars. Thus HUW 510 showed a better adaptation for heat stress when sown timely as compared to other two varieties. The increase in days to anthesis and maturity provide a larger crop maturation period and thus helping to escape the heat stress. The temperature increase shortens the maturation duration and accelerate the growth and development processes of crops in all the cultivars studied. The study of the effect of different concentration of CO_2 and temperature variability on three varieties showed a similar effect in all the situations, however, at different rates. The small increase in temperature showed a positive effect in yield and number of grains per m^2 compared to baseline concentration of CO_2 for all the cultivars. However, when the temperature was increased further the yield and number of grains per m^2 decreased similar to other studies. As the temperature increased, the evapotranspiration of the crop increased due to increase in the soil evaporation and crop transpiration thus lowering the water use efficiency of the crop. The decrease in crop yield due to shortened maturation period also results in lowered water use efficiency [9].

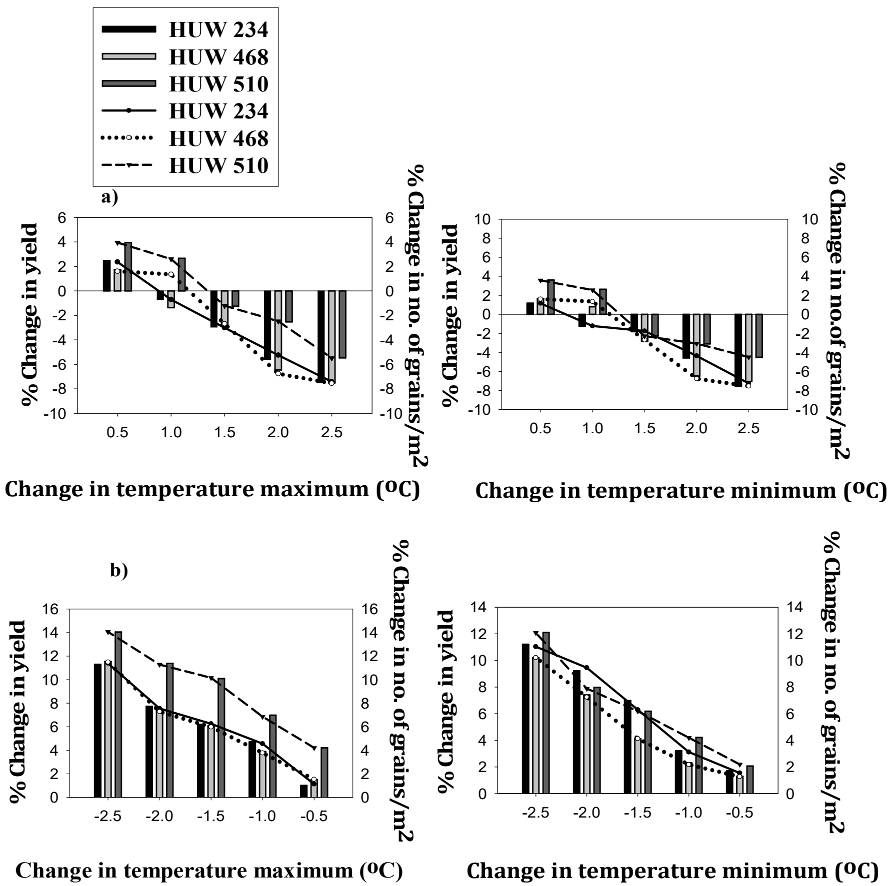

Fig. 3 : Percent change in yield and number of grains per m^2 with increase and decrease in maximum and minimum temperature w. r. t. temperature at baseline concentration of CO_2.

The increase in CO_2 concentration increases yield and number of grains per m^2 due to carbon fertilization. The effect of elevated CO_2 on yields shows 10-15% increase per 100ppm CO_2 compared to baseline. The result is in consensus with other studies, who reported 12% increase per 100 ppm CO_2 and 10-16 % increase per 100 ppm CO_2 increase compared to baseline respectively. The percent increase in wheat yield in the present study is 30-40 % which is in accordance with other study who found the increase in spring wheat at 30 to 65% in Spain [10,11]. CO2 fertilization results in the decrease of evapotranspiration by reducing stomatal conductance [12, 13].

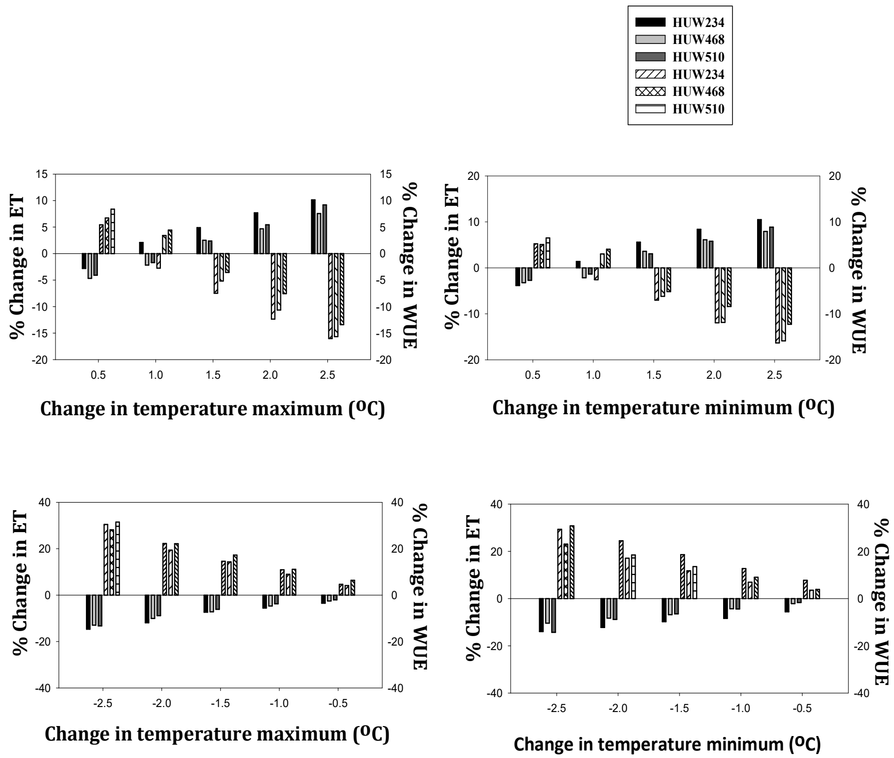

Fig. 4 : Percent change in physiology (water use efficiency and evapotranspiration) with increase and decrease in maximum and minimum temperature w. r. t. temperature at baseline concentration of CO_2.

Thus, crop models can be used to quantify abiotic stresses using the assumption that the responses to weather derived from experiments for different parameters are valid at regional scales. The crop simulation models assess climate change impact on crop production and explore the related mechanism is an effective way to provide some useful decision-making suggestions for food safety in the future.

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Some aspects of Temperature and Warming in Selected Locations of Maharashtra

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Abstract

Climatology and trends in the maximum and minimum temperatures for Pune and Kolhapur based on the data for the period 1971 to 2015 have been studied. In addition, mean temperature and Diurnal Temperature Range (DTR) for both the locations have been worked out to understand changes in both the temperatures. Results show an increasing trend in the minimum temperature during all the months and season of winter in both the locations (significant either at 95% or 90% confidence levels). There is no significant change observed in the maximum temperature during summer in Pune while slight decreasing trend observed in Kolhapur. High Temperature Days has also been worked out which shows no significant changes in both the locations during summer. The trends have been statistically analysed using Student t-test with various confidence levels.

Key Words: *Urbanisation, DTR, High Temperature.*

1. Introduction

In India, warming is on the rise in the urban areas due to deforestation, increase in the built-up area, increasing use of concrete etc, which alter energy balance (Manju Mohan *et al*, 2011). Urban warming is the phenomenon associated with increase in minimum temperature while maximum temperature remains unchanged. This is mainly due to absorption of long wave radiation by the building and roads leading to re-radiation in the night time which is continuous.

Impact of increased anthropogenic activities on the urban climatology has been studied elsewhere in the world and also in many locations of the country clearly indicates increase in the minimum temperature leading to continuous warming. Urbanisation also leads to increase in the absorbing and releasing aerosols due to increased construction activities which also indulge in the energy balance of the urban areas in clear contrast with adjoining rural areas (Ramachandran and Sumita Kediya, 2012).

Sahai (1998) opined that due to increasing population in many countries, urbanization and industrialization are spreading around the globe at an explosive pace. Micro-level climate change is already occurring in urban areas. Local temperature is one of the major climatic elements to record the changes in the atmospheric environment in these areas.

Many studies also indicate Urban Heat Island (UHI) effect which is due to rapid and unplanned urbanisation of cities and reduction in vegetation leading to increased rise in temperature compared to non-urban areas. Many workers studied UHI in various locations of the country and brought out the impact of urbanisation on the climate [Pramod Soni *et al* (2017), Kandya (2015), Manju Mohan *et al* (2011)]. Effects of heat wave rise in urban areas due to population density, close concrete structures etc lead to Urban Heat Island (UHI) effect. Pollution and dust also trap the heat in the urban areas. Incidence of heat strokes, dehydration and deaths are also observed.

Incidences of heat waves and high temperature are on the rise which have serious ramifications in the society. As per IMD Forecasting Circular (No. 5/2015), heat wave is a condition when maximum temperature departure from normal is 4.5°C to 6.4°C and severe heat wave is a condition when maximum temperature departure from normal is more than 6.4°C for the regions were the normal maximum temperature is more than 40°C.

As per Ahmedabad Heat Action Plan (2017), Ahmedabad experienced a major heat wave during May 2010, as the temperature reached 46.8°C. There was a need for proper mitigation strategy to combat excess heat. Subsequently Heat Action Plans were prepared and evaluation shows positive outcomes in reducing mortality during the hottest months of the year in Ahmedabad. During historic heat wave in the country in 2015, over 2300 deaths across the country were reported. However, Ahmedabad reported fewer than 20 heat-related deaths.

In the present study two urban locations of Maharashtra – Pun and Kolhapur – have been selected to investigate long term trends and climatology of both maximum and minimum temperature along with mean temperature and DTR. Trends in High temperature days have also been studied for both the locations.

2. Data and Methodology

Long term maximum and minimum temperature data for the period 1971 to 2015 for Pune and Kolhapur locations has been collected from National Data Centre (NDC), IMD, Pune. Data for the years 2010 and 2013 has been missing for Kolhapur. Hence, a total of 45 years' data for Pune and 43 years for Kolhapur have been used in the present study. The data have been quality checked before using for analysis. Pune and Kolhapur locations have been selected in the present study as the locations witness urbanisation with increasing population density.

From the data, mean minimum temperature during the months (Jan-Feb) and season of winter, mean maximum temperature during the months (March-May) and season of summer, mean temperature [(Tmax + Tmin)/2] during all the seasons (winter, summer, southwest monsoon and post-monsoon) have been worked out. In addition, trends in all the above parameters during the corresponding seasons have also been worked out.

Diurnal Temperature Range (DTR) – difference between Tmax and Tmin - has also been worked to assess the long term changes in minimum temperature.

In addition, increase in maximum temperature has also been investigated by developing High Temperature (HT) Days. HT Days has been fixed based on Human Body Core Temperature – when the maximum temperature is more than 37°C, which leads to hyperthermia (Jaswal *et al,* 2015). Mean, standard deviation and coefficient of variation had also been worked out for HT days for both the locations. In addition, maximum no. of HT Days which occurred during the months and season of summer has been worked out.

Significance in the trends in the parameters has been ascertained using Student's t-test at 99%, 95% and 90% confidence levels.

3. Results and Discussion

3.1 Minimum and maximum temperatures and their trends

Results on minimum temperature during the months and season of winter and maximum temperature during the months and season of summer for both Pune and Kolhapur are presented in Table 1 and also in the Figures 1 and 2. Trends in all the above parameters during the months/ seasons have also been presented.

Mean minimum temperature during winter is 11.7°C in Pune and 15.8°C in Kolhapur. Minimum temperature in both the locations show an increasing trend (significant either at 95% or 90% level). In addition, minimum temperature exhibits increasing trend in all the months of winter in both the locations (Table 1 and Fig. 1 and 2). Omvir Singh *et al* (2013) has found similar results and attributed increase in the temperature (in two phases) to urbanization in Doon Valley, Uttarakhand.

Kandya (2015) has observed that the diurnal temperature range (DTR) over Delhi region is decreasing rapidly. The DTR for Delhi was 12.48 degrees in 2001 and reduced to 10.34 degrees in 2011, indicating that the minimum temperature is steadily increasing. This has been attributed to the urban heat island (UHI) effect and urbanization over the years. Heat is absorbed by the roads and buildings in the day-time and released at night leading to increase in minimum temperature. Urbanisation-related warming has been observed elsewhere in China (Jun Wang and Zhong-Wei Yan, 2016), Korean Republic (Kug and Ahn, 2013) and Greater London (David Grawe *et al.,* 2013).

Mean maximum temperature is 36.7°C for Pune and 36 °C for Kolhapur during summer season. There has been varying trends observed in the maximum temperature in both the locations during various months and the season of summer. However, a decreasing trend has been observed over

Table 1. Mean (°C) and trends (°C/decade) in min. and max. temperature in Pune and Kolhapur.

Parameter & Season / month	Pune		Kolhapur	
	Mean (°C)	Slope (°C/decade)	Mean (°C)	Slope (°C/decade)
Min Temp – winter season				
Jan	11.1	0.25*	15.1	0.25*
Feb	12.2	0.26*	16.6	0.22*
Winter	11.7	0.26*	15.8	0.23*
Max Temp – Summer season				
March	35.5	-0.04	35.6	-0.21*
April	37.7	0.03	36.9	-0.22*
May	37.0	0.06	35.6	-0.21*
Summer	36.7	0.02	36.0	-0.28**
Mean Temp – winter	21.2	0.17*	23.6	0.06
Mean Temp – Summer	28.1	0.06	28.6	-0.05
Mean Temp – SWM	26.1	-0.19	24.7	-0.001
Mean Temp – Post-monsoon	22.5	0.32*	24.2	0.17
DTR – winter	19.1	-0.19	15.7	-0.33**
DTR – Summer	17.3	-0.06	14.6	-0.26
DTR – SWM	7.4	0.04	6.7	0.01
DTR–Post-monsoon	15.7	-0.19	12.4	-0.21

** significant at 99% confidence level; * significant either at 95% or 90% confidence level.
DTR – Diurnal Temperature Range.

Kolhapur (-0.28°C/decade) during summer and similar trend observed in the months of summer in Kolhapur. No significant change has been observed in the maximum temperature in all the months and season of summer over Pune. Rathore *et al* (2013) observed that state-averaged mean maximum temperature over Maharashtra shows increasing trend during summer.

Pramod Soni *et al* (2017) and Meywerk and Ramanathan (1999) had opined that increase in absorbing aerosols due to urbanization influence solar radiation by absorbing radiation leading to atmospheric heating at tropospheric level. Ramachandran and Sumita Kedia (2011) has observed that aerosol radiative forcing in the atmosphere peaks to 54 Wm^{-2} during post-monsoon over urban- and industrialised location of Ahmedabad.

Table 2. Statistical details of High Temp (HT) Days during summer in Pune and Kolhapur.

Parameter	March	April	May	Summer
Pune				
Slope	-	0.039	0.073	0.11
Mean	7.6	20	15	42.7
Std Dev	5.4	4.3	5.5	9.6
CV	71.5	21.4	37.0	22.4
Max no of HT Days (Year)	19 (1977, 2004)	28 (1973)	26 (1983)	73 (1971)
Kolhapur				
Slope	-0.107*	-0.11	-0.096*	-0.313*
Mean	8	16	8	32.5
Std Dev	5.3	6.0	4.2	10.4
CV	63.5	38.3	50.3	32.1
Max no of HT Days (Year)	21 (1985)	28 (1973, 1975)	21 (1980)	59 (1973)

* significant either at 95% or 90% confidence level.

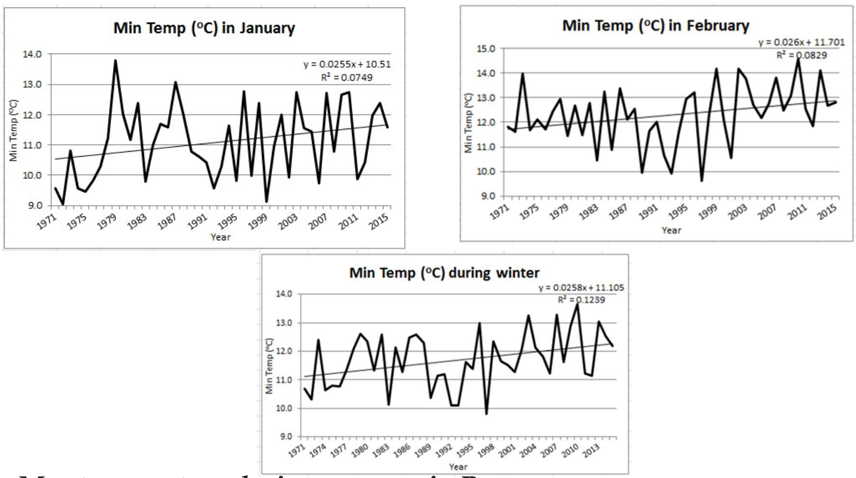
3.2 *Mean temperature, DTR and their trends*

Results on mean temperature and Diurnal Temperature Range (DTR) during all the seasons - winter, summer, southwest monsoon (swm) and post-monsoon for both Pune and Kolhapur are presented in Table 1. Trends in all the above parameters during the months / seasons have also been presented.

Mean temperature over Pune during winter is 21.2°C which shows increasing trend of 0.17°C/decade (significant at 95% level). During all the remaining seasons, mean temperature has been found to be 22.5°C, 26.1°C and 28.1°C during post-monsoon, southwest monsoon (swm) and summer seasons, respectively. No significant changes have been found in the mean temperature in these remaining seasons. In Kolhapur, the lowest mean temperature of 23.6°C during winter and highest mean temperature of 28.6°C during summer season have been found. However, there has been no significant change in the mean temperature during the seasons in Kolhapur (Table 1).

Diurnal Temperature Range (DTR) has been found to be the lowest during winter (7.4°C in Pune and 6.7 °C in Kolhapur) and highest during winter (19.1°C in Pune and 15.7°C in Kolhapur). However, there has been no significant change in the DTR during all the seasons in both Pune and Kolhapur (Table 1). Rathore *et al* (2013) observed that DTR shows increasing trend during winter, summer and southwest monsoon seasons over Maharashtra. Archana Rai *et al* (2012) analysed long-term Indian temperature data and found a significant increasing trend of 0.484, and 0.52°C (100 yr)$^{-1}$ in mean (T*mean*) temperature and DTR, respectively, during the period 1901–2003.

a. Min temperature during winter in Pune



b. Max temperature during summer in Pune

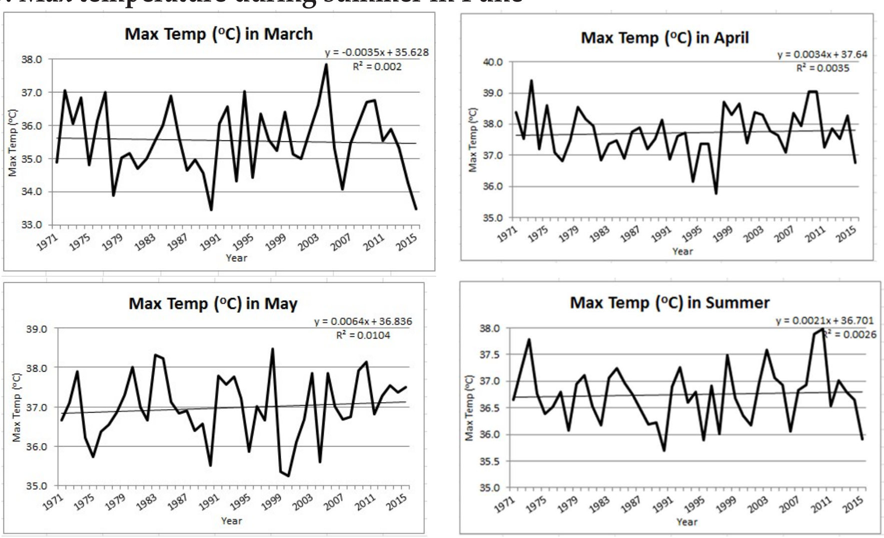
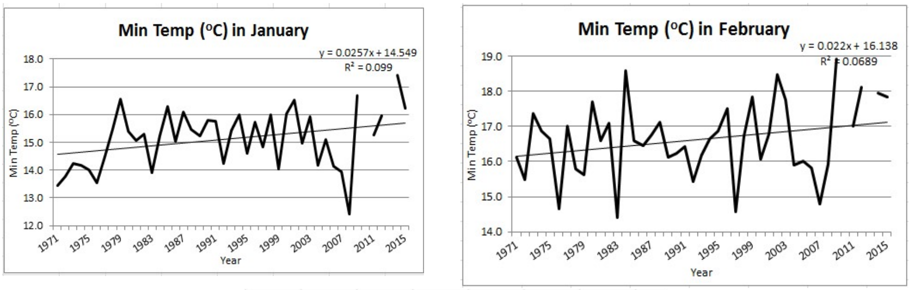


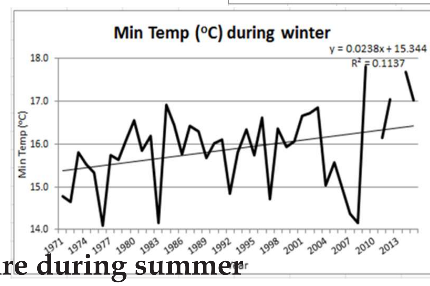
Fig. 1 : Min and max temperature during winter and summer seasons in Pune

3.3 High Temperature (HT) Days:

Statistical details of HT Days along with trends during summer season in both Pune and Kolhapur are presented in Table 2. Mean HT Days during March to May varies from 8 to 20 in Pune and 8 to 16 in Kolhapur. During summer season, Pune exhibits 43e mean HT Days and Kolhapur exhibits 33 mean HT Days.

a. Min temperature during winter





b. Max temperature during summer

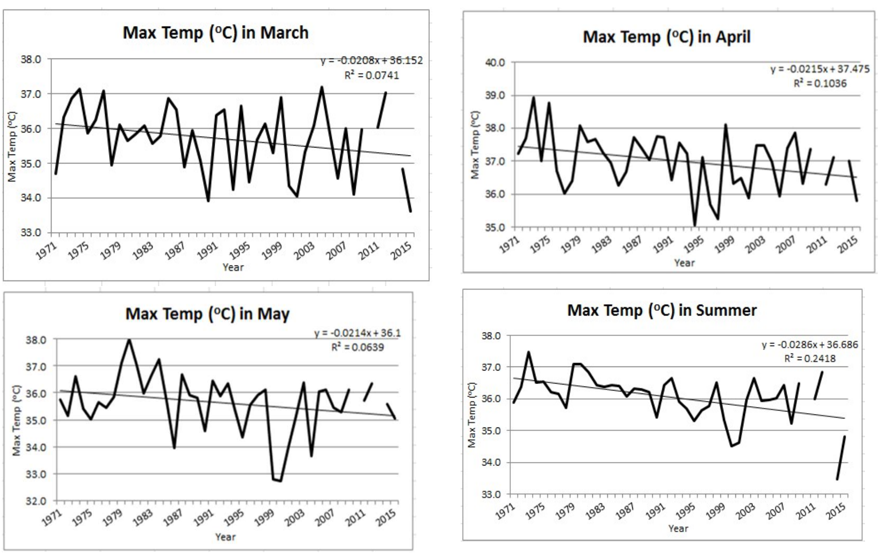


Fig. 2 : Min and max temperature during winter and summer seasons in Kolhapur

Standard deviation in HT Days varies between 4.3 and 5.5 in Pune and 4.2 to 6 in Kolhapur during March to May. Standard deviation in HT Days during summer has been 9.6 in Pune and 10.4 in Kolhapur. Coefficient of variation in HT Days has been the maximum during April – 71.5 in Pune and 63.5 in Kolhapur.

Analysis also reveals that maximum no of HT days in a month / season of summer occurred in varying years in both the locations. Highest no of HT Days (28) occurred in 1973 in both the locations. During summer, highest no. of HT Days (73) occurred during 1971 in Pune and a maximum of 59 HT Days had been observed during 1973 in Kolhapur.

Jaswal *et al* (2015) found a steep increase in HT days in highly populated cities of Mumbai, New Delhi, Chennai, Jaipur and Visakhapatnam during the period of 1991–2013. The HT days over southern India show significant positive correlation with Nino 3.4 index.

4. Conclusions

From the analysis of long term data – T*max* and T*min* for the period 1971 to 2015 for Pune and Kolhapur, following conclusions are drawn:

1. An increasing trend in the minimum temperature during all the months and season of winter in both the locations (significant either at 95% or 90% confidence levels).
2. Mean temperature during winter in Pune shows an increasing trend (significant at 95% confidence level).
3. No significant change observed in the maximum temperature during summer in Pune while slight decreasing trend observed in Kolhapur.
4. Trend in the High Temperature Days shows no significant changes in both the locations during summer.

The analysis has been carried out in a single-phase manner during the period 1971 to 2015. Analysing the data in two different phases – 1971 to 2015 and 1981 to 2015 – would bring more details on warming in the locations due to urbanisation activities.

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