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FROM THE DESK OF THE EDITOR

This volume of National Geographical Journal of India (NGJI) is being brought as a special volume on Environmental Issues in memory of Prof. Shanti Lal Kayastha, who left for heavenly abode on January 6, 2018. Prof. Kayastha was a well-known geographer and an environmental scientist of international repute. He contributed a great deal on theme of spatial dimension of environment in relation to society through rigorous research and teaching. Prof. Kayastha initiated research on theoretical and practical aspects of environment and environmental hazards in India on a systematic basis. He guided some of his research students on themes of concepts, perceptions and problems of urban pollution, flood plain and human adaptation, rural water supply, population and impact of development on environment.

Prof. Kayastha was the Editor of the NGJI since its inception in 1955. His association with the journal was for over three decades. He served the journal with remarkable commitment and sincerity. Being the Editor of a journal involves hard work, commitment and patience. Prof. Kayastha, not only looked after the academic content of the papers he received but also their language. During those days, it was difficult for geography teachers and researchers to obtain information about academic events and geographical news about India and the world. An important highlight of the NGJI, when he was at the helm as the honorary editor, was the appearance of Notes and News of geographical importance.

His colleagues, students and admirers assembled to mourn his death. On that occasion, one of the colleagues floated the idea of bringing special issues of NGJI as a befitting tribute to Prof. S. L. Kayastha. The idea was informally discussed amongst the colleagues of the department. Subsequently, the President of NGSI and Executive Committee resolved to go ahead with the idea. It was also decided to combine fours issues of the journal into two special issues; one on Environmental Issues and second on Population Geography. The editor contacted senior geographers and academicians from different parts of the country. It is extremely heartening to note that the editor received sufficient number of research papers within a very short period of time for two special issues of NGJI. With the support of the editorial board of the journal, these papers were edited, processed and organized. This issue contains 23 papers on themes of environment and related issues including reminiscences and biography of Professor Kayastha. Anand Mohan and Arvind Mohan have penned down and reconstructed the personality out of his reminiscences magnificently. Sarfaraz Alam has written a brief biographical memoir of Prof. Kayastha where in he has provided an account of his academic and professional achievements. H.S. Sharma has contributed his paper on issues and challenges of environmental sustainability in India. In the paper, he has discussed environmental problems faced by India in great length. Ranjan Basu has discussed in detail the status of biodiversity. Sachin Kumar and B.S. Marh have contributed their paper on need for scaling up community driven green livelihood initiatives. They have convincingly argued as to why small initiatives matter and play vital role in conservation of environment. Sneh Gangwar and Baleshwar Thakur have provided a vivid account on disaster, displacement and rehabilitation with a focus on Kosi floods in North Bihar. M. Okenndro and

R.A.S. Kushwaha have discussed landslide hazard zonation in and around Litan village along NH202, Ukhrul district of Manipur that puts serious constraints on communication of Manipur with other parts of country. S.C. Rai and Mukesh Kumar have discussed challenges and problems of use and conservation of Kabartal Wetland ecosystem of Bihar. Swati S. Nanda has conceptually dealt with connection between women and natural resource management from the perspective of developing countries. Nilotpal Kalita et. al. have attempted an experimental study on estimation of soil loss sensitivity in the Jinari river basin using universal soil loss equation. Alka Singh and V.N. Sharma have described the extent and causes of deterioration of Ramgarh Lake of Gorakhpur district of Uttar Pradesh.

R.C. Joshi and Masoom Reza have made an interesting study of the selected central Himalayan villages. Nityanad Deka and A. K. Bhagabati have highlighted pertinent issues related to ecology and economy of a village environment of the Brahmputra valley of Assam. Salahuddin Quereshi has dealt with perspectives on urban climate change and policy measures in India. Bikramaditya K. Choudhary and A. K. Tripathi have made their scholarly contribution to the theme of urbanization and urban climate. Arindam Dasgupta and Suman Paul have discussed salient features of urban sprawl of Barddhaman district of West Bengal and its impact on land use and socio-economic condition. Amrita Dwivedi and V. K Kumra have made their contribution on societal perception of waste water management and condition of holy river Ganga in Varanasi city. Ghazal Salahuddin paper is on issue of sustainability of Ahmadabad. Dipak Prasad and Srabani Sanyal have written their paper on water quality assessment of pond water in Jaunpur City. Shweta Yadava, Rashmi and Ram Bilas have written their paper on the topic Environmental Impact Assessment of River Ganga. Praveen Kumar Rai, Varun Narayan Mishra and K. N. P. Raju have submitted their paper on methodology and applications of remote sensing and GIS in environmental mapping monitoring.

I heartily congratulate all the authors and co-authors for contributing to this special volume. It is my firm belief that this part of the 64th volume would be well received by academia and professionals in teaching and researchers in Universities and Colleges.

Ram Sakal Yadava
Editor, NGJI

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Reminiscences of Professor Shanti Lal Kayastha

Anand Mohan[1] and Arvind Mohan[2]

यहाँ की है यह पवित्र शिक्षा।
कि सत्य पहले फिर आत्मरक्षा।। (कुलगीत- काशी हिन्दू विश्वविद्यालय)

Prologue

The spirit force behind this beautifully composed "Kulgeet" of Banaras Hindu University was adopted by our father in letter & spirit and he led a pious and peaceful life in the holy city of Varanasi.

Our father maintained a highly disciplined routine throughout his life span. 'Early to bed, early to rise'; a simple living and high thinking and frugal life style were his standard yardstick. Offering morning prayers, listening to BBC radio news, long morning walk, reading editorial column of the "The Statesman Newspaper" and scribbling diary in beautiful handwriting made a fine start of his day. He encouraged us to learn Hindi and advocated for a Hindi daily newspaper. Apart from academics, he had a passion for photography, was an enthusiastic swimmer who crossed Ganga in one go and started Boat & Swimming club of BHU as its chairman. The typewriter remained as his handy companion along with rich collection of National Geographic magazines, Reader's Digest and Mont Blanc pens.

The biggest attractions for all of us were his lively discussions during dinner at the dining table. Father would talk on wide ranging topics which everybody always eagerly looked for. He inculcated in us fine habits of dining together. While eating, he desired that family should talk on different issues rather than involve in newspaper or magazine reading, watching T.V. etc. Much of the narration in the following pages is a consequence of the information we have gathered over a period of time during such family dinner culture.

Journey from Kangra to Varanasi

After submitting an application on plain paper, stating qualifications and experience, while working as Lecturer in Government College, Rupar, father received a telegram; "Appointed Assistant Professor in Geography, Banaras Hindu University, Grade Rs. 250-15-400/20-600 Join Immediately". As expected, grandfather was very pleased to know about his appointment and further entrusted him with the responsibility of higher studies of his brothers from this famous

1. Professor and Registrar, Dayalbagh Educational Institute, Agra.
2. Professor, School of Biotechnolgy, Banaras Hindu University, Varanasi.

seat of learning (B.H.U.). Grandfather stated that he had been to Allahabad only accompanying Lala Lajpat Rai as a volunteer for social work, stayed in Kayastha Pathshala of Justice Shankar Saran and returned from there.

In the midst of a major shuffle in life, father felt the fear of losing his old job at Rupar versus the new offer from B.H.U. His anxiety was put to rest by his mentor Sir Bakshi Tek Chand, who had drafted the Constitution of India with Shri B.R. Ambedkar and Justice Rao. Finally, father boarded Amritsar-Howrah Mail at Amritsar and reached Varanasi Cantt. station on 13.7.1948. He hired a tonga (a horse-driven vehicle) to Banaras Hindu University, Malviya Bhawan, the residence of Pundit Govind Malviya ji, Pro-Vice-Chancellor of B.H.U. After getting his papers checked there, he got the joining report at office-residence of Dr. Amar Nath Jha, Vice-Chancellor of B.H.U. and finally reported to Dr. H. L. Chibber, Head of the Geography Department. Dr. Chibber, originally a reputed scholar of Geology, was a strict disciplinarian. He often attended the lectures, to observe teaching skills of the young faculty. This drove father to work for long hours; reading new books, making notes for lectures because he never believed in short cuts. The Department of Geography then had a small teaching staff; they also had to take classes in Central Hindu College at Kamachha.

Early days in B.H.U.

Pundit Govind Malviya ji allotted him residence in Holkar House for 14 days. He advised the Assistant Estate Officer, Shri R.N. Vyas to let stay there for 3 months.

During 1948-51, father had to shift to a number of places for residence. He was given one room in a house, which was later occupied by Prof. R.S. Tripathi, Professor of History and Principal of Arts College. Later on, Dey Baba asked Shri R.N. Vyas to allot a house to father. He was allotted the first floor of New E/2 (near B.H.U. Post Office) while Prof. Ahuja and family occupied its ground floor. It was whispered that the former occupant of this house had died due to tuberculosis and university professors were reluctant to stay in that house. Father happily stayed there for 3 years or so and Prof. Ahuja until his retirement. Prof. Krishan Kumar ji of College of Agriculture resided in the adjoining, New E/3, house. He was Professor of Plant Physiology in Agriculture College, B.H.U. He was very gentle and kind and they often walked together for their Institutions. His son Shri Prem Saran Satsangi studied in the Children's School located opposite to their residence (now Kendriya Vidyalaya) later on became the Eighth Spiritual Head of Radhasoami Satsang, Dayalbagh. Nobody then knew that as part of the destiny, this connection will forge the road ahead for *satsang* seed in our family.

Opposite to father's house lived Prof. A.K. Narain (Professor of Ancient History and Culture) with his uncle Bhikku Kashyap (in Budh-Kuteer). Incidentally, both of them bought their first 'Raleigh' bicycle together from Piplani Katra.

In those days, the Vishwanath Temple in B.H.U. was under construction and its finer details were narrated to father by the manager of the temple when he joined their mess. This is said that Birla ji's father used to come in a horse driven *baggi* to see the development of construction of temple. After the temple was built, a plaster of Paris statue of Malviya ji made in B.H.U. was taken to J.J. School of Arts, Bombay by Prof. Trilochan Pant where a bronze statue was casted and erected outside facing the Vishwanath temple.

Research path finder

A memorable event in father's work in B.H.U. was the discussion with Professor A.E. Morgan, a member of the National Commission on Education, headed by Dr. S. Radhakrishnan. The third member was Dr. Zakir Hussain. Father was asked by the Vice-Chancellor, B.H.U.

to look after Prof. Morgan. The Commission stayed and held its meetings in the Nadesar Palace, Varanasi Cantt. As advised, father used to go to Nadesar Palace and see that Prof. Morgan was comfortable. He enquired if father was doing any research. It was mentioned that that he has been advised to work on "Geographical Investigations in the Himalayas" to which, he took exception and observed "that does not make the thread of research tight". He suggested father to work on a river basin, which is natural geographical unit. Father told him that this was an onerous task because of inaccessible terrain, non-availability of toposheets of the study area and lack of even rudimentary data. But, Prof. Morgan insisted to take up this challenge. He told him that he had been Chairman of Tennessee Valley Authority, Vice-Chancellor of two universities, and presently President of Land Grants College. So, "take heart and work". Dr. Radhakrishnan came in and asked "Who is this young man, you are so fond of? We have a meeting in 10 minutes".

This exhortation of Prof. Morgan had a lasting effect. It stayed with father, and finally he decided to work on the "The Himalayan Beas Basin: A Study in Habitat, Economy and Society". It was a very difficult job. This basin his lay unit between River Ravi in the North and River Sutlej in the South, in hilly and rugged mountainous terrain. It was large and wide unit; River Beas extended from Rohtang Pass near Lahul and Spiti to Mirthal. Both data and source-materials were almost non-existent. The source data was in Lahore, now in Pakistan, and the study area was here, in India. Toposheets of the area were restricted by Government of India. There was no administrative unit existent then as Himachal Pradesh. It comprised of long Kangra district that included Kulu sub-division, Mandi State and part of Chamba State. It was thus divided up. Communications were pitiable and rough, entailing footpaths and pony trails. Bus service was also poor. There were no hotels or restaurants and one had to live literally in the countryside. With faith in the 'Divine Power that Sustains' and his own enthusiasm, he plunged into icy cold water of River Beas and its uncharted terrain, moving from place to place during all summer and Puja vacation every year. Prof. V. V. Narlikar helped to obtain toposheets of the area for legitimate research work. The Defense Secretary was Prof. Narlikar's friend in Cambridge and thus he got the toposheets finely scissored out frontiers bordering Pakistan, Lahul & Spiti and Tibet. Dr. M. S. Krishnan, Director-General of Geological Survey of India kindly helped in getting them mounted on cloth and folded into a handy portfolio. Father could also get useful data and maps on Geology of the area. Forest Research Institute (F.R.I.) Dehradun helped to provide details of actual distribution of various forest types in climatic regions of basin area that varied from tropical to sub-arctic. Data had to be collected on hydrology of river Beas and tributaries by actual measurements and from office records, visits to offices of Agricultural Department, revenue record offices of Kanungos and Patwaries, tahsil and district offices to read gazetteers and settlement reports. The finance altogether was very exhausting. Father also made his own surveys of villages and towns. Along with his younger brother, Sh. Om Prakash, they would carry handy luggage, some ration and cooking utensils, stove etc.; so that one could make *'Khichri'* for food; often the food was worse than that of a beggar. But somehow it sustained them. Footsored and bone-tired, they would seek safe place for night-rest; any shop, *sarai*, shepherd's dwelling, whatever that was there, to get a night rest. Often they trudged on foot, crossing streams and high mountain passes like Rohtang Pass. The glacier and moraines were slippery and only luck and god's grace helped them to traverse such remote places. These ordeals and tribulations bore fruit in completing field-work, for writing the thesis and drawing maps and dia-

grams. Entire summer and Puja vacations were spent for over the years in the field work.

At the end of summer vacation of 1955, when father returned home to tell his parents that he has finished field-work and could do the thesis writing and preparation of maps in Varanasi; they felt very happy.

He finally completed and submitted his Ph.D. thesis in 1957 for evaluation. Prof. L. D. Stamp, Director of London School of Economics, and Prof. S.P. Chatterji, Head of Geography Department., Calcutta University and Director, National Atlas & Thematic Mapping Organization (N.A.T.M.O.), were examiners. He received his Ph.D. degree in 1958. His thesis was published by Banaras Hindu University. In 1965, the N.G.S.I. started its Journal: *The National Geographical Journal of India*. In the first issue was his article on Himalayan Beas Basin: A Hydrological Study. Soon, he received a request for permission to reprint it in the Journal of Hydrology and River Valley Development, Calcutta.

Blessed marriage

Father wanted to settle down after 7 years of his arrival in B.H.U. His marriage took place in October, 1955, and he brought our mother, (Kusum) to Gurtu Hostel residence where he was a warden. She organized the house very well and used to prepare nourishing food for well all. She belonged to a noble *Satsangi* family from Himachal. Her maternal grandfather, Late Hemraj Ji was a friend and class-fellow of Param Guru Huzur Mehtaji Maharaj in Govt. College, Lahore. When sometime in 1957, Param Guru Huzur Mehtaji Maharaj visited Banaras; mother expressed keen desire to go to the residence of Vakil sahab, Shankar Saran Lal Ji, and obeisance to making before Gracious Huzur Mehtaji Maharaj. When she bowed before him, he at once recognized her and asked "How are you here, a Pahari girl?" She said that she was married to S. L. Kayastha who is Professor in B.H.U. Gracious Huzur remarked 'Lecturer not Professor' and very kindly enquired if her husband had come here and on affirmative reply, he said let him come. Awaiting his turn, father went and bowed before him and was blessed with *'Prasad'*. I (Anand) was a child and was on the lap.

Passage of time from Gurtu Hostel to 'Akhnoor Hut'

New hostels were built in the B.H.U. campus. Pundit Govind Malviya asked to suggest to Acharya Narendra Dev, new Vice-Chancellor of B.H.U. to name one of the hostels in the name of 'Darbhanga', as Maharaja of Darbhanga had helped B.H.U. when B.H.U. was short of funds. Acharya ji was a bit of socialist. He did not approve of Maharajas and Rajas and hostels were named as Dr. I.N. Gurtu and Dr. S. Radhakrishnan.

Father served as warden of Dr. I.N. Gurtu hostel for 3 terms between 1952 and 1956. In those days, there was no hotel in Lanka (shopping area). Aiyyar's Café provided only coffee and dosha. So he was not happy to organize work, food, administration and research activities.

Many students of fame lived there, Namvar Singh, Kedar Nath Singh. Both became Professors of Hindi in J.N.U. and Delhi University. Shri Ram Pratap Singh also lived there; the Mr. B.H.U. (Best Body). He studied Calisthenics in Sweden and became Director of Physical Education in Modern School, New Delhi and many such others. Gurtu hostel was nerve centre of B.H.U. but it was peaceful and Prof. V. V. Narlikar appreciated this. (it was famous for Prof. Narlikar to chant *slokas* while bathing and they had put blackboard in their house to let Jayant and Anant, the two sons, to solve mathematics problems. Both practices had lasting impact on their children. We also followed these good practices, i.e., reciting *sabda path* and use of blackboard in our house. Father cared for

students, helped them pay fees, and took them for treatment and buy medicines. Later, father was allotted New G/4 in Jodhpur Colony (opposite B.H.U. Staff Club), formerly occupied by Prof. B.G. Ghanekar where he lived till retirement for 26 years. Prof. Ghanekar during his long stay had developed the area with many useful trees; lemon, jack fruit, tamarind (Imli), guava, jamun, neem, mango, phalsa, etc.

Prof. Ghanekar was a devotee of Hanuman ji. He had repaired the temple of Hanuman ji located in Principal's colony. On Hanuman Jayanti day there was ceremonial worship including Shehnai, tabla, lights and puja. Entire Ghanekar family used to visit on this day from Pune, as long as they lived. Prof. Chittar Singh and family used to take care of the small temple afterwards. As children we looked forward to receiving the *Prasad* (Peda).

Our new home (New G/4, Jodhpur Colony) was lucky for all of us. Father's brothers (Ved Kayastha, 1954; Rajeshwar Kumar 1955-63) and cousin brothers (Brij Gupta, 1954; Surendra Mahajan 1952; Madan Gupta 1949), both sons (Anand and Arvind); grandchildren (Kanika, Hans, Kanwal, Arpan; Swami Das (brother-in-law) received their education at B.H.U. while staying with him. This demonstrates that in true sense, parents were kind and large hearted. It goes without saying that parents put up a brave face during hardships and odds. Father had a passion for work; he did teaching, research and also tabulation work. I (Anand) recall that in a summer noon when father sweating all over would come home on bicycle for lunch, I shall not open the door till he gave me a pan (betal). We had badminton court in New G/4 where all of us enjoyed playing badminton in the evening.

In 1969, father bought a brand new Ambassador Car when very few people in B.H.U. had a car. The family car, which was lucky for all of us now this vintage car is maintained by Anand in Dayalbagh. Father was informed in 1969 by Dr. Braj Mohan of 2 plots being sold in Nand Nagar (close to B.H.U.), which he purchased from Bhardwaj brothers (One of wher was Lecturer in Law Faculty, B.H.U.). During 'Emergency', he slowly built up the residence, and named it ‘Akhnoor Hut’ (’Akhnoor’derived from beautiful location 28 Km from Jammu, in the foothills of the Himalayas, on the banks of the Chenab River). By the time of father's retirement in 1984, our beautiful home 'Akhnoor Hut' in Nandnagar was ready and we shifted there and lived happily for more than 30 years. We have planted fruits and flowers and for us it is a blessed house to live in. Father enjoyed a morning walk every day with Arvind in the ambient surroundings of B.H.U.

Some passing events

At one point in life father was appointed (in absentia) as Professor and Head of Geography Department, Raipur University. But Prof. K.L. Shrimali, the then Vice-Chancellor of B.H.U, conveyed that Madhya Pradesh was not the right choice for Kayastha. On the advice of Prof. V. V. Narlikar to consult a special person in the city, father went there. The person remarked that Banaras is shubh (anspicions) for you and advised not to leave. So father stayed on in Varanasi eventually lived here for over a long period of 65 years.

Another event narrated by father was during his stay in a small hotel in Manali doing research work, a Bengali lady asked him about his work. He told her that he was Assistant Professor of Geography in B.H.U. doing research work on Himalayan Beas Basin. She said that she knows B.H.U because her father, Prof. Majumdar was also a teacher in B.H.U.. He had three daughters; one daughter married Professor Kriplani. This sister later became the first women Chief Minister of Uttar Pradesh, Sucheta Kriplani. Another sister married Prof. S. Chawla of Mathematics, who shifted to Government College, Lahore, and was guide of Prof. R.P.

Bambah, a renowned mathematician and who later became Vice-Chancellor of Punjab University, Chandigarh. Prof. Bambah was one year junior to father in Government College, Lahore and both shared the same mess, as both were vegetarians.

Once, Prof P.K. Parija (Pro-V.C. of B.H.U., who later became V.C. of Utkal University) asked father to receive a lady coming from London. After receiving her, on their journey to B.H.U., father enquired about her work in London. She said that she has her own laboratory engaged with many researchers. She was a botanist and ecologist of international repute. She had come at the invitation of Pt. Jawahar Lal Nehru, Prime Minister of India, to organize the Botanical Survey of India. Later, when father read the book "Lilavati Daughters", he found that her name Edavaleth Kakkat Janaki Ammal was there. She was a simple lady and devoted scientist, and India is proud of her.

Post-retirement spiritual activities

On the day of his retirement on the 30 March 1984, father received an invitation from Dr. (Mrs.) G.P. Sherry, Director, D.E.I., to deliver a lecture there. Father was a bit hesitant for a while but mother mentioned that 'Seva (service) in Dayalbagh' is an auspicious and rare opportunity. He delivered lecture on 2 April 1984 (The Dayalbagh Herald, April 17, 1984, p.1). Later, he joined as Senior I.C.S.S.R. Fellow in DEI and delivered a series of lectures and framed courses on Environmental Studies. Our mother desired that they married their sons in Satsangi families to which father agreed and both of us were married in two such families.

Even when father was not an initiated Satsangi, he visited Dayalbagh often, along with our mother for satsang and seva and was fortunate enough to receive benign blessings of Gracious Huzur Dr. M. B. Lal Sahab. Only by grace and mercy of Revered Param Guru Huzur Dr. Lal Sahab, he became initiated Satsangi on 16-2-1986.

Thankfully our parents our regularly visited Dayalbagh and continued to receive the divine grace and merciful blessings of most Revered Prof. Satsangi Sahab that remains as life time treasure.

On the 29th October 2015, along with Anand, Roopa, Arvind, Ritu, Swami Das, Purnima and other relatives and children, parents presented Prasad before Gracious Huzur who very kindly blessed them on Diamond Jubilee of their wedding. In the same evening, Anand arranged a small get together followed by dinner for family members. After prayer, children presented a short programme to honor their grand-parents, which also included reciting *Kulgeet* of B.H.U. which was composed by Dr. Shanti Swarup Bhatnagar. We are extremely fortunate to receive the divine grace and benign blessings of most Revered Gracious Huzur that we treasure in our lives as life time achievement.

Epilogue

We were a blessed family with our beloved father as family head. As school and college students we had the complete liberty to choose our subjects. Besides studies, we both enjoyed badminton for a number of years. From a small badminton court in the house where we played with parents, we moved to the University and both of us became B.H.U. badmitton team's Captains and represented in enter university meets. Back to studies, we both had the opportunity to go abroad for post-doctoral training; this helped us to shape our future course of research and studies. Father encouraged us a lot to excel in teaching and advised us 'never to be a boring teacher'. He also wanted us to maintain a standard in research, by way of publishing well. He interacted with his grandchildren all the time and guided them and made sure that ours is a happy family. We owe him a lot for what he did for all of us. Down to Earth, father was an institution in himself. Thank you so much dear father!

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Shanti Lal Kayastha
A Humanist amongst Human Geographers

Sarfaraz Alam[1]

Abstract

Prof. Shanti Lal Kayastha, a widely-acclaimed geographer and environmental scientist and a doyen of Indian Geography, was a wonderful confluence of multiple and to some extent divergent traditions- of the Himalayas and the Ganga Valley, of Banaras and Lahore, of Aligarh Muslim University and Banaras Hindu University, of colonial and post-colonial India. Born and spent his childhood in the Himalayan town of Kangra (then a part of Punjab State, but presently a part of Himachal Pradesh), he mostly lived and worked at Banaras Hindu University, situated on the bank of the river Ganga. He was one of those distinguished geographers from the Indian Sub-continent who studied as well as taught in both colonial and post-colonial India. He has the distinction of being one of those exceptional geographers from the Indian sub-continent who had studied as well as taught geography in both India and Pakistan. Prof. Kayastha was the strongest link between Aligarh and Banaras Schools of Geography. In his passing away, one of the most authentic connect in the Geographical Schools of Indian Sub-continent has been severed. It is precisely for these reasons that the mapping of academic trails of Prof. S.L. Kayastha is attempted here.

Early years and education

Shanti Lal Kayastha was born on March 30, 1924 in Kangra town of Himachal Pradesh, then a part of Punjab Province. His father, Late Madho Ram, a well known lawyer, was active in the public life of the Kangra town. Being an ardent Arya Samajist, he served the local Arya Samaj as its President for a number of years. After completing his school education from Dayanand Anglo Vedic High School at Kangra, young Kayastha joined Government College, Lahore (now known as Government College University, Lahore) for graduation in 1938. He successfully completed his graduation in 1942. During his stay there, he was taught by A.N. Kapur, a famous professor of geography and an alumnus of famous Butler Department of Geography, Aligarh Muslim University (AMU). There his roommate in the hostel was Mr. Dev Anand, who later went on to become one of the leading cine actors of Bollywood. During his times, the Principal of the College was famous sports administrator of India Shri Guru Dutt Sondhi, the first and the only Indian Principal during the colonial period (1939-1945).

During those days, AMU was the most important centre of geographical learning in the

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Indian Sub-continent. On the advice of his teacher, he joined Department of Geography of AMU for post graduation in 1942. He obtained his master degree in Geography in 1944. At AMU, he was taught by some of the top geographers of Indian Sub-continent of that time - Kazi S. Ahmad, S.M. Tahir Rizvi and Syed Muzaffar Ali. One of his illustrious classmates and life-long friends was Late S.M. Rafiullah (Professor of Geography at AMU Aligarh). Kayastha had interests in sports as well. He was the captain of prestigious Riding School of AMU. It is from his stay in Aligarh Muslim University that he had imbibed the dressing mannerism and culture of care. Interestingly, he was one of the three post graduates from AMU to join Geography Department of Banaras Hindu University during the formative years, others being Shri B.K. Dutt and Prof. Anand Swaroop Jauhari.

After completing his M.A., he served as a Lecturer of Geography in Fateh Chand College for Women, Lahore for a brief period in 1944. In the same year, he joined Government College, Rupar in Punjab (presently in Haryana). Geography Department was being established in Punjab University, Lahore. He appeared in interview for lectureship. But, he was offered the post of demonstrator. He declined the offer as he was already a Lecturer in Government College, Rupar. Prof. Kayastha taught in Government College, Rupar for about four years.

Banaras Hindu University

A new geography department had just been established (1946) in Banaras Hindu University under the leadership of legendry geologist and geographer Prof. Harbans Lal Chhibber. Young S.L. Kayastha was selected for the post of Assistant Professor of Geography in 1948. The Geography Department of Banaras Hindu University provided him the most ideal space and environment where he could hone his skills and explore his potential. In the first few years of his say in B.H.U., he worked very hard to sharpen his teaching skills. Then he enrolled for his Ph.D. in the same department under Prof. R.L. Singh. It would be important to note here that on the recommendation of his favourite teacher, Prof. Syed Muzaffar Ali, Kayastha got letter from the famous British geographer, Prof. L. Dudley Stamp, to enrol for Ph.D. research under his supervision. However, the very fact that he had to look after the financial and educational responsibilities of his extended family, he could not join under Prof. L.D. Stamp. Nonetheless, the turn of this event in no way dispirited Prof. Kayastha. He soon enrolled for his Ph.D. research in his own Department in 1955 under the supervision of Prof. R. L. Singh and after seven years of rigorous research, involving strenuous fieldwork in the difficult terrain and hostile climate of the Himachal Himalayas, he completed his Ph. D. in 1962. In this way, Dr. S.L. Kayastha acquired the distinction of being the first to obtain Ph.D. degree from the Department of Geography of Banaras Hindu University.

Shaping of the Department of Geography

After the untimely demise of Prof. H.L. Chhibber, he worked assiduously to build the department with Prof. R.L. Singh. For most, he would work silently without thinking about rewards. Right from the day of joining the Department, he played a key role in shaping it in various capacities - as an excellent teacher, as a hard working researcher, as an innovative research guide, as an effective head of the department, as a scholarly editor of the National Geographical Journal of India, as an active office bearer of the National Geographical Society and as an active member of various committees.

Prof. Kayastha was a dedicated teacher with tremendous sense of discipline. He would explain his students the geographical significance of national and international events of contemporary times. He would instill in his stu-

dents the value of geographical perspectives. According to his students, Prof. Kayastha's classroom lectures were always contemporary and updated no matter what topic he was teaching. He used to add recent data, information and insights into his day-to-day lectures from newspapers, magazines, journals and books. At times, he used to carry newspaper in the classrooms when he had to discuss events of geographical significance. He was very meticulous in whatever he did in the classroom, from the lecture delivery to checking of practical files. His students tell that Prof. Kayastha used to carry scale and protector for evaluating practical files in practical classes and would measures drawings with micro precision.

One of the major contributions of Prof. Kayastha was giving scholarly profile and direction the National Geographical Journal of India, a quarterly journal published by the NGSI. Prof. Kayastha was the Editor of the NGJI since its inception in 1955. It was a long association of over three decades. The works of editors become even more challenging when he/she receives papers full of grammatical errors. He served as the editor of the journal with remarkable commitment and sincerity. Being the Editor of a journal involves lots of hard work, dedication and patience. Prof. Kayastha, not only looked after the academic content of the paper he received but also English languages. A number of Indian geographers must have expressed silent gratitude to Prof. Kayastha for publishing their articles after personally putting lots of hard work. During those days, it was difficult for geography teachers and researchers to obtain information about academic events and geographical news about India and the world. An important highlight of the NGJI, when he was at the helm as the honorary editor, was the appearance of Notes and News of geographical importance. For this, he would painfully collect information from magazines and newspapers. It was an arduous task indeed.

Being an academician of utmost integrity, he never used his position as the Honorary Editor of NGJI to advance his own research work or academic network. His selfless services for the dissemination of geographical knowledge as its editor deserve all praise. He undertook this challenging task at a time, when the publication of research work used to be very difficult. The journal in his hands was nurtured with utmost sincerity and integrity. No wonder that it is due to the solid base that he laid that the journal is regular even after six decades of its first volume. It is one of the few journals of geography from India which is regular and publishes original works of geographers and allied scientists. Chauncey D. Harris (1980) aptly appreciated NGJI for covering 'original articles on all aspects of the geography of India, especially settlement, urban, economic, and physical geography, and also book reviews' (NGJI, 1989: 115). On the other hand, one of the leading exponents of South Asia Geography, Joseph E. Schwartzberg, described NGJI as 'one of the most substantial and regular periodicals in India, covering geographical studies particularly of India but also of other parts of Asia' (NGJI, 1989: 115). These words were indeed testimony to the scholarship, hard work and sincerity of Prof. S. L. Kayastha.

Prof. Kayastha also played leading roles in the day-to-day functioning and activities of the National geographical Society of India (NGSI) in various capacities - a joint secretary, secretary, president, member of executive council, etc. After the untimely demise of Prof. H. L. Chhibber, he together with Prof. R.L. Singh, were largely responsible for organizing most of the events under the aegis of the society.

Another important contribution of Prof. Kayastha was in the form of introduction of new papers in course curriculum of the Department. The very fact that he was a voracious reader not only of geography texts but also of allied

disciplines, he was able to introduce fresh papers in the course curriculum of the department. It is to his credit that he introduced Environmental Studies, Resource Geography, Population Geography and Indian Ocean Realm at post graduate and undergraduate level courses in the Department.

Prof. S.L. Kayastha retired in 1984 after completing 36 years of distinguished services to B.H.U. and 41 years (1944-1984) in service of geography teaching and research. Post retirement, Prof. Kayastha joined Indian Council for Social Science Research (I.C.S.S.R.) as Senior Fellow for two years (1986-88). Later on, he was associated with Dayalbagh Educational Society, Agra, for the rest of his life.

As a researcher

Prof. Kayastha will be remembered as one of the pioneer researchers in the field of geography and environmental studies in India. As mentioned above, in the first decade of his life as teacher in college and university, Prof. Kayastha fully focused in honing his teaching skills. Once he established his credentials as an ideal teacher, he also started focusing on research works. He completed his Ph.D. work in 1962. It was indeed a voluminous work of great academic value. It was later published as a book by the Banaras Hindu University Press under a joint scheme sponsored by the University Grants Commission and the Banaras Hindu University. It was the first Ph.D. thesis from any department of B.H.U. to be published as a book by the B.H.U. Press. This work is still utilized by students of Geography in India and abroad.

Geography Department of Banaras Hindu University has been an internationally known centre of geographical research since its very inception. It is a very well known fact that in the early decades, the Department was famous for research in geomorphology, urban geography and rural studies. In the 1960's and early 1970's, Prof. Kayastha followed the conventional trend of research by focusing the study of habitat, economy and society of the Himachal Himalayas using both regional and systematic approaches.

During late 1960's and early 1970's, the discipline of geography was undergoing a serious philosophical debate in the West. The new debate was on the question of relevance of geography for human wellbeing. Prof. Kayastha was quick to seize this opportunity. Very soon, Prof. Kayastha emerged as a trend setter in geographical research in India. During 1970s', he radically departed from the conventional tradition of geographical research for more humane-oriented themes. He encouraged his students to work on problem oriented themes which had direct bearing on human life such as planning, environmental pollution and conservation, resources management, population growth, hazards and disasters. Whenever he would find a news item or a research paper related to the research topic of his students, he would not only encourage them to read the same but discuss about the geographical significance of the topic with them. Prof. Kayastha was very liberal in choosing a theme for his research. As a result, we find enormous diversity of themes on which he has worked. As a matter of fact, the themes of his research changed with the changing national and international environments. The continuous 'evolution' and sporadic 'revolutions' in the discipline of geography at the national and international stage also shaped his research priorities. A brief overview of some of the important areas of his research is presented below.

Regional geography: S.L. Kayastha started his research journey in mid-1950's when he enrolled for his Ph.D. at B.H.U.. The main focus of his doctoral research was on the Himalayan Beas basin. He adopted French tradition of regional geography to study in exhaustive details about Himachal Himalaya in general and Himalayan Beas basin in particular. It

contained almost every aspect of the geography of the region, be it physical, economic and demographic and socio-cultural. It was later published as a book by B.H.U. Press. According to Pradyumna P. Karan (1966: 328), the book, developed on a sound methodology, has a wealth of information about a little known area of the Himalayas. He described efforts of S.L. Kayastha as a pioneering one by an Indian geographer.

His writings on this region were published as research papers in journals and books in which he not only emphasized the bio-physical and socio-cultural diversity of the Himachal Himalayas but also studied its resources in great details and contrary to the then prevailing popular views, S.L. Kayastha was able to prove that the Himachal Himalaya has an enormous treasure of natural resources.

Integrated Area Development: An important area of his research was area development since his Ph.D. research days. He is widely credited with being the first to undertake the study of a river basin as a spatially viable unit for integrated resources development and planning. His Ph.D. work, The Himalayan Beas Basin: A study in Habitat, Economy and Society was a path-breaking study in this direction. The Department under the leadership of Prof. Kayastha got funding through Special Assistance Programme from the UGC in 1981 to prepare development plan for the tribal dominated region of South Mirzapur. The title of this project was South Mirzapur Integrated Area Development Project. For this project, he organized a team of dedicated researchers (one Research Associate; four Junior Research Fellows; a Cartographer and a Statistician) and other manpower (a driver and an attendant). Through this project, he was able to create infrastructure in the department. It is interesting to note that at present Geography Department is amongst very few departments of Banaras Hindu University which have their own departmental jeep and driver. Both were created through this project. Later on, three of his research students worked and completed their Ph.D. on this region.

Population Geography: For Prof. Kayastha, the study of population in its spatial dimension was an important aspect of research. But study of population was not one-dimensional like most geographers of his times. He conceptually linked the spatial dimension of population with environment, hazard and development in his research. He was internationally recognized for his original ideas, including by the International Geographical Union. He played active role in the activities of the IGU Commission on Population Geography. He participated in the meetings of the IGU Commission in Karachi, Kathmandu, Sydney and New Delhi. Kayastha delivered as lecture on Planning for Population Change in the IGU Commission meeting in Macquaire University, Sydney. This lecture was later published in the Professor Moonis Raza Commemoration volume. He also participated in the New Delhi Symposium and presented a paper on population growth in India and its impact on environment and development. It was published in Demographic Transition. However, his most noteworthy contribution to the activities of the IGU Commission on Population Geography was as the co-editor of its prestigious publication, "Population and Disaster", published by Basil Blackwell, Oxford. Its review appeared in the prestigious Nature. After retirement, Prof. Kayastha published a popular book in 1998 with the title Geography of Population: Selected Essays. He also participated in the Commission on Population Cartography of the International Cartographic Association (ICA) meeting on Population Mapping Technology, which was held as part of IUSSP Congress. He had profound knowledge of Indian population maps.

Environmental Studies: One of Prof. Kayastha's most significant achievements is that

his contributions on environmental and related themes helped to provide due place of environment issues in geography books and syllabus. It is Prof. Kayastha who first initiated Environmental Studies in Geography in India on a systematic basis. He guided many of his researchers on themes of concepts, perceptions and problems of urban pollution, flood plain and human adaptation, rural water supply, population and impact of development on environment. He formulated ecological mapping of several universities on a pilot basis as part of the U.G.C. Geography Panel of Experts of which he was the Chairman. He compellingly raised the issue of Sustainability of Metropolitan Centres in the Third World Countries during the International Union of the Scientific Study of Population (IUSSP) Congress in Vigyan Bhawan in New Delhi in 1989.

Prof. Kayastha was a full member of the I.G.U. Commission on Environmental Problems. His significant contributions and rich deliberations received high recognition in India and abroad. An important landmark in his academic life was his contribution of a chapter on Environmental Policies in India in edited volume of Chris C. Park - Environmental Policies: World Overview (Croom Helm, London). Prof. Kayastha left a lasting impression during the 24th I.G.U. Congress. He took part in the United Nations University-IGU Panel discussion and was honored as a guest speaker at the Centenary Celebrations of Hosie University, Tokyo.

Prof. Kayastha gave Presidential Address to the Indian Council of Geographers in Mysore in 1982 on the topic 'Perspectives on Environment and Development' in which he advocated geographers to delve themselves to research environmental studies. In this lecture, he pointed out that the problem of environment can only be properly understood when it is studied as human problem. Prof. Kayastha was given the responsibility by Indian National Science Academy (INSA) to prepare a report on Environmental Geography, which was published in the National Report: 1988-92. Similarly, in 1994, he was entrusted to prepare a status report on Environment and Development by the University Grants Commission. Another noteworthy contribution by him on the theme of environment was in the form of a research paper on Forests and Ecology in the Himalaya which he presented in the IGU Symposium on Mountain Geosystems Dynamics held in Delhi in 1991. Prof. Kayastha wrote a book titled Environment and Development: Issues and Imperatives, which was published in 1999 by Dayalbagh Educational Institute, Agra.

Prof. Kayastha was able to establish a new trend of research in the field of Environmental Geography. The analysis of spatial patterns of environmental problems is now emerging as an important theme of research in Environmental Science; which Prof. Kayastha treated rather systematically. In particular, he studied the nexus between population, environment and development. What is more, rather than purely relying on western concepts, he was able to develop understandings about this interrelationship from the developing countries perspective. He emphasized this point of view in various seminars and writings. One of his significant contributions is the development of new ideas and knowledge on environmental processes and patterns from the developing countries perspectives.

Hazards and disaster studies: Flood is regular phenomena on in India and cause huge loss to human life and properties. During his times, most of the studies on flood in India were related to hydrological and geomorphic perspectives. Prof. Kayastha broke away from this tradition and studied flood in relation to society. He wrote few influential papers linking floods and human society with his research student R.P. Yadav. These were published in reputed journal and books. For example, their study on flood-

induced migration in the Ghaghara zone (1991) was path breaking in the sense that he was one of the earliest geographers to work on this linkage. In this, they convincingly argued that the problem of floods in this area is owing to growing population pressure on land and gradual settling of people in the marginal low-lying areas which experience inundation in almost every monsoon season. In another paper (1977), they argue how the social costs of floods are unequally borne by different social groups of this area. The big chunks of land are owned by absentee landlords of the Banghar zone, and the poor farmers either work in the fields on a rental basis or as share croppers.

Prof. Kayastha's works on issues related to natural and human-induced disasters are path-breaking in the field of geography. He delivered Professor N.K. Bose Memorial Lecture on Population, Disaster and Disaster-Reduction Strategies during the Indian Science Congress in Indore in 1991. It was later published in the Geographical Review of India. In 1997, he delivered an invited talk in the Indian Science Congress in Delhi on Geography and Sustainable Development: Environmental Scenario and Perspectives. He was delegated as an UNEP Consultant to the International Conference on Environmental Life Elements and Health in Beijing in 1990 and his paper was published in the proceedings published by the Chinese Academy of Sciences. In 1994 IGU/UNDP International Seminar in New Delhi, he presented a paper on Disaster in India in which he focussed on characteristics, mitigation and management of disasters.

A voracious reader and traveler

Prof. Kayastha had diverse research interests. He would meticulously read news papers, magazines and journals and update his teaching and research. After retirement, he would wait for the new issue of the journal. If there was delay in reaching the journal, he would call his student Prof. V.K. Kumra (who is presently professor of geography in the Department) to inquire the cause for the delay. He would read all the articles of the National Geographical Journal of India. During the last few years of his life, when his eyes became weaker, he would use magnifying glass for reading purpose. He would keep on reminding the successive editors of the journal about its quality and regularity of publication.

Prof. Kayastha was a widely travelled Geographer both in India and abroad. He described his fascination for travels as below: 'I was always fascinated by people and places. I could travel to many parts of India and observe the regional diversity and cultural harmony of this great country from Kashmir to Kanyakumari and from Gujarat to Assam' (Kayastha, 2008). It is quite surprising that inspite of such a long teaching and research career in college and university, which started in 1944; he could start his academic visits outside India in the last decade of his academic career in 1977. Between 1977 and 1989, he visited and lectured in several countries such as Romania, Nigeria, Mexico, U.S.A., U.K., Japan, Brazil, Spain, Nepal, Pakistan, U.S.S.R., France, Australia and China.

Honour, awards and achievements

Prof. Kayastha created a niche for himself in teaching and research of geographical and environmental studies. He was highly respected by the academia as well as the Indian state. Due to his selfless services for the discipline of geography and environment for a long period of time, Prof. Kayastha was honored and awarded by not only Geography and the larger scientific community. He served as the head of the Department of Geography for two terms, during 1977-1979 and 1983-1984. He was Chairman of Advisory Committee of the National Atlas and Thematic Mapping organization (NATMO), Kolkata. Prof. Kayastha was also the Chairman of Geography Panel of Experts (UGC) and a Full Member of International Geographical

Union Commission on Environmental Problems. He was also a corresponding member of Working Group on Environmental Perception as well as Commission on Population and Environment of IGU. He was the Member Secretary of the UGC National Committee for Geography. On the occasion of the Silver Jubilee of the NGSI in 1971, the Society conferred on him the Sardar Vallabh Bhai Patel Medal for his contributions to the development of Geography in India.

CITATION ON THE AWARD OF
THE NATIONAL GEOGRAPHICAL SOCIETY OF INDIA
SARDAR VALLABH BHAI PATEL MEDAL

TO

Dr. S. L. Kayastha

Dr. S. L. Kayastha is well known for his contributions to Indian Geography in general and regional geography in particular. In addition to numerous articles, his pioneering work on 'The Himalayan beas Basin: A Study in Habitat, Economy and Society' has won wide acclaim.

Dr. Kayastha is a senior geographer of the country. He has not only confined himself to his own research and publications but has significantly contributed to the publication and dissemination of geographical research work as editor of the National Geographical Journal of India.

In recognition of the merit of his work, the National Geographical Society of India takes great pleasure and pride in awarding him, on the occasion of the Silver Jubilee of the Society, the Sardar Vallabh Bhai Patel Medal.

Varanasi, India.
10th January, 1971.

The contribution of Prof. Kayastha for the development of geography was recognized by many other geographical societies of India. He was elected as the President of the Indian Council of Geographers (B.H.U.baneswar) for the year 1981-82. For his invaluable contribution to the cause of geography in India, Prof. S.L. Kayastha was conferred with *Bhugol Vachaspati* at Indian Geography Congress at the University of Allahabad in 2008. On account of his invaluable contributions to Geography and Environmental Studies, he was unanimously elected as the President of the Geology and Geography Section of the Indian Science Congress Platinum Jubilee Session in Pune in 1988. There he delivered his presidential address on Frontiers in Environmental Geography: Reappraisal of Environmental Problems and Policies in India. In his address, he powerfully put forth the need and rationale of looking at the environmental problems in the country from spatial point of view before the scientific community of India. His lecture was well-received and widely appreciated amongst the scientific community of India.

Prof. Kayastha was President of the National Association of Geographer of India (NAGI) during 1993-94. His presidential address on Environment, Development and Quality of Life provided a direction to research in Indian geography. In the present times, one can see many young geographers working for their

Ph.D. theses on the theme of linkages between development, environment and quality of human life. This lecture was subsequently published in Anu Kapur collection of presidential addresses of all the Presidents of NAGI (Indian Geography: Voices of Concern, 2002).

Prof Kayastha was a member of Indian Science Congress. He regularly attended the conference from 1956 to 2001. When Indian Science Congress was held at B.H.U. in 1981, he served as the co-editor of the souvenir volume, which he produced very meticulously. Prof. Kayastha was also the UGC National Lecturer, an honour bestowed on only a handful of Indian geographers.

As a human being

Geographers are specially known for their profound knowledge of concepts of time and space. It is through these concepts that they try to describe and unravel complexities of geographical realities. As expected, these concepts occupy prime space in classroom deliberations. In this respect, Prof. S.L. Kayastha was one of his kinds. He had cultivated a deep value for time and space in his own day-to-day life. His students tell that he was a very punctual man. He was always on time for his classes and meetings. Prof. Kayastha had a sense of sanctity of space and would never visit the department in casual dress. Inshad, he would come well-dressed in the department is dressing sense was always a matter of appreciation among colleagues and students of the department.

Though Prof. Kayastha was a very private man in his personal life, he was readily accessible to students and researchers. In personal conversation, he was a man of few words and would keep away from gossips with colleagues and students. He had dislike for colleagues gossiping in the department. No one has ever seen Prof. Kayastha losing his temper even in the most adverse situation. He had likings for neat and clean writings and would tell his students not to indulge in overwriting of words in sentence.

He never shied away from works of the department but seldom cared for taking credits for works he did. He was a great team man any academic leader could ever aspire for. In a personal conversation to the author, he credited Prof. H.L. Chhibber for developing in him a sense for honesty and dedication for academic and administrative works. Prof. Kayastha was a deeply spiritual man. But he had dislikes for all kinds of orthodoxies. He had cultivated liberal ethos and modern outlook. In his classes, he would particularly put emphasis on the need to cultivate the value of scientific temper, spirit of inquiry and rationalism.

Prof. Kayastha was extremely courteous, polite and soft spoken. He was a large-hearted man and extremely humane. He possessed loads of patience and would listen to his students and colleagues and would never impose his personal views on them. Throughout his life, he stood for his students, colleagues and relatives in thick and thin. He was indeed a true gentleman Professor.

In every-day routine, his was a textbook example of a disciplined life. He would get up in the early morning hours and would go out for a walk in the serene campus of Institute of Science of B.H.U.. When his body was weakening and unable to support his passion for walking, his younger son, Prof. Arvind Mohan Kayastha, would drive him from his Akhnoor Hut, located just outside the B.H.U. campus, to the Campus and would walk holding his hand.

He had cultivated some great friends in academia beyond B.H.U.. One such friend was Moonis Raza, the well-known Marxist and legendary Geographer. They had their common association with Aligarh Muslim University; both did their post graduation in geography from there during 1940's, though S.L. Kayastha was one batch senior to Moonis. It is not mere coinci-

dence that they travelled together and participated in several academic events in India and abroad. They had shared commitments for the cause of the downtrodden. In their own respective ways, they made efforts to use geography for solving problems of the nation and the society. Not surprisingly, Prof. Kayastha dedicated his last major essay, titled 'India and the World: Some Impressions of Travels' (National Geographical Journal of India, 2008), in memory of late Prof. Moonis Raza. It was indeed a rare gesture towards a fellow geographer and friend who died way back in 1994.

Personal encounter

I am fortunate to have met and interacted with him on quite a few occasions. I, first, met Prof. S.L. Kayastha in 2006. Prof. R.S. Yadava, who is at present the Head of the Geography Department of B.H.U., took me to Akhnoor Hut where I saw the legend for the first time. At that time, I had a long and engrossing discussion with him. When my first research paper, Geopolitical Discourse and Environmental Security: Contextualizing Bangladesh, was published in the NGJI (2008), he wrote a personal congratulatory letter to me. In the full page handwritten letter, which I have kept as my prized possession, he gave invaluable comments and suggestions on the paper. Again, when I was writing Biographical Memoir of Prof. H. L. Chhibber (FNI/FNA and founder Head of Department of Geography and Founder President of the NGSI) for the Indian National Science Academy, he provided invaluable insights about him and the early years of the Department running in four pages. He also narrated many stories and anecdotes about early history and working environment of the Department.

The Legacy

An important hallmark of a great teacher is the legacy one leaves. In this respect, Prof. Kayastha's heritage in the field of environmental studies and population geography can very aptly be regarded as rich. It is due to his untiring efforts that environment geography was mainstreamed in the syllabus of geography departments of most Indian universities. Prof. Kayastha initiated this paper first in the Geography Department of Banaras Hindu University at the post graduation stage. Today, Environmental Geography paper is taught in Geography Departments of most Indian Universities. He also introduced papers on Resource Planning, Applied Geography and Population Geography. The relevance of these papers has only grown with time.

During the last years of his active service in the Department, Prof. Kayastha applied to the UGC for DRS in 1984. It was subsequently awarded to the Department in 1986. Under this scheme, five new specialized teachings posts were created in the Department (two Professors, of which one was specialized post in Integrated Area Development; one Reader with specialization in remote sensing, and two Lecturers with specialization in climatology and geomorphology, respectively.

He produced a group of teachers and researchers who went on to create a niche for themselves in the field of geography allied disciplines. It is quite remarkable that at one point of time, there were six faculty members of the Department of Geography of Banaras Hindu University viz. Profs. V.K. Kumra, M.B. Singh, R.S. Yadava, Ram Bilas, B.N. Singh and S.P. Mishra who had completed their research under the guidance of Prof. Kayastha. Prof. Kayastha had a pulse for Geography and he promoted the cause of this discipline in various capacities, as a teacher, researcher, head of the department and editor of journal as well as office bearer of academic bodies and committees, with missionary zeal.

One hardly comes across a person who excels in academic world as well as look after

the family with great achievement. With sheer hard work, he was successful in creating a place for himself in the world of Geography community. At the same time, he was able to raise a great family. Prof. Kayastha was married to Late Kusum (Kaistha) Kayastha. His two sons viz. Anand Mohan and Arvind Mohan have done outstandingly well in their professional life. The eldest son was a Professor of Geology at B.H.U. before he took voluntary retirement to serve as the Registrar of Dayalbagh Educational Institute (Deemed University), Agra. The younger son, Arvind Kayastha, is a Professor at School of Biotechnology, B.H.U.. He is a well known researcher in the field of biotechnology and his works have been widely recognized by scientific community and the state. He has been elected as Fellow of National Academy of Sciences (FNASc) and Fellow of National Academy of Agricultural Sciences (FNAAS) in recognition for his pioneering research in the field of biotechnology. He is also a recipient of Prof. C.N.R. Rao Education Foundation Award, 2012 for his path-breaking research in the field of biotechnology.

Prof. Shanti Lal Kayastha left for heavenly abode on January 6, 2018 after a fulfilling and wonderful life, leaving behind a more humanized human geography, a bigger and better-equipped department of geography, a moving geographical society (NGSI), a cultured and educated family and an innumerable number of students who have been serving the humanity as teachers, researchers, planners, professionals and administrators with utmost honesty and dedication.

Select Works of Prof. S. L. Kkayastha

Select papers published

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Environmental Sustainability Issues and Challenges in India

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Abstract

The last four or five decades saw a growing concern for the widening gap between human greed and nature's capacity to reproduce itself to satisfy this greed. Voices have been raised all over the world about global warming and climate changes, land degradation, depletion of ground water resources, biodiversity and pollution of air, water and land. Coming down to the regional and national levels the situation has become highly alarming. It has been noted that 20% of the world population uses 70% of the earth resources, while 20% lives on meager 5% resources. It appears that a symbiotic relationship between man and nature is gone and a new consumerist culture has taken deep routes.

Sustainable development is perhaps the most quoted word in the few decades especially after publication of "Our Common Future" - A Report on the World Commission on Environment and Development by Brundtland in 1987. Sustainable development is a dynamic process and not static.

It has been observed that during last 100 years the monsoon rainfall has been trendless particularly on all India scales but the trends in regional monsoonal rainfall during 100 year period have been observed. Trend analysis of 1 day extreme rainfall series based on the period 1951-2007 shows that extreme rainfall amounts are increasing in many places all over India. In Rajasthan deserts some pockets show an increasing trend of extreme rainfall events such as Luni Basin in July, 1979, Jaipur in July 1981 and Barmer in August 2006.

The impacts of climate change are visible in all walks of life in India i.e. on agriculture, water resources, bio-diversity, coastal ecosystems, melting of Himalayan glaciers and human health. The paper deals with above issues highlighting the issues of climate change, sustainability and desertification with reference to India and Rajasthan.

Keywords: *sustainable development, sustainability, climate change, biodiversity, Hamalyain glaciers, desertification and human health*

Introduction

Environment is a subject of frequent discussion. Geography being an interdisciplinary subject, environment therefore is a core area of this discipline. The last four or five decades saw a growing concern for the widening gap between human greed and nature's capacity to reproduce itself to satisfy this greed. Voices have been raised all over the world about global warming

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and climate changes, land degradation, depletion of ground water resources, biodiversity and pollution of air, water and land. All these problems which we face today are largely the bi-products of our scientific achievements and unwise use of natural resources to fulfil greed and ambitions. Forests have been degraded; animals have been killed; less privileged and poor have been exploited; soil, water, air and food have been polluted; human body has been toxicities. We have more and more mundane and material things but less and less of those which make us happy and contented (Misra, 1987).

It is disappointing to note that the rate at which natural resources are being depleted, has put a question mark on the very survival of life on this planet. Coming down to the regional and national levels the situation has become highly alarming. It has been noted that 20% of the world population uses 70% of the earth resources, while 20% lives on meager 5% resources. It appears that a symbiotic relationship between man and nature is gone and a new consumerist culture has taken deep routes.

Sustainable development is perhaps the most quoted word in the few decades especially after publication of "Our Common Future" - A Report on the World Commission on Environment and Development by Brundtland in 1987.

The report defines SD as "Sustainable development is the development that meets needs of the present without compromising ability of future generations to meet their needs." (March,20,1987). The concept of sustainable development is a first ideational break through to halt this fendering of the nature. The development is not only growth, but also the transformation of economic and social attributes with the goal of raising the quality of population and achieving the gradual formation of new ethical values (Fidel, 1987). There are divergent views on sustainable development, but due to paucity of space author as not want to discuss all these issues. However, it may be stated that sustainable development cannot be a static concept; hence it cannot be defined once for all. Sustainable development is a dynamic process having equity, justice, integrative and balanced nature and common goals but different routes. It accepts nature not only as a resource for development but also as the earthly womb for survival and development of human kind. It is participatory in nature.

Environmental challenges in India

After having discussed the concept of sustainable development, author It would like to mention some of the environmental challenges the country is facing today.

Growing population and poverty

The population of India has already reached 1.25 billion mark (Census, 2011). A population of over thousand of million is growing at 2.11% every year. The growing population puts considerable pressure on its natural resources and reduces the grains of development. Hence, the greatest challenge before India is to limit the growth of population. Although the decadal growth rate of population in India was reduced to 17.70% in 2011 against 21.54% in 2001. The highest growth rate of more than 53% in 2011 had been reported from Dadar and Nagar Haveli and Daman Diu while lowest 0.60% from Nagaland and 4.90% from Kerala. After independence several schemes and programmes have been initiated to control population and results are quite encouraging. However, population control does automatically lead to development, yet the development also leads to a decrease in population growth.

India has often been described a rich land with poor people. It has been stated by some scientists that poverty is closely linked to degradation of environment. The poverty and environmental degradation have a nexus between

them. The vast majority of Indian population are directly dependent on natural resources for their basic needs of food, fuel, shelter and fodder. About 30% of India's population is still below the poverty line despite several programmes of development. Environmental degradation has adversely affected the poor who depend upon resources of their immediate surroundings. Thus, the challenge of poverty and the challenge of environmental degradation are two sides of the same challenge. The population growth is essentially a function of poverty. To every poor, every child is an earner and helper and environmental concerns have little relevance for him. This mismanagement engenders even greater poverty, due to greater lack of financial and technological resources needed to confront increasingly adverse environmental conditions. The result is a degrading vicious cycle of population growth , poverty and environmental degradation as is evident in Fig. 1.

Air pollution

The air pollution in India has grown at an alarming rate. The major cities fail to meet the ambient air on account of health based standards. Most of the cities are in state of severe air pollution and in addition, oxides of nitrogen and air toxic pollutants have another serious issue towards public health. New Delhi during

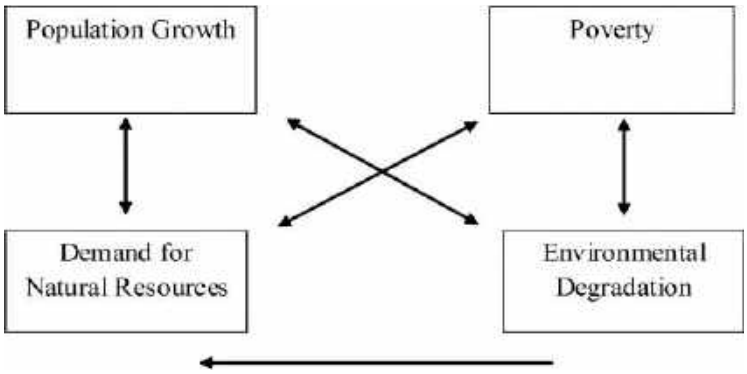

Fig. 1. The Vicious Cycle of population growth, poverty and environmental degradation (Fidel Marquez Sanchez, 1998)

winter season becomes a Gas Chamber. World Health Organization Report- 2016 indicated that 20 cities of India are the worst polluted. Gwalior ranks the first while Dhanbad is at 38th and New Delhi at 11th position. New Delhi ranks at the 5th position in India. Most of cities of north India accounts for high level air pollution as a result of burning of agricultural waste during winter in Haryana, Punjab and Northern Rajasthan. Increasing number of motor vehicles, fog and high density of population are other causes of air pollution. Washington based Institute of Health Matrix and Evaluation in its report "State of Global Air-2017 revealed that 52% of deaths in China and India are caused by air pollution. The particulate matter is 2.5 which is considered to be the highest in India in comparison to other countries."

The International Energy Agency-2017 also indicated that nearly 16 lakhs of children dies every year because of air pollution and ozone depletion in India, if not controlled this figure would reach 75 lakhs by 2040. The production and consumption of energy are the main causes of increase in greenhouse gases emission. The Report of India Forest Research and Education-2016 also indicated that in energy sector 1.51 billion tons of carbon is emitted in India, while the increase of forest is very low. As a result only 12% of CO2 is absorbed by the for-

est and the rest is resorted into air pollution. India has initiated some programmes to mitigate the air pollution but it is limited only to metro cities where some improvement in the air quality has been reported. However, in most cases the air pollution levels are still unacceptably high. Thus, there is an urgent need for a policy intervention to mitigate air pollution.

Climate change

Climate change is probably the most complex and challenging environmental problem faced by the world today (Ojwang, et al, 2010) and increasingly recognized as a potent threat to agriculture in general and food security in particular. Several studies on climate change have been made by IPCC, IGBP (International Geosphere Biosphere Programme) and World Meteorology Department. In India several studies have been made individually or collectively by scientists (Krishna Kumar, et al, 2011, Venkateswaslu, et al, 2010; O'Brien et al, 2004; Kavi Kumar et al 2007; Panda, 2009; Ravindranath, et al, 2011; Sharma, 2010; Amal kar, 2012; Hingane, et al 1985; Singh and Sontakke, 2002; MOEF, 2010a, 2010b; Rupakumar, et al 2006; Rama Rao, et al 2013, 2016). All these studies have indicated that the average temperature had been increasing at the rate of 0.95 to 10.00^{0}C during 1901-2012. The trend of mean temperature in India and Rajasthan for the period of 115 years (1901 to 2015) have also been calculated. The data of temperature of past 115 years have been obtained from data.gov.in.imd and India water portal. The changes in mean temperature during above mentioned period both for India and Rajasthan are significant at 0.01 level (99% confidence level). The analysis of (Fig. 2 and 3) indicate that 0.083^{0}C increase in temperature for 115 years has been produced in case of India which remained 0.39^{0}C for Rajasthan. It is not worthy that India has witnessed a sharp rise in temperature after 1980, *i.e.* 0.02^{0}C per year; before it was 0.0036^{0}C per year. Similarly the state of Rajasthan noticed a of 0.0007^{0}C per year rise before 1980 and it became 0.005^{0}C per year after 1980. The trend of temperature rise in India is more in north eastern states on account of rising isolation level due to vegetal degradation (ISRO 2016). The fig. 2 and 3 further indicate that the mean temperature from 1901 to 1928 was below 24^{0}C which after that till 1988 remained below 24.50^{0}C and then it touched 25^{0}C mark in 1996 and 2012. In earlier study the mean temperature in Rajasthan during 1901 to 2012 had shown a significant warming trend of 0.51^{0}C per 100 years and about 0.95^{0}C per 112 years (Sharma, 2018).

It has been observed that during last 100 years the monsoon rainfall has been trendless particularly on all India scales but the trends in

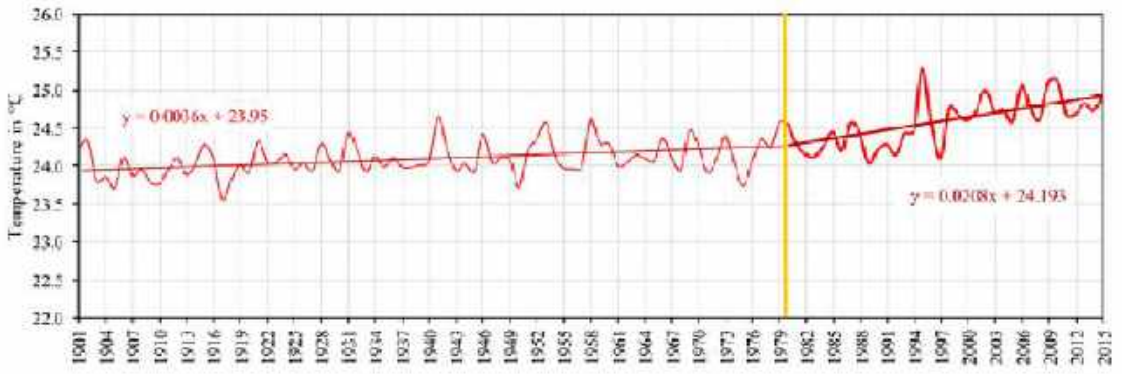

Fig. 2: Trend of Mean Temperature in India (1901 to 2015)

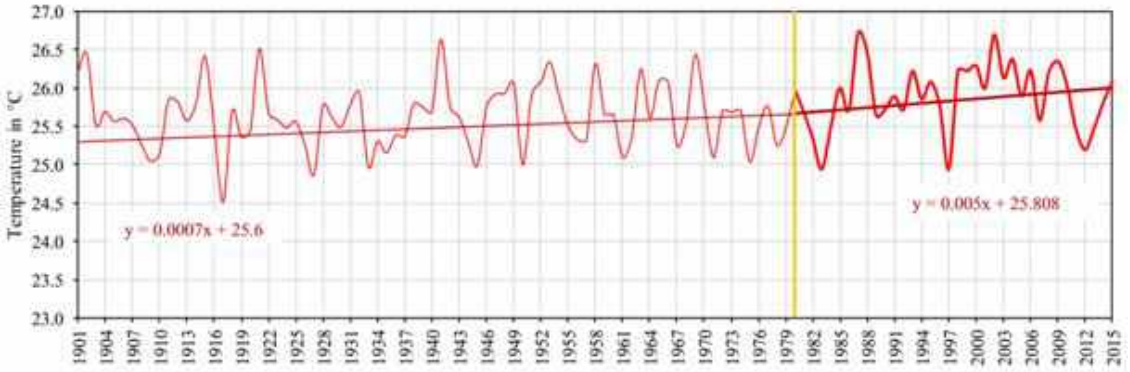

Fig. 3: Trend of Mean Temperature in Rajasthan (1901 to 2015)

regional monsoonal rainfall during 100 year period have been observed (Pant, and Hingane, (1988, 1997, 1998). Trend analysis of 1 day extreme rainfall series based on the period 1951-2007 shows that extreme rainfall amounts are increasing in many places all over India. In Rajasthan deserts some pockets show an increasing trend of extreme rainfall events such as Luni Basin in July, 1979, Jaipur in July 1981 and Barmer in August 2006 (Sharma, H.S. 2018).

The impacts of climate change are visible in all walks of life in India *i.e* on agriculture, water resources, bio-diversity, coastal ecosystems, melting of Himalayan glaciers and human health. Recently Ram a Rao, et al 2016 have made a significant study on vulnerability of Indian agriculture to climate change. The mapping of vulnerability, sensitivity and adaptability has been done at district level. It has been stressed that there is an inverse relationship between vulnerability, sensitivities and adaptive capacity. The areas which are externally vulnerable to climate change are very low in adaptive capacity to cope with the climate change.

Table 1 gives the distribution of districts with a varying degree of vulnerability. It can be seen that most of the districts with very high and high vulnerability are in the states of Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Karnataka and Maharashtra. Similarly, of the 115 districts that are highly vulnerable to climate change and variability, 18 are in Uttar Pradesh, 16 in Madhya Pradesh, 15 in Bihar, 9 in Haryana, 7 in Chhattisgarh and 6 each in Jharkhand, Gujarat and Rajasthan. Investments that enhance adaptive capacity and resilience may be targeted to these districts.

Vulnerability and suggested policy interventions

After dividing districts into degree of vulnerability Rama Rao et al. suggested some measures for policy makers as following:

- The most important factors responsible for vulnerability were identified in each component in case of more vulnerable districts, those with 'very high' and 'high' vulnerability. Thus, in case of variables that determine exposure of the district to climate change and variability, increase in drought incidence, increase in minimum temperature and decrease in rainfall during June and July, emerged as important factors suggesting the possible technological and other interventions needed.
- Changes in rainfall pattern are better tackled by a combination of measures such as altering sowing dates, altering crop duration to maturity and enabling supplemental irrigation wherever possible.

- In districts where likely increase in incidence of extreme rainfall events is an important source of vulnerability, interventions that protect human and physical resources along with a more coordinated settlement planning are needed.
- This increased frequency may be, wherever possible, seen as an opportunity to harvest and store water for later use.
- Low rainfall, high drought incidence, low available water holding capacity of soils, high flood proneness and larger area under agriculture are the most important sensitivity-related factors contributing to vulnerability.
- This suggests that the current approaches and interventions related to rainwater harvesting, watershed development and breeding for drought-tolerant crop varieties should continue to receive priority.
- In some districts, a very high proportion of land is under crop production pointing to the pressure on land. In such cases, there is a need to explore the possibility of enhancing non-farm employment opportunities. In case of adaptive capacity lacking or inadequate irrigation facilities, and low groundwater availability are important factors determining vulnerability.
- The importance of irrigation in agricultural development can hardly be overemphasized.
- Making irrigation sustainable and more equitable is more important. The changing rainfall pattern, spatial and temporal, needs to be appropriately and adequately factored in planning for expansion of irrigation facilities.
- It is also needed to lay more emphasis on supplemental and critical irrigation using rainwater harvesting.
- The planning for irrigation should also consider developing appropriate crop plans/cropping pattern that optimize returns to farmers as well as maximize returns to water use. The connotation of water use efficiency needs to be taken in its broader meaning.
- Strengthening adaptive capacity is also helpful for farmers in dealing with other development problems. In any case, consideration of information related to all indicators used in the construction of vulnerability index, will be helpful in identifying interventions that are more specific to the district.
- It may be added that considering any intervention that is not relevant to and useful in dealing with current problems of agriculture are less likely to be accepted by farming community, it is preferable to identify interventions that help farmers deal with future climatic stress as well as with current climatic variability (Rama Rao, et al. 2016).

Desertification / Land degradation

Desertification is the continuous degradation of land under the influence of natural and anthropological causes in arid, semi-arid and dry-sub humid conditions. Desertification affects two thirds of countries of the world and one third of the earth's surface, on which one billion people live (one sixth of world's population). The processes of desertification and land degradation are observed to have accelerated during recent years. This is one of the serious problems in India.

Till 2001 no authentic data were available regarding area under desertification/land degradation in India by Govt. of India (2001). In 2001 under the auspices of Ministry of Environment and Forests, Govt. of India a project on status mapping of desertification was initiated under RAP (TPN-I) activity of United Nations (SAC 2007). According to this atlas nearly 105.48 mha or 32.07% was under desertification/land degradation. In order to monitor de-

Table 1: Distribution of districts according to the degree of vulnerability (2021-50) in different states Vulnerability

State	Very high	High	Medium	Low	Very low	Total
A&N Islands	0	0	0	0	1	1
Andhra Pradesh	2	1	1	1	8	13
Arunachal Pradesh	0	0	0	5	9	14
Assam	1	1	1	7	13	23
Bihar	6	15	7	6	3	37
Chhattisgarh	0	7	4	5	0	16
Dadra & Nagar Haveli	0	0	0	0	1	1
Daman & Diu	1	0	0	0	0	1
Goa	0	0	0	0	1	1
Gujarat	14	6	1	1	3	25
Haryana	0	9	6	2	2	19
Himachal Pradesh	0	4	2	3	3	12
Jammu & Kashmir	0	1	6	3	4	14
Jharkhand	3	6	7	2	0	18
Karnataka	14	5	0	2	6	27
Kerala	0	0	4	7	3	14
Madhya Pradesh	14	16	9	4	2	45
Maharashtra	12	5	3	6	7	33
Manipur	0	0	3	3	3	9
Meghalaya	0	0	1	3	3	7
Mizoram	0	0	1	7	0	8
Nagaland	0	0	0	3	5	8
Orissa	0	1	9	14	6	30
Pondicherry	0	0	0	0	1	1
Punjab	1	4	4	6	2	17
Rajasthan	25	6	1	0	0	32
Sikkim	0	0	0	2	2	4
Tamilnadu	6	5	9	4	5	29
Telangana	0	1	2	0	6	9
Tripura	0	0	0	0	4	4
Uttar Pradesh	12	18	24	14	2	70
Uttrakhand	3	4	1	1	4	13
West Bengal	1	0	8	3	5	17
India	115	115	114	114	114	572

Source: C.A. Rama Rao, et al. 2016, Current Science, Volume 110 Number 10, May 2016, pp. 1939-46

sertification a second cycle DSM was again started using AWiFS data of 2003-05 and 2011-13. Accordingly, 96.40 mha area of the country was undergoing the process of land degradation that en..... 29.32% of the total geographical area of India during 2011-13 while during 2003-05 the area undergoing process of land degradation was 94.53 mha (28.6% of TGA). There was a cumulative increase of 1.87 mha area undergoing process of desertification in India constituting 0.57% of the TGA of India (Desertification/Land Degradation Atlas of India, SAC, ISRO, 2016). The difference in two surveys 9.08 mha (Fig. 4). The difference of 10.95 mha (105.48 mha in 2007 and 94.53 mha in 2016 data) needs explanation and justification by ISRO.

The most significant processes of desertification in the India are water erosion (10.98% in 2011-13 and 10.83% in 2003-05) vegetal degradation (8.91% in 2011-13 and 8.60% in 2003-05) and wind erosion (5.55% in 2011-13 and 5.58% in 2003-05) vide Fig. 5.

Forests and development

India accounts for only 20% area under forest cover against 33% needed for maintaining ecological balance. Despite sincere efforts and investments in forest sector, the situation is undesirable. Forests serve catchment for Indian rivers with increasing demand of water, plan to harness the mighty rivers through large irrigation projects were made. Certainly this would submerge forests, displace local people, damage flora and fauna. As such the dams of the river Narmada (Sardarsarovar), the Bhagirathi and elsewhere have become areas of political and scientific debate. The issue of riparian forest plays an important role in maintaining the hydrology of the watershed as well as maintaining the flow at downstream. Forests in India have been shrinking due to pressure of agriculture and other uses. Thus, the deforestation is one of the serious environmental problems in India. Degraded forest constitutes a considerable proportion of the total forest cover in India. The major factor of degradation is the diversion

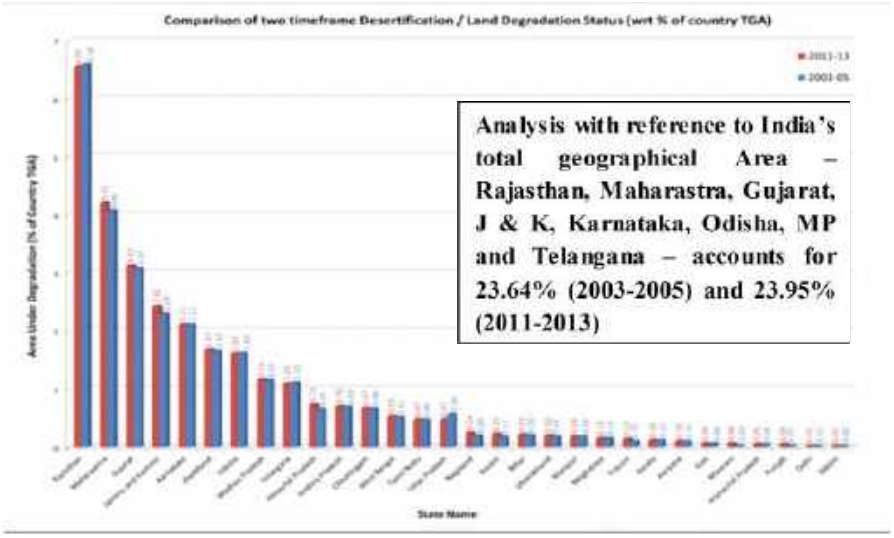

Fig. 4

Source: Desertification and Land Degradation Atlas of India, Space Application Centre, ISRO, Govt. of India 2016

Process of Desertification/Land Degradation	2011-13		2003-05		Change (mha)
	Area (mha)	Area (%)	Area (mha)	Area (%)	(2011-13)-(2003-05)
Vegetation Degradation	29.30	8.91	28.28	8.60	1.01
Water Erosion	36.10	10.98	35.61	10.83	0.49
Wind Erosion	18.23	5.55	18.35	5.58	0.12
Salinity	3.67	1.12	4.01	1.22	0.34
Water Logging	0.65	0.20	0.60	0.18	0.05
Frost Shattering	3.34	1.02	3.11	0.95	0.23
Mass Movement	0.93	0.28	0.84	0.26	0.09
Manmade	0.41	0.12	0.37	0.11	0.04
Barren/Rocky	1.89	0.57	1.88	0.57	0.01
Settlement	1.88	0.57	1.48	0.45	0.40
Total Area under Desertification	96.40	29.32	94.53	28.76	1872523
No Apparent Degradation	226.73	68.97	228.68	69.57	1954372
Total Geographical Area (mha)	328.72				

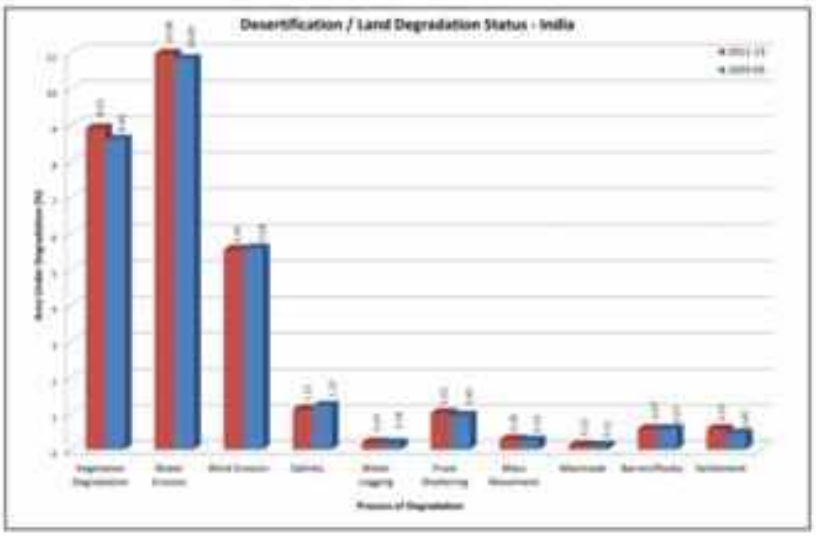

Fig. 5

Source: Desertification and Land Degradation Atlas of India, Space Application Centre, ISRO, Govt. of India 2016

of land into other uses such as road network in hills and housing, industrialization and river valleys and hydropower projects. However, the diversion of forest land has been reduced after 1980 when the Forest Protection Act was implemented. It is estimated that the number of Mangrove Forests have more than halved in the last 20 years. Thus, there is a need to bring back degraded forests under vegetative cover. The tribal communities inhabiting forests respect

nature and protect trees, birds and animals. They understand well that forests give sustenance to them. We must recognize the role of these people in restoring and conserving forests. The modern knowledge and skill of forest department should be integrated with traditional knowledge and experience of local people. The strategy of the Joint Management of Forests should be evolved in a planned way.

Depletion of water resources

India experiences an average precipitation of 1170 millimeters (45 inches) per year, or about 4,000 cubic kilometers of rains annually or about 1720 cubic meters of fresh water per person every year. Despite extensive river system safe clean drinking water as well as irrigation water supplies for sustainable agriculture are in shortage all over India. Ground water is also depleting at a fast rate particularly in north western and southern parts of the country.

India has seven major rivers- the Ganga, Bramputra, Indus, Narmada, Krishna, Godawari and the Cauvery and numerous tributaries. New Delhi has set up the Central Water and Power Commission to have a systematic plan to harness not only water but also generate power.

It is essential to realize the use of surface and ground water resources judiciously. Factors like community waste, industrial affluent and chemical fertilizers and pesticides have polluted surface water and affected the quality of ground water.

The demand of water in agriculture, industrial and domestic sectors has brought problems of over-exploitation of ground water resources, continuously declining ground water levels, sea water ingress in coastal areas and ground water pollution in different parts of India. In India out of 5723 blocks, 839 blocks fall in over exploited category, while 226 and 550 blocks are under dark and critical and semi critical zones respectively. 30 blocks are under saline category. However, 4078 blocks are under safe category. Though water level in major parts of India generally does not show any significant rise/fall. Definitely, significant decline in the level of ground water has been observed in certain pockets of 289 districts of Andhara Pradash, Assam, Bihar, Chattisgarh, Rajasthan, NCT Delhi, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Maharastra, Orissa, Punjab and Tamilnadu. The stage of ground water development in India is 58% while in Rajasthan it is 172% which is highly disturbing (CGWB, 2009).

Consequences of urbanization

31.15% people in India live in urban areas (2011). Urbanization and industrialization have given birth to a great number of environmental problems that need urgent attention. Over 30% of urban Indians are living in slums. Out of nearly 3,245 towns and cities, only 21 have partial or full sewerage and treatment facilities. Hence coping with rapid urbanization is a major challenge in India today.

Author has discussed some of the major environmental problems of India which need attentions at a policy level. It is anticipated that the exploding population will continue to build pressure on land, water and air. This would further hasten the vegetal degradation by ever increasing demand for firewood and other requirements. The future climate change would have greater effects in all walks of life particularly water resources and agricultural growth.

The policy makers must respond to the challenges posed by ensuring climate change and its impact on all spheres of life. Although science based policy is an illusion, political arguments are and will be more important in choosing between policy options than scientific arguments. However, decision making must be informed by purposeful knowledge and science is a must to illuminate the values, goals and instruments of policy making and to sensitize policy markers (Sharma, 2010).

Author would like to stress upon the fact that research in geography must move beyond a disciplinary focus to address sustainability issues of India in the framework of complex dynamical systems. Geography has already achieved much in support of sustainable development. The community of geographers should therefore commit to help and build an improved, integrative, participatory and useable science that is applicable from local to global scale.

Conclusion

In the foregoing analysis some of the major environmental problems of India have been discussed. These problems need attentions at a policy level. It is anticipated that the exploding population will continue to build pressure on land, water and air in India. This would further hasten the vegetal degradation by ever increasing demand for firewood and other requirements. The future climate change would have greater effects in all walks of life particularly water resources and agricultural growth.

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Status of Biodiversity in West Bengal: Threat to Conservation and Scope of Restoration

Ranjan Basu[1]

Abstract

Despite wide scale deforestation during the colonial and post-colonial periods in the name of economic development, the populous state of West Bengal located in eastern India, still maintains three different forest types in northern hills and piedmont areas, western plateau and its fringe areas as well as littoral forest of the of the Ganga delta. Aquatic ecosystems of the water bodies and wetland, snow and rain fed rivers along with brackish estuaries have diversified the landscape. Expansion of arable land, human settlements and transport arteries has truncated luxurious forests on one hand and taken its toll on floral and faunal diversity of wild terrestrial and aquatic environ on the other. Introduction of high yielding varieties of paddy and hybrid vegetables has led to shrinkage of the biodiversity base in the agrarian landscape too. Transformation of land use has negative impact on the nesting prospect of the birds whose species diversity is also at stake. In-situ conservation of biodiversity is a challenging task now either for the authorities or for the concerned scientists.

Keywords: *gene pool, threatened species, bio-piracy, sacred groves, hybrid varieties, genetically modified crops*

Introduction

Diversity of species, gene and ecosystem is the order of the humid tropics. In fact, higher the diversity of ecosystems, higher would be the diversity of species and genes. Krebs (1989) observed a biodiversity gradient from the humid tropics to the polar region which is the product of six causal factors: a) Time, b) Spatial heterogeneity, c) Competition, d) Predation, e) Productivity and f) Environmental stability. West Bengal being a part of eastern India, by virtue of its location between 21°30'N and 27°15'N latitude covering a stretch from the Bay of Bengal to the Eastern Himalayas, experiences humid tropical climate. Biodiversity of this State can be traced both at the ecosystem level and the species level. The State exhibits mountain ecosystem with temperate forest in the Darjiling Himalayas of the north, sub-humid forest clad ecosystem on the Western Plateau and its fringe area, a diversified forest ecosystem ranging from piedmont forest of the north and mangrove forest of the active delta, a fresh water ecosystem in the form of Ganga-Brahmaputra-Subarnarekha river basins as well as numerous water bodies and wetlands along with a coastal and marine ecosystem in the 220 km. long coastline. The

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State, occupying only 2.7 per cent of the total geographical area of India, hosts 23 per cent of the vertebrate fauna. About 50 per cent of the mammal species of the India is reported from Darjiling Himalayas which is famous for her rich floristic assemblage of trees, bamboos, ferns and orchids inclusive of medicinal and aromatic plants. At least 12 per cent of the total flowering plant species of India are known to exist in this State. About 70 species of tree mangrove is harbored in the Sundarban mangrove ecosystem which is largest in the Indian sub-continent. Because of large scale deforestation, changes in land use pattern, water pollution and over utilization of terrestrial and aquatic resources biodiversity of West Bengal has been threatened.

Geographical personality of West Bengal

Humid tropical climate of West Bengal is characterized by alternate wet and dry spells of monsoon. Rainfall in this State varies between 1,234 mm in Birbhum district of the relatively drier south-western part and 4,136 mm in Jalpaiguri district of the northern part situated in the foothills. Maximum temperature in the dry summer months of April-May ranges from 30 C to 45 C while minimum temperature in the brief winter months of December-January dwindles between 10 C and 20 C. Monsoonal rainfall is mainly concentrated between June and October while rest of the seven months may be considered as xeric period. Total area of 88,752 sq. km. is drained by so many rivers of which the rivers of Himalayan origin are mainly snow fed while the rivers of plateau origin flowing through the western part are rain fed. Alluvial soil dominates the vast stretch of plains from the foot-hills to the bay; red and lateritic soils cover the western plateau while hilly areas lie under the cover of shallow brown forest soil and thin tropical podzolic soil. Seasonal fluctuation of thermal and moisture regime, variation of topographic, riverine and edaphic character has been reflected in the diversity of biota in the area concerned.

Objectives

This academic endeavour has taken up the cudgel to fulfill the following objectives:

(i) To make an appraisal of the forest and agricultural policy implemented so far in India;

(ii) To take a stock of biodiversity in wild terrestrial, aquatic and domesticated environ of West Bengal and to identify the threatened floral and faunal species thereon;

(iii) To find out the reasons of man-animal conflict and vanishing diversity of biota in the State in question while making a quest for its restoration.

Materials and methods

The present work is based mainly on secondary data collected from the Government and different Non-Government sources. Some primary data were also generated for Environmental Impact Assessment (EIA) following checklist method. A questionnaire was also designed meant for the target groups who are either direct or indirect stakeholders in the riparian areas and regions adjacent to forests and water bodies. Stratified random sampling technique was followed with a sample size of 600 persons representing six different ecosystems in the state of West Bengal.

Role of CBD and WTO

After enforcement of International law on biodiversity in 1993 the Convention on Biological Diversity (CBD) which initiated its activities in 1992 at the Earth Summit of Rio-de-Janeiro in 1992, identified three distinct thrust areas: I) Conservation of biodiversity, II) Sustainable utilization of biotic resources and III) Equitable sharing of benefits derived out of their utilization. The countries which participated in the deliberations agreed to implement these

through framing certain policies which would take care of the entire range of life forms found on the Earth inclusive of wild flora and fauna, crops, livestock and micro-organisms with due consideration of the habitats in which they survive.

But the global scenario became complicated enough after institutionalization of General Agreement on Tariff and Trade (GATT) through World Trade Organization (WTO) of which India became a member in 1994. Any Multi-National Company (MNC) now can get access to any plant or animal species in India. Any selected gene from the gene pool of the tropical forests of India is also accessible to them. Poor people mostly from the tribal communities traditionally utilize the medicinal plants collected from the wild environ. Sarpagandha, used as a medicine by the tribal people communities for controlling blood pressure is on the verge of extinction now because of its over-exploitation by several companies (Gadgil and Guha, 1992). This is nothing but bio-piracy for control of which strict legislation is necessary (Shiva, et.al., 2002). These MNCs were trying to get the products derived out of neem and turmeric patented taking the vantage of Trade Related Intellectual Property (TRIP) Right. An American company produced a new variety of rice named as Texmati through hybridization of Texus paddy with Basmati variety of scented Punjabi paddy from Pakistan. In all three cases India won the tussle in the appropriate International Forum by submitting evidence of geographical indicator of their place of origin. Lackadaisical approach of the concerned authorities in India to get the Indian traditional products derived from the indigenous gene pool poses as a problem. Many hybrid varieties of agricultural products including that of rice and wheat introduced by the Indian Council of Agricultural Research (ICAR) either in West Bengal or in other States during the phase of so called 'Green Revolution' are yet to be patented.

Critical appreciation of the forest policy in India

Many forests in West Bengal were declared by the Government as Protected Areas (PAs) thus prohibiting local people to utilize the wild floral and faunal resources (Table-1). In fact deprivation of the local people from the right to exploit wild organisms started during the colonial period. Timbers of the Protected Forests were utilized by the British rulers for making railway sleepers and furniture after rejecting right to forest traditionally enjoyed by the tribal people. Such a colonial legacy is still being retained in the Forest Policy of India even after seventy years of independence. There can be no denial of the fact that the Government never followed a pro-people Forest Policy and often dwindled between Protectionist and Destructive Forest Policy which ultimately satisfied the vested interest of the social pressure groups. It has been observed in many cases that an iron triangle is formed by the industrialists, bureaucrats and politicians who try to de-notify the PAs and make the area available either for mining or industry (Gadgil et.al., 1992).

In case of afforestation, the Forest Department of the Government has decided to introduce exotic varieties like Eucalyptus and Akashmani in preference to indigenous varieties which are preferred by the people of tribal origin. Under-growth as well as biomass of a Eucalyptus forest is much lower than that of a forest dominated by the forest with domination of indigenous tree species. Tribal people use the leaves of the trees like *Sal* as utensils, they extract oil from the seeds, use tubers as food, flowers and leaves as medicine, prepare liquor from the flowers of *Mahua* while twigs are used for fuel. In fact *Sal-Palash-Mahua-Kusum-Kend* forms an ideal tree combination for them. Besides, they utilize numerous non-timber forest products (NTFPs) like honey, shellac and resin etc. from the forest with indigenous species

Table 1: Protected areas in West Bengal

Name	District	Area in SqKm.
Ballavpur Wildlife Sanctuary	Birbhum	2.02
Bibhutibhushan Wildlife Sanctuary	Nadia	0.64
Bethuadahari Wildlife Sanctuary	Nadia	0.67
Buxa Wildlife Sanctuary	Jalpaiguri	314.52
Buxa National Park	Jalpaiguri	117.00
Buxa Tiger Reserve	Jalpaiguri	758.82
Chapramari Wildlife Sanctuary	Jalpaiguri	9.60
Garumara Wildlife Sanctuary	Jalpaiguri	8.61
Garumara National Park	Jalpaiguri	79.45
Haliday Island Wildlife Sanctuary	South 24 Parganas	3.501
Jaldapara Wildlife Sanctuary	Jalpaiguri	16.502
Jorapukri Wildlife Sanctuary	Darjiling	0.04
Lothian Island Wildlife Sanctuary	South 24 Parganas	38.00
Mahananda Wildlife Sanctuary	Darjiling	58.043
Narendrapur Wildlife Sanctuary	South 24 Parganas	0.10
Neora Valley Wildlife Sanctuary	Darjiling	88.00
Ramnabagan Wildlife Sanctuary	Barddhaman	0.14
Raigunj Wildlife Sanctuary	Uttar Dinajpur	1.30
Sajnekhali Wildlife Sanctuary	South 24 Parganas	362.00
Sinchal Wildlife Sanctuary	Darjiling	38.88
Singhalila Wildlife Sanctuary	Darjiling	78.60
Sundarban Wildlife Sanctuary	South 24 Parganas	
Sundarban Tiger Reserve	South 24 Parganas	592.40
Sundarban Biosphere Reserve	South 24 Parganas	2,585.10
Grand Total		4,421.40
Tiger Reserve		3,313.92
Other Protected Areas		1,107.48

Source: Department of Forest, Govt. of West Bengal

combination. Interestingly, they procure the forest resources based on their need only whereas the private companies who sometimes take lease of a substantial chunk of forest, uproot the targeted trees on a mass scale for generating profit out of the trading of sports goods and furniture. Introduction of the exotic species with patronage of the Government has rendered dis-service to the floral diversity of the virgin forest on one hand and injustice to the material culture of the tribal people on the other.

Diversity of ecosystems

The State of West Bengal is characterized by assemblage of different major ecosystems. Such diversified ecosystems have been reflected in the diversity of the organisms as well.

These can be listed as: a) Mountain ecosystem of the Darjiling district; b) Forest ecosystem of the hills and piedmont areas (locally known as Terai-Dooars) along with Gangetic plains and mangrove forests in Sundarban; c) Sub-humid ecosystem of the South-western part of West Bengal covered by red and lateritic soils; d) Fresh water ecosystem encompassing lentic and lotic systems prevalent in river basins, natural as well as man-made wetlands and water bodies; e) Coastal and marine ecosystems in the southern part of West Bengal along the 220 km long coastline and f) Island ecosystem in Sundarban separated from one another by the estuaries.

Species diversity

The faunal species diversity of the State cover almost all major groups from protozoa to mammals and is estimated at 11,042 species which represent 11.89 per cent of the total faunal diversity of India occupying only 2.7 per cent of a geographical area. Out of these 11,042 species 1,136 species belong to Protista group and 9,906 species belong to invertebrates and Chordates group. 3,580 species of flora representing seven groups has been recorded in the State out of 45,986 species known in India; but these are mainly Angiosperm or flowering plants. The floral diversity of the state is 20.45 per cent of the Indian species.

Threatened and endangered species

Rapid changes in land utilization pattern, accelerated rate of deforestation for different purposes in the name of development and Government policy of preferring exotic species are mainly responsible for destruction of habitat. Besides, because of human interference on the different ecosystems in the form of inflicting injury to the targeted species has made so many floral and faunal species threatened and endangered.

Status of the flora

West Bengal has recorded so far 152 species of flora as threatened. Table-2 given below provides a list of such species along with their region of occurrence. Out of these threatened plants, five species are considered to be rare, four species as endangered and two species as vulnerable.

The floral diversity is conspicuous in Darjiling Himalayas along with *Terai-Dooars* region in the foothills of Northern part of West Bengal and in the mangrove forests of Sundarban adjacent to the Bay of Bengal. Plant association in Darjiling Himalayas is characterized by abundance of various trees like Oak, Laurel and bamboos apart from several species of Rhododendron, orchids, ferns, bryophytes and lichens. Here orchidaceae type flowering plant forms the single largest family with nearly 600 species. There are ten dominant families of angiosperms in the area. It would not be out of the context to mention that 40 per cent of the total Himalayan flora is indigenous and majority of them occur in the eastern part. As many as 15 species of gymnosperms occur in the eastern Himalaya with existence of at least five genera in this region. Among the pteridophytes which include ferns and fern allies, 70 per cent of polypodiaceous taxa of India are observed in this region. About 50 per cent of more than 2,000 moss species are grown in this region while more than 320 species of liverworts are found here with high percentage of endemism. About 728 taxa of lichens out of 2,000 species said to be existing in India, occur in the eastern Himalaya with a variety of fungal flora too. This region is also famous for medicinal and aromatic plants of different genera. This is also considered as a centre of origin of about 82 species of crop plants. A tentative list of flora of West Bengal has been given in Table-3:

Mangrove forests of Sundarban is composed of as many as 70 species of which 35 species

Table 2: Threatened floral species of west Bengal and their regions of occurrence

Name of species	Region of main occurrence	Name of species	Region of main occurrence
Anogeisus latifolicus	SWB	Dalbergis latifolia	NWB, SWB
Ancathus volubilis	SWB	Daphme Cannabina	NWB
Avicennia alba	SWB	Daphniphyllum hinalayanse	NWB
Aeginlitis rotundifolia	SWB	Dendrobium lituiflorum	NWB
Antistrophe oxyantha	NWB	D.sulcatrum	NWB
Aristolochia tagala	NWB	Desmodium gyrans	V
Arundinaria falconeri	NWB	Dioscorea bibifera	NWB, SWB
A.hookeriana	NWB	D.pentaphylla	NWB
Acer hookeri-Endangered	NWB	D.prazeri	NWB
A.osmastonii -Endangered	NWB	D.Puber	NWB
Bambusa nutans	NWB	Dodonea viscose	NWB
Bauhinia macrostachya	NWB	Drosera burmannii	SWB
Boehmeria rugulosa	NWB	D.peltata	NWB
Buchanania latifolia	NWB	D.indica	-
Butea superb	SWB	Drypetes subsessillis	NWB
Bulleyia yunnanensis-Rare	SWB	Diplomeris hirsute-Vulnerable	NWB
Begonia satrapis-Rare	NWB	Excoecaria agallocha	SWB
B.scutata-Rare	NWB	Elaeocarpus aristatus	NWB
Caldesia oligococca	NWB	E.ganitrus	NWB
C.pamassifolia	NWB	Elaeodendron glaucum	NWB
Caesalpinia crista	NWB	Engelhardtia aolebrookiana	NWB
Calamus erectus	NWB	Eriodotrya dubia	NWB
C.latifolius	NWB	Eulophia bicallosa	NWB
Canarium sikkimense	NWB	Feronia elephantine	SWB
Carissa spinarum	NWB	Firmiana pallens	NWB
Chisoheton paniculatus	NWB	Flacourtia cataphracta	NWB, SWB
Cinnamommum cecidodaphe	NWB	Geodorum densiflora	NWB
C.zeylanicum	NWB	Gloriosa superb	NWB
Crataeva religiosa	SWB	Gnetum scandens	NWB
Cycas pectinata	NWB	Grewia microcos	NWB
Ceriops tagal	-	Habenaria marginata	NWB
C.decandra	-	H.oleosa	NWB
Cleome monophylla	SWB	Helicteres isora	SWB
Casearia graveolenens	SWB	Homalium zeylanicum	NWB
Codonopis affinis-Rare	NWB	Hova lanceolata	NWB
Christtella clarkei-Vulnerable	NWB	H.globulosa	NWB
Cissus spectabilis	NWB	Hynenodictyon flaccidum	NWB

Huidyotis brunonsis	NWB
H.scabra	NWB
Heritiera fomes	SWB
Isoetes coromandelina	-
Ichnocarpus frutescens	NWB, SWB
Juniperus pseudo-savina	NWB
Knema erratica	NWB
Kandelin candal	SWB
Leycesteria belliana	NWB
L.glaucophylla	NWB
Livistonia genkinsiana	NWB
Luculia gratissina	NWB
Lumnitzera racemosa	SWB
Machilus clerkeana	NWB
M.glaucescens	NWB
M.parviflora	NWB
Mallotus phillippinensis	NWB, SWB
Medinilla rubicund	NWB
Michelia Montana	NWB
Micromeles thonsoni	NWB
Musa balbisiana	NWB
Miliusa velutina	SWB
Metathelypteris decipiens	NWB
Neohouzeana dullooa	NWB
Nervilia falcate	NWB
Nypa fruticans	SWB
Najas merina	-
Oberonia ensiformis	NWB
O.rufilabris	NWB
Odina wodier	NWB, SWB
Olea dioica	NWB
Ormosia glauca	NWB
Ougeinia oojelensis	SWB
Ophiorriza lurida	NWB
Podocarpus neriifolia	NWB
Populus glauca	NWB
Pseudo-gardeneria angustifolia	NWB
Pygmaeopremma herbacea	NWB
Polygala arillata	NWB

P.eroptera	SWB
Pinpinella tongloensis- Endangered	NWB
Polyalthia serasydes	SWB
Rauvolfia serpentine	NWB, SWB
R.tetraphylla	SWB
Reevesia pubescens	SWB
Rhododendron smithi	NWB
Rhynchostylis retusa	NWB
Saccopetalum longiflorum	NWB
Salix daltoniana	-
Santalum album	SWB
Semecarpus anacardium	NWB, SWB
Siphonodon celastrineus	NWB
Sorbus ursine	NWB
Soymida febrifuga	SWB
Spiranthus sinensis	NWB
S.australis	-
Strychnos nux-vomina	SWB
Styrax serrulatum	NWB
Symplocos racemosa	NWB, SWB
Solomonia ciliate	SWB
S.polygala	SWB
Sonneratia alba	SWB
S.casaeolaris	SWB
Scyphiphora hydrophylacea	SWB
Ternstroemia japonica	NWB
Tetracera sarmentosa	NWB
Tiliacora acuminate	SWB
Tylophora indica	SWB
Utricularia bifadla	NWB
U.caerulea	NWB
U.scandens	NWB
U.stellaris	-
U.striatula	-
Vatica lancaefolia	NWB
Vitex peduncularis	NWB
Xylia xylocarpa	SWB
Xylocarpus granalum	SWB
Zeuxine nervosa	NWB

Note: SWB : Southern part of West Bengal, NWB : Northern part of West Bengal

Source: Sanyal, et al., 2012

are true mangroves, 28 species are associates while seven species are obligate associate (Naskar et al, 1999). Once abundant mangrove flora Sundari has now become rare and endangered.

Status of fauna

The status of biodiversity in West Bengal published by the Zoological Survey of India (Sanyal, 2012) provides the latest figures of threatened and endangered faunal species in West Bengal. As many as 29 species of mammals, 27 species of birds, 21 species of reptiles and one species of amphibian are considered as endangered. Based on the IUCN red-list categories, out of 78 threatened faunal species in the state 26 species belong to the Schedule-I category and five species to the Schedule IV category of Indian Wildlife Protection Act, 1972. Besides, 31 species of fishes, eight species of Arthropods, two species of Molluscs and one species of Annelids are considered as threatened. Among these one species of fish and two species of Arthropods belong to Schedule I. A list of threatened faunal species of West Bengal has been depicted below in Table-4:

The State of West Bengal has an association of species diversity with representation of almost every group of animal phyla. The State has also recorded concentration of more than 23 per cent of vertebrate fauna and 10 per cent of invertebrates found in India. The faunal diversity too is impressive in Darjiling Himalayan

Table 3: Tentative list of flora of West Bengal (after Prain, 1905)

Category	Order	Genera	Species
Angiosperms			
Dicotyledons	110	690	1,493
Monocotyledons	25	203	625
Total	135	893	2,118
Gymnosperms	3	3	4
Pterydophyta	10	25	66
Grand Total	148	921	2,188

Note: Prain did not account other flora i.e. Bacteria, Algae, Fungi, Lichens, Moss, Liverworts etc. He also did not include Dooars and Darjiling Himalaya

and *Terai* region in the piedmont zone as well as in the mangrove and estuarine ecosystems of Sundarban encompassing the active delta of the river Ganga. Endemism of different faunal elements is conducive for diversity of species which is evident in salt-lake marsh and in Sundarban. Two lakes known as Subhash *Sarobar* and Rabindra *Sarobar*, situated within the core city of Kolkata, an association of many aquatic, semi-aquatic and invertebrate species can be found. They have formed their niche leading to formation of ecotone in the lacustrine ecosystem.

Indian Wildlife Protection Act of 1972 revised from time to time, follows certain principles of categorizing wildlife, in the light of which the status of wildlife in West Bengal may be discussed. A significant share of 'Protected species' of vertebrate fauna is said to be existing in this State. Among the carnivores, tiger, leopard cat, snow leopard, clouded leopard, golden cat, marbled cat, *jungle* cat and fishing

Table 4: Threatened faunal species of West Bengal and their region of occurrence

	Mammalia	
Common Name	Scientific Name	Region of Occurrence
Hodgson's Giant Flying Squirrel	Petaurista magnificus	NWB
Bhutan Giant Flying Squirrel	P.nobilis	NWB
Black Giant Squirrel	Ratufa bicolor	NWB
Hairy Faced Bat	Myotis annectans	NWB
Whiskered Bat	M.mystacinus	NWB
Trefoil Horseshoe Bat	Rhinolophus trifoliatus	NWB
Indian Pangolin	Manis crassicaudata	EWB
Grey Wolf	Canis iupus	SWB
Asiatic Wild Dog	Cuon alpinus	NWB, SWB
Sloth Bear	Melurnus ursinus	NWB, SWWB
Red Panda	Ailurus fulgens-Sch.I	NWB
European Otttar	Lutra lutra	EWB
Oriental Small Clawed Ottar	Aonyx cinerea	NWB, SWB
Bengal Mangoose	Herpestes palustris-Sch.I	SWB
Striped Hyena	Hyaena hyaena	SWWB, NWB
Leopard Cat	Prionailurus bengalensis	EWB
Fishing Cat	P.viverrinus	NWB, SWB
Clouded Leopard	Neofelis nebulosa	WWB
Leopard	Panthera pardus	EWB
Tiger	Panthera tigris-Sch.I	NWB, SWB
Asian Elephant	Elephas maximus-Sch.I	NWB, SWWB
Sumatran Serow	Capricornis sumatraenis	NWB
Hispid Hare	Caprolagers hispidus-Sch.I	SWB, NWB
Indian Rhinoceros	Rhinoceros unicornis-Sch.I	NWB
Swamp Deer	Cervus duvaucelli-Sch.I	SWB, NWB
Gaur	Bos frontalis	NWB
Water Buffalo	Bubalus bubalis- Sch.I	SWB, NWB
South Asian River Dolphin	Platanista gangetica- Sch.I	SWB, NWB
Irawaddy Dolphin	Orcaella brevirostris- Sch.I	SWB
	Aves	
Goliath Heron	Ardea goliath	SWB
White Stork	Ciconia ciconia	NWB
Greater Adjutant	Leptoptilos dubius- Sch.I	SWWB, SWB
Lesser Adjutant	L.javanicus	EWB
Eurasian Spoonbill	Platalea leucorodia	EWB
Fulvous Whistling Duck	Dendrocygna bicolor	NWB, SWB

Ibis	Threskiornis aethiopica	SWB
Jerdon's Baza (Hawk)	Aviceda jerdoni	NWB
Black Baza	A.leuphotes	NWB
Eurasian Sparrow Hawk	Accipiter nisus	NWB
Besra	A.virgatus	NWB
White Bellied Sea Eagle	Haliaectus leucogaster	NWB
Red Headed Vulture	Sarcogyps calvus	SWB
India Vulture	Gyps indicus-Sch.I	SWWB
White Rumped Vulture	G.bengalensis- Sch.I	NWB
Osprey (Sea Hawk)	Pandion haliaetus	NWB
Falcon	Falco perefrinus- Sch.I	NWB
Grey Peacock-Pheasant	Polyplectron bicalcaratum	NWB
Blood Pheasant	Ithaginis cruentus	NWB
Kalij Pheasant	Lophurus leucomelana	NWB
Indian Peafowl	Pavo cristatus	NWB
Black Necked Crane	Grus nigricollis	NWB
Pallas's Fish Eagle	Hatiaectus leucoryphus	NWB
Barn Owl	Tyto alba	SWB
Rufous-necked Hornbill	Aceros nipalensis	NWB
Black Hornbill	Anthracoceros malabaricus	NWB
Marsh Babbler	Pellomeum palustris-Sch.I	NWB
	Reptiles	
Indian Soft-shell Turtle	Aspideretes gangeticus- Sch.I	SWB
Indian Peacock Soft-shell Turtle	Aspideretes hurum- Sch.I	SWB
Three Keeled Land Turtle	Melanochelys tricarinata- Sch.I	SWB
Gharial	Gavialis gangeticus- Sch.I	SWB
Saltwater Crocodile	Crocodylus porosus	SWB
Olive Ridley Sea Turtle	Lepidochelys olivacea- Sch.I	SWB
Northern River Terrapin	Batagur baska- Sch.I	SWB
Hawksbill Sea Turtle	Eretmochelys imbricate- Sch.I	SWB
Green Sea Turtle	Chelonia mydas- Sch.I	SWB
Red-Crowned Roof Turtle	Kachuga kachuga- Sch.I	SWB
Black Pond Turtle	Geoclemys hamiltonii- Sch.I	SWB
Indian Flap shell Turtle	Lissemys punctata	SWB
Indian Narrow-headed Soft-shell Turtle	Chitra indica-Sch.I	SWB
Bengal Monitor	Varanus bengalensis	EWB
Yellow Monitor	V.flavescens	SWB

Water Monitor	V.salvator	SWB
Indian Python	Python molurus- Sch.IV	NWB
Asiatic Python	P.reticulatus	NWB
Indian Egg-eating Snake	Elaschistodon westermanii- Sch.I	NWB
Dhaman / Rat Snake	Ptyas mucosus	EWB
Indian Cobra	Naja naja	EWB
Amphibia	Trilototriton verrucosus- Sch.IV	EWB

Note: EWB- Entire West Bengal, SWB- Southern West Bengal, NWB- Northern West Bengal, SWWB- South West Bengal

cat, Himalayan black beer, hyena, jackal and fox, three species of mongoose and two species of otters have been threatened. Tiger Reserves of Buxa and Sundarban have played satisfactory role for preservation of the food chain through maintenance of the niche of wild cat.

The Great Indian one-horned rhinoceros is now struggling for survival because they are easy prey of the poachers. Javan rhinoceros, once found in the deltaic part of undivided Bengal has become extinct along with water buffalo, swamp deer, Indian muntjse, gharial, soft-shell turtle and barking deer. Poaching of rhinos and elephants for their precious horns and ivories respectively is a problem of wildlife management to reckon with. Many other herbivores like gaur, wild buffalo, bharal, goral, serow, hog-deer and sambar, once widely found in northern part of West Bengal have also been threatened along with Indian porcupine, Chinese pangolin and Malayan giant squirrel. Hispid hare can be found only in restricted areas of the Northern part of West Bengal. Existence of rare species known as pygmy hog has been reported from Gorumara forest of this region.

The avi-fauna of West Bengal composed of 219 species have mostly been enlisted in different schedules of Indian Wildlife Protection Act, 1972. Among the aquatic birds, pelicans, spoonbills, storks have also been threatened. Due to habitat destruction by anthropogenic interference in the higher part of the eastern Himalayas, several ground dwelling bird species particularly the pheasants have become rare along with snow pigeon and purple wood pigeon. Eagles, falcons, bazards, hawks and owls also have been threatened mainly because of contamination by pesticides. The Bengal florican, once found in the *Terai* grasslands is struggling for survival. Though pink headed ducks are not found now-a-days in West Bengal, black necked crane has been spotted recently in Buxa area of *Dooars* region in the north.

Destruction of habitat as well as illegal wildlife trade are responsible for inflicting injury to the diversity of reptile fauna especially different species of snakes, crocodiles, monitor lizards, turtles and tortoise. Though king cobra and python both have been identified in the tiger reserve of Buxa and biosphere reserve of Sundarban, four species of Monitor lizards and three species of crocodiles are considered to be endangered. Four species of marine turtles including olive ridley, hawks bill and green turtle are found in the coastal and littoral tracts of West Bengal. Marine turtle hatchery and captive breeding program of crocodile have played crucial role in restoration of normal population size of these species.

Among the amphibians, population size of the edible frog species was declining steadily till mid-1980s for assuring steady supply in the export market taking the advantage of absence of any regulatory measure. After imposition of ban

on such export there is a tendency of restoration. The amphibians and other aquatic life forms have paid the penalty of wetland reclamation in so many areas of West Bengal.

Over utilization of the aquatic resource base has made havoc to the diversity of riverine fishes. Several varieties of fish well known to the fish loving population of West Bengal even two decades ago, have almost disappeared from the market (Tab 5). Fishing with fine nylon nets by the mechanized trawlers has a negative impact on the food chain of the marine ecosystem in the Bay of Bengal. Catching the juveniles induced by such a method of fishing has gone against the spirit of biodiversity conservation. Many non-target fishes and small fries are often destroyed by such indiscriminate fishing. Collection of prawn seeds from the estuaries is also responsible for depletion of many non-target aquatic species. It is estimated that for collection of 500 prawn seeds about 5kg of juvenile fishes are destroyed per net per day. Water pollution in the downstream of the river Ganga and catching the juveniles of anadromous fish like hilsa which prefer fresh water for spawning are causing immense injury to their population size. Recent emphasis on monoculture of lobster and shrimp in the water pools of Sundarban locally known as *bheri* is also going against the declared Government policy of biodiversity conservation. In the controlled river systems of West Bengal having big dams and reservoirs diversity of fishes has been drastically reduced because of restrictions imposed on their normal movement from upstream to downstream.

Man-animal conflict

Because of deforestation the mangrove forest of Sundarban has been subjected to southward recession; the forests of hilly and piedmont areas in the northern part of the State as well as the forest cover of the western plateau and its fringe areas have been truncated in many areas. Such recession and truncation of the forest cover has led to destruction of the habitat of wild animals. There are several reported incidences of straying of tigers in Sundarban beyond the limit of the buffer zone. Herd of wild elephants often enter into the tea gardens of *Terai-Dooars* region in the north and into the arable lands of plateau region in the south - western part of West Bengal in search of food. In absence of the provisions for forest corridors it has become gradually difficult for the wildlife to get sufficient space for roaming and to get

Table 5: Vanishing river fishes in Northern Part of West Bengal

Local Name	Scientific Name
Aar	Mystus seenghala
Boumach	Botia lohachata
Bele	Glossogobius giuris
Boal	Wallago attu
Barali	Barilius barilia
Chanda	Stromateus argenteus
Dagor	
Darika	
Foloi	Notopterus notopterus
Kalbasu	Labeo calbasu
Khalisha	Kolisa lalius
Kursa	Labeo gonius
Mahashol	Tor tor
Maurala	Amblypharyngodon mola
Mrigel	Cirrhinus mrigala
Pabda	Ompok pabda
Pathar chata	Barilius tileo
Piyali	
Raikhor	
Ritha	Rita rita
Shol	Channa stiatatus
Tangra	Mystus vittatus
Tapa	Tetradon cutcutia
Teenkanta	

Source: Ghosh, 2003

easy access to food reserve available in different seasons. Elephants often become victims of accident on the railway tracts and highways while crossing them in a herd along with their babies.

There are several incidences of unauthorized entry of the local poor people into the forest in search of fuel, non-timber forest products and fishes or crabs in the water bodies and estuaries within the jurisdiction of the reserve forests. They are often allured by poachers to satisfy the interest of the underworld trade of wildlife and their specific body parts. Such unauthorized encroachment into the forest either driven by acute necessity or by mere greed is responsible for shrinkage of the biodiversity base in the wild environ. Several projects under Man and Biosphere Program (MABP) are still considered as non-starters to address the problems in the forest-society interface.

Scarcity of the sacred groves and ponds

Many tribal as well as non-tribal rural communities in different parts of India maintain sacred groves and ponds where hunting of animals and slashing of plants are prohibited. These actually have been maintained as wildlife sanctuaries through involvement of the local communities. Gadgil et. al. (1997) has argued that such groves and ponds may serve as important refugia for threatened and rare species. Many such groves are likely to preserve the micro climate of the area, recharge aquifers and enhance nutrient cycling. Many of them are primary sources for perennial streams and are the last resorts for many aquatic creatures in dry seasons.

Unlike southern and north-eastern States of India, West Bengal has very few sacred groves and ponds. The British rulers, through the provision of Permanent Settlement Act of 1793, empowered the local landlords to bring all 'unproductive' woodlands under cultivation in order to maximize the yield of land revenue. Oppression of these landlords and money lenders compelled the forest dwelling tribals to migrate elsewhere. Many of them moved to the tea gardens of *Terai-Dooars* region and to the coal belt of the western part of undivided Bengal as labor force. The second phase of destruction of the sacred groves started with the implementation of the Forest Act, 1876 which brought most of the virgin forests including the sacred groves under the Forest Working Plans for extracting timber. The third phase of destruction started after independence in the name of industrialization and urbanization which wiped out the remnants of the sacred groves and ponds from the village landscape (Ghosh, 2013).

Agricultural policy in question

High yielding varieties (HYV) of paddy, winter wheat and other vegetables have been introduced in West Bengal replacing rich genetic diversity of crops since the decade of 1960's. Consequently, the local varieties of paddy like *Gobindabhog, Kamini and Pahari Atap, Chamarmoni, Sitashal, Jhingashal* etc. characterised by fine texture and fragrance were replaced by HYV seeds of Jaya, Padma, Ratna and Minikit etc. for satisfying hunger of the teeming millions. Magnitude of the loss of crop diversity in the State has never been assessed. In fact a marketing strategy followed after the so called 'Green Revolution' has led to a dangerous trend of homogenization of agricultural practice. Policy makers failed to realize the potential of germplasm. The cost of production in case of HYV culture is beyond the capacity of the marginal farmers. It would have been ideal for the State to set up 'community based germplasm bank' for short and mid-term preservation of indigenous varieties of seeds. Such a measure would have been favorable either for isolating the useful genes or for recombining them with the ones which are currently under use. The seed policy of the State Government needs to be reviewed. Varietal diversity of cereals (Table-6) and Non-cereal crops (Table-7) has been depicted below:

Table 6: Varietal Diversity of Cereals and Grains in West Bengal

Rice	±400 (5,556 Pre-Green Revolution period)
Finger Millet	Several
Wheat	02

Source: Ghosh, A.K., 2003

Table 7: Varietal Diversity of Non Cereal Crops

	Number				Number
Vegetables	Potato	2+	Spices	Chilli	12
	Brinjal	25		Ginger	2+
	Cabbage	18	Plantation Crops	Coconut	5
	Cauliflower	22		Areca nut	3
	Tomato	17	Fibre Crops	Jute	2
	Lady's Finger	15		Mesta	10
	Cucumber	11	Flower		Numerous varieties
Fruit Crops	Mango	150+			750 (75 com mercially col lected)
	Banana	25	Medicinal plants		
	Guava	8			
	Pineapple	6			
	Litchi	7			

Source: Ghosh, A.K., 2003

Rural biodiversity

In fact there was no attempt to register the diversified floral and faunal resources of the rural areas of West Bengal under State initiative. The first People's Biodiversity Register (PBRs) in this State was prepared by a team of students with assistance from ENDEV - a Society for Environment and Development in 1999 (Ghosh, 2013). Similar effort was made by another NGO known as *Paschimbanga Bigyan Mancha* later on. Up to the end of calendar year 2012, the State has been successful in setting up Biological Management Committees (BMCs) in 35 local bodies in the rural areas. AState Biodiversity Board (SBB) also has been set up in the mean time. An initiative also has been taken towards formation of Biological Management Committees (BMCs) at the local level.

Major findings

Based on available secondary data as well as primary data generated from the direct and indirect stake holders through questionnaire, several observations can be recorded on the status of biodiversity in West Bengal.

- **Benefits of biodiversity:** Floral and faunal diversity in the State of West Bengal is in fact providing food security to the local people through supply of crops, vegetables,

fruits and animal protein. Living organisms of the State provide the human society numerous drugs and medicines which are being utilized by the pharmaceutical companies. Formation of soil, nutrient cycles, absorption of solar energy, purification of air and water are dependent on the biodiversity base in this part of the tropical country of India. Value of these ecological services has never been measured. Competition, predation and productivity of the organisms ultimately control their population size. Maintenance of biodiversity is therefore essential for preservation of ecological services. Besides various nature-oriented activities like wildlife and bird watching, hiking, angling, camping and adventure tourism along with eco-tourism enjoyed by millions of people provide aesthetic and cultural benefits too. Biodiversity of different ecosystems in West Bengal has the potential to augment the local economy of even the remote areas.

- **Destruction of habitat:** For expansion of agriculture, animal husbandry, mining activities, urbanization and infrastructural development, thousands of hectares of forests, woodlands, water bodies and wetlands have been converted ento cultivated land. The rate of shrinkage of such natural landscape is alarming in the area under study. Wetlands and estuaries, though occupy relatively smaller area of the State, support high biodiversity and biological productivity. But these are either being drained or disrupted extensively thus leading to loss of biodiversity.
- **Fragmentation:** Reduction of wild habitat into smaller fragments has led to drastic reduction of biodiversity because different species of wild animals like big cats and elephants require large territories for their subsistence. Many wild species inclusive of avifauna, dwelling in the core area of the forests, reproduce successfully in the tranquility of the forest interior away from the hustle bustle of the human society. Such fragmentation may lead to formation of small groups of isolated population who become vulnerable to catastrophic events like natural calamities, famine and epidemic. A small group of population may not have enough breeding adults necessary for survival of the community.
- **Hunting and commercial fishing:** Hunting of targeted wild animals like tigers, rhinoceros, elephants and deer along with crocodiles and dolphins in the estuaries of West Bengal apart from indiscriminate netting of small or big fishes and turtles are responsible for depletion of many species. In fact the food chain of the forests and water bodies are seriously affected.
- **Commercial products and live specimens:** Despite international ban on trade in products out of endangered species, smuggling of hides, ivory and horns either for folk medicines or for live specimens has a turnover of millions of dollars every year. Mortality rate in the live animal trade is too high. The trade in wild species for pets is a lucrative business. Over harvesting of selected plant species also threatens the plant kingdom.
- **Diseases:** Pathogens often behave like predators. A pathogen normally establishes a balance in which it is vigorous enough to reproduce, but not that lethal to destroy its host. Consequently, in case of outbreak of a certain disease in new environment, this balance may be disturbed and an epidemic may break out to sweep away the plant association of the entire habitat. Disease like Anthrax sometimes affects wild animals like elephant in West Bengal.
- **Pest control and pollution:** Toxic pollut-

ants have disastrous effects on the organisms. Persistent chlorinated hydrocarbons like DDT, BHC and PCB with their high residue level not only affect the soil and water, but these are known to enter into the food chain and often concentrate in fat and milk of the mammals; these are also responsible for making eggs of the birds sterile. Bee population, well known for helping the process of pollination, if affected, may in turn lead to serious reduction in the yield of the flowering plants. Cattle population consuming hay is often affected; fishes in the riverine ecosystem often suffer from accumulation of toxic pollutants.

- **Introduction of exotic species:** Alien species introduced into the areas of any ecosystem pose as a threat to biodiversity. These introduced varieties are free from the control of predators, parasites, pathogens and competitors which was in vogue in their place of origin. In West Bengal Parthenium is such a species which has appeared through the imported bags of food grains and has established itself through the process of plant succession along the major transportation arteries.
- Introduction of Eucalyptus and Akashmoni species in preference to an indigenous combination of Sal-Palash-Mahua-Kusum-Karanj is never liked by the tribal communities who traditionally use the biodiversity base of the indigenous combination.
- Introduction of Genetically Modified Organisms (GMOs): In different States of India, viz. Maharashtra, Andhra Pradesh etc. Bacillus thuringiensis (Bt) variety of Genetically Modified Cotton, was introduced thus compromising the indigenous diversity of the seeds. These actually have inflicted much injury to the diversity of crops. With bitter experience of Bt Cotton, Bt Brinjal was never approved by the Genetic Engineering Approval Committee (GEAC) under the Ministry of Environment and Forest. West Bengal is fortunate enough not to introduce any GM crop.

There is of course silver line amidst the dismal picture of biodiversity loss. ENDEV, a non government organization has taken initiative for revival of indigenous salt resisting varieties of paddy crops like Hamilton, Matla, Nona bokra, Talmagur, Lal ghetu and Sada ghetu on the saline soil of Sundarban.

Concluding remarks

Participatory management of forest involving the local marginalized people seems to be the best option for conservation of biodiversity in West Bengal. Several projects under Man and Biosphere (MAB) program, meant for the hilly areas, rivers, deltas, estuaries and coastal belt, if implemented with an orchestrated effort of the relevant government departments as well as the interested non government organizations is expected to give rich dividend towards restoration of floral and faunal species diversity. Existing racket of the poachers, traders of live specimens and saw mill owners in connivance with a section of the people walking in the corridor of power, need to be dealt with iron hands. Bringing the level of pollution of Ganga water under control is a task of the Ganga Action Plan Authority who has been severely criticized by the honorable High Court of Kolkata recently for emphasizing more on beautification of the strand rather than upgrading the quality of her water to a level which can be considered as fit for bathing. It is expected that this body will fulfill its mission to make the river habitable for the aquatic creatures. Use of fine nylon nets for fishing should be disbanded without further delay so that non target aquatic life can survive and food chain in the rivers, estuaries and shallow sea is allowed to run smoothly. It would be better to discourage monoculture of shrimp and lobster. Bio-pesticide is the best green alternative to the chlorinated hydrocarbon group of

pesticides and their availability in the market at a cheaper price needs to be assured. Time is mature enough now to revise the government policy of preference to exotic species over the indigenous species combination for rendering justice to floral biodiversity as well as to traditional material culture of the tribal people. Seed bank for preservation of the indigenous crop seeds is a loud demand of the conscious farmers now. Such a demand has already been justified by the experts in this field, especially after devastation of the notorious tropical cyclone 'Aila' in the coastal belt of West Bengal. Non introduction of GM crops in the State may be considered as a bold step. Environmental Impact Assessment prior to conversion of land use though mandatory now a days in India, instances of habitat destruction is not unknown in West Bengal. Creating provision of forest corridor for hassle free movement of the wild animals is a challenging task now. Good will still prevails, no doubt, but that requires making an impact on ground reality too.

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From Bonsai to big Banyan: Scaling up Community Driven Green Livelihood Initiatives

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Abstract

Livelihood promotion has assumed unprecedented primacy in the contemporary developmental discourse primarily because three core developmental challenges, namely economic poverty, social inequality and environmental nonsustainability appear to be inextricably linked with livelihoods. At the same time, the world is witnessing multiple stressors at global, regional and local levels interacting and reinforcing each other to affect livelihood opportunities. It is also important to highlight that all types of livelihood interventions may not be sensitive to environment. In fact, insensitive livelihood policies and practices have been found as one of the core reasons behind growing environmental degradation. In this context, the call for sustainable development makes it imperative to design and promote green livelihood projects. Against this backdrop, this paper assertively proposes that it is imperative to scale up community driven green livelihood initiatives (CDGLIs) in order to ensure just, inclusive and sustainable development for the teeming millions of the country. After summarizing the concepts related to promotion of CDGLIs and scaling up, the paper articulates key rationale for the same. Finally, it ends with listing out key considerations for successful scaling up of CDGLIs.

Keywords: *community driven development, development, green livelihoods, livelihoods, scaling up*

Introduction

The three core developmental challenges, namely economic poverty, social inequality and environmental nonsustainability, appear to be inextricably linked with livelihoods. Livelihood has been one of the core concerns of the humanity in general and academicians and policy makers in particular. But in recent years, the issues surrounding livelihoods have become central to all the developmental debates across the globe probably because of the three reasons: development of sustainable livelihood approaches (SLA) framework by the Department for International Development of UK (DFID, 1995-2005) and adherence to the same by a number of influential donor agencies; inclusion of Target 1 B in the Millennium Development Goals (MDGs) (UN, 2001) and later of Goal 8 in the Sustainable Development Goals (SDGs) (UN, 2015) which aim at developing and implementing strategies for decent and productive

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work for men, women and young people and related policies and programmes in all the signatory countries; and enhanced precarization of labour evident through declining employment-to-population ratio, growing informalization, the declining wage share and increasing income inequality (van der Hoeven, 2010). At the same time, climate change also appears to have exacerbated the processes of growing vulnerabilities of the communities (International Institute of Sustainable Development, 2003) bringing the issue of livelihoods under sharper focus. In the Indian context, despite huge investments and genuine intentions, as Datta, Kandarpa and Mahajan (2014) conclude, livelihoods of a large number of people are not yet stable. Against this backdrop, this paper assertively proposes that it is imperative to scale up community driven green livelihood initiatives (CDGLIs) in order to ensure just, inclusive and sustainable development for the teeming millions of the country. After summarizing the concepts related to promotion of CDGLIs and scaling up, the paper articulates key rationale for the same. Finally, it ends with listing out key considerations for successful scaling up CDGLIs.

Concept of livelihoods

Oxford English Dictionary defines livelihood as a means of securing the necessities of life (Livelihoods, 2015a) while Merriam Webster Dictionary defines it as a way of earning money in order to live (Livelihoods, 2015 b). Etymologically, this word is said to have evolved from Old English l?fl?d meaning 'way of life ' and Middle English livelode which means course of life. Therefore, a livelihood is not just a means of survival. It goes deeper, and is rooted in a way of living over a period of time. However, as Morse and McNamara (2013) point out, the notion of sustainable livelihood, as we know it today, can be said to have arisen out of the 1992 Earth Summit held in Rio and its promotion of Agenda 21. A stated aim in Agenda 21 is that everyone must have the "opportunity to earn a sustainable livelihood". In a discussion paper, Robert Chambers and Gordon Conway in 1992 offered following definition of a livelihood:

"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term" (Chambers and Conway 1992: 7-8).

This definition was adopted by Department for International Development (DFID), UK to develop a series of Guidance Sheets (DFID, 1995-2005) which developed and elaborated upon a framework of Sustainable Livelihood Approach. (SLA). This framework uses the concept of capital assets as a central feature and considers how these are affected by the 'vulnerability context' in which they are derived, and by 'transforming structures and processes' (alternatively labelled 'policies, institutions and processes'), to constitute 'livelihoods strategies' which lead to various 'livelihoods outcomes'. It has since been adopted or adapted by international and national organizations (governmental and non-governmental) resulting in to a number of sustainable livelihood approaches. In sum, SLAs may be seen as: a set of principles guiding development interventions; an analytical framework to help understand what is and what can be done and; an overall developmental objective (Farrington , 2001). Over the years, this perspective has gained momentum representing a shift from a need based-resource centered solution to people-centred, holistic and dynamic approaches where people are not seen as beneficiaries but as a change agent who can actively explore opportunities and cope with

changes positively (e,g., de Haan and Zoomers, 2003; Owusu, 2009; Scoones, 2009).

Rationale for focusing on livelihoods

From the individual's point of view, at the most fundamental level, physiological and safety needs are considered most basic in the hierarchy of human needs (Maslow, 1943). Both the need groups are inextricably linked with livelihoods. Thus, primary rationale for focusing on livelihoods comes from the survival urge of human kind. From the policy side, there is a constitutional obligation for ensuring livelihoods for the citizens of India. Article 39 (a) of The Constitution of India states:

"The State shall, in particular, direct its policy towards securing … that the citizens, men and women equally, have the right to an adequate means to livelihood".

Further, the Bombay High Court held that the right to life, in Article 21 of the Constitution, encompassed means of livelihood (Bombay High Court, 1985). The right to livelihood cannot be excluded from the content of the right to life. From the development practitioner's side, alleviation of poverty and eradication of social inequalities remain core challenges and both the challenges are linked with inadequate livelihoods. It has been found that provision of sustainable livelihoods has improved economic and social conditions of the disadvantaged communities and households. People with sustainable livelihoods have found themselves empowered not only to take care of their own life but also in a position to affect policies at regional and national level. Further, recent times have recorded multiple stressors on livelihoods which have been defined as simultaneous or subsequent conditions or events that provoke/require changes in livelihoods (Olsson et al, 2014). Stressors may be climatic (e.g., shifts in seasons), socio-economic (e.g., market volatility), and environmental (e.g., destruction of forest) in nature, that interact and reinforce each other across space and time to affect livelihood opportunities and decision making. Stressors that originate at the macro level include climate change, globalization, and technological change. At the regional, national, and local levels, institutional context and policies shape possibilities and pitfalls for lessening the effects of these stressors. These stressors have brought livelihood discourse under spotlight.

Understanding livelihood initiatives and green livelihood initiatives

Poor people do engage in their own ways to earn a living which can be called, in the formulation of Cowen and Shenton (1998), as "immanent approach" to development. Livelihood initiatives essentially exemplify an "interventionist or intentional approach to development," which is a focused and directed process whereby government and non-government organizations implement development projects and programmes. In the context of livelihoods, the interventionist approach, the deliberate attempt to initiate and nurture a livelihoods project may be termed as livelihood promotion which has been defined as an organized attempt to enable poor people to earn a living adequate to support themselves and their families with basic needs and services (Mahajan, 2009). All such planned initiatives aiming at promoting livelihoods may be termed as livelihood initiatives.

However, it should be borne in mind that all livelihood initiatives may not promote 'green' livelihoods which derive their rationale from a vigorous development on the front of moving towards a green economy (UNDP, 2011; UNEP, 2010, 2011) in recent years. Green economy needs green enterprises and green initiatives. While the concept of 'green jobs' has been defined (UNEP/ILO/IOE/ITUC , 2008), there is no formal definition of 'green livelihoods'. However, in this paper, green livelihoods include any livelihood project which is based on environment friendly use of natural resources or any environmental project with a livelihood dimension.

In consonance with definition of green economy by UNEP, green livelihood project is one which is low carbon, resource efficient and socially inclusive. To illustrate, Badrinath Prasad Tokri Karyakram of a AAGAS, an Uttrakhand based NGO is an example of green livelihood project (Bisht and Dastidar, 2012). It aims at reducing the use of polythene at the Badrintah shrine with baskets made of Ringaal (a species of Bamboo) which are being made largely by the woman artisans belonging to scheduled castes and tribes.

CDGLI: concept and rationale

Following much disappointment with traditional top-down development strategies, governments in developing countries, donors and international organizations, are increasingly relying on the so-called participatory or community driven approach to development (CDD) (Conforti and Ciamarra, 2005). International Fund for Agricultural Development (IFAD, 2009) defines community driven development (CDD) as a way to design and implement development policy and projects that facilitates access to social, human and physical capital assets for the rural poor by creating the conditions for transforming rural development agents from top-down planners into client-oriented service providers; empowering rural communities to take initiative for their own socio-economic development (*i.e.* building on community assets); enabling community-level organizations -especially those of the rural poor - to play a role in designing and implementing policies and programmes that affect their livelihoods; enhancing the impact of public expenditure on the local economy at the community level. Community-driven development (CDD) treats poor people and their institutions as assets and partners in the development process and gives control of decisions and resources to community groups. Summarizing experiences of community driven development, Dongier et al (2000) found that CDD can make poverty reduction more efficient, effective, demand responsive, scalable and it has potential to build positive social capital. Owing to these reasons, it becomes imperative to promote community driven development initiatives and assist in maximizing impact of their work.

Community driven development can be supported by both state and non-state actors (Gillespie, 2004). Non-state actors include corporate sector as well as civil society organization (CSOs) or non-governmental organizations (NGOs). NGOs have played an important role in poverty alleviation, social mobilization, increasing empowerment and improving livelihoods of people in India (Premchander, 2013). Since sustainable livelihood development primarily depends on local contexts, needs, and priorities (UNESCO, 2005), NGOs are best placed to understand these contexts and priorities in designing relevant livelihood solutions not just due to obvious economic imperative but also due to their unambiguous social justice agenda.

Scaling up CDGLI

The concept

While discussing the theme of this paper with the colleagues, a comment was heard by the first author: "Isn't it the fact that small is beautiful?" Obviously, he was alluding to the extremely influential book with the same title by the well known British economist Schumacher (1973) but this comment really made me think. Of course, small is beautiful but at least in the context of livelihood interventions, 'small' is grossly insufficient. Big is a necessity. While it is important to experiment with small (bonsai) pilots but these projects have to be brought to a scale with a larger reach (like a big banyan). There has always been a tendency among development agencies and practitioners to enlarge their reach and maximize impact. Hence, 'scaling up' remains a key term in the contemporary development lexicon. A number of scholars/institutions have attempted to define the concept

of scaling up (e.g., Creech, 2008; IIRR, 2001; Desai, 2007; Hancock, 2003; Hartmann and Linn, 2008; Shoham, Dolan and Gostelow, 2013; World Bank, 2005). A review of definitions makes it evident that the concept of scaling up is being variously articulated by different scholars. In spite of, or because of, the wide use of the term, there is no consensus on the concept (Simmons, Fajan and Ghiron, 2007). Picciotto (2003) observes the multidimensionality of the term and rightly points towards climbing up, reaching out and drilling down as in the growth of a tree in which branches spread and roots deepen simultaneously. In its most conventional sense, it means codification of a demonstrably successful solution and its subsequent transference to other areas and target groups in order to achieve greater impact. However, following Omar (2013), it can be safely concluded that despite variations, these definitions do point towards an increment in provision.

Types

Rather than just being quality of impact, scale and sustainability, as Hartmann and Linn (2008) have pointed out, in practice, scaling up involves a multidimensional process of change and adaptation. They cite Uvin (1995), who has identified four different dimensions of scaling up: quantitative, functional, political, and organizational. Quantitative scaling, also known as horizontal scaling up or scaling out is the geographical spread to more people and communities within the same sector or functional area. Functional scaling up is expansion by increasing the types of activities and integration with other programs. Political scaling up refers to expansion through efforts to influence the political process and work with other stake-holder groups, with state agencies, parliamentarians and political parties. Organizational (or institutional) scaling up means the expansion of the organization implementing the intervention, or the involvement of other existing institutions, or the creation of a new institution. This can involve both horizontal and vertical organizational expansion, the former involving similar institutions while the latter means going up the ladder from community to local to regional to national (and in some cases even supra-national) institutions. As evident, scaling up can take place through three different organizational paths: expansion, replication, and spontaneous diffusion. While some authors distinguish collaboration (which can be in the form of formal partnerships to informal networks) as an additional method of scaling up, others (e.g. Hartmann and Linn, 2008) consider it falling somewhere between the expansion and replication approaches.

In another formulation, Kohl and Cooley (2005) mention five main vectors along which the scaling up of a pilot can occur: Geographic coverage, *i.e.* extension to new locations; Breadth of coverage, *i.e.* extending number of people being served in current categories and localities; Depth of services, *i.e.* providing additional services to current clients; Client type, *i.e.* extending to new categories of clients; and Problem definition *i.e.* extending current methods to new problems. A recent publication (ACCESS Development Services, 2014) lists four types of scaling up processes, namely: scaling deep, scaling along, scaling out and scaling through. Without moving to other geographies, scaling deep addresses more needs of the same people. In scaling along, the organizations are able to build capacity to evolve with the evolving needs of the target group. The terms scaling out is used in the context where a solution that is codified and seems to be working is applied in a different area/domain. In scaling through, a model that is sufficiently codified is transferred to other franchisees to replicate in other geographies.

Rationale

The ultimate goal of community driven development projects is to move from being is-

lands of excellence that serve and empower a handful of communities, to operating at a national scale, where all regions of the client country can benefit from the project's approach. By scaling up, the aim is to reach the greatest possible number of poor people, and to motivate and empower the greatest number of communities to take control of their own development (World Bank, as cited by Gillespie, 2004).

Touching greatest possible number of individuals and communities has been the prime motivation behind every scaling up effort. There are a number of innovative social projects scattered all over the globe. But as International Fund for Agricultural Development (IFAD) asserts "innovation without scaling up is of little value" (IFAD 2007a, p. 6), and further: "effective scaling up is a key measure of successful innovation" (IFAD 2007b, p. 8). Perhaps that is why in the scholarship on livelihoods, donor agencies and livelihoods practitioners, each stakeholder has realized its importance.

Recent critiques point out the lack of scale thinking in the discourse on sustainable livelihoods (e.g., Scoones, 2009; Morse and McNamara, 2013). Perhaps that is why the theme of the India Livelihood Conference (2013) was Quest for Scale. But it is not just the discourse imperative which provides a rationale for scaling up community driven initiatives or social innovations, this is being largely pushed by grant makers/donor agencies who want to enhance the impact of the initiatives supported by them. In order to broaden the conversation in philanthropy about scale and impact, Grant makers for Effective Organizations launched the Scaling What Works initiative in 2010. After the conclusion of this project in 2013, a selection of articles got published in a special supplement in the Spring edition (2014) of Stanford Social Innovation Review entitled "Smarter Philanthropy for Greater Impact: Rethinking How Grant makers Support Scale (Enright, 2014). This supplement emphasized the relevance of scale up social innovation in order to enlarge impact and effectiveness.

Another impetus for scaling up particularly in the Indian context is in offing from corporate sector. Section 135 of the new Indian Companies Act (2013), mandated that companies with a net worth of more than Rs.500 crores or revenue of more than Rs.1,000 crore or net profit of more than Rs.5 crore will have to spend at least 2% of their average net profits of the preceding three years on corporate social responsibility (CSR) (Malik and Jenkins, 2013). This will have a cascading effect on philanthropy since nearly 8000 companies will have to spend a combined total of up to Rs. 150 billion (US$2 billion) annually on CSR activities (Ghuliani, 2013). In another estimate nearly 16000 companies will be spending USD 2.5-3.6 billion (Ratha, 2015). Companies support a wide range of important causes such as health and education, as has been persuasively argued by Ratha (2015) that a sharper focus on promoting livelihoods for the poor is better aligned with the abilities and needs of the companies. More money means more investment which in turn needs a framework to scale up existing initiatives.

Seen as an enterprise, a livelihood intervention needs to be scaled up just to avail economies of scale which refers to cost advantages that enterprises obtain due to size, output, or scale of operation, with cost per unit of output generally decreasing with increasing scale as fixed costs are spread out over more units of output. Scaling up is also being seen as a way to give voice and visibility to the community. Small successes are not even noticed. Bigger successes affecting quite a few individuals / households will generate more clout for advocacy for other rights of the community. There is an impetus for scaling up from the consumers as well who are demanding for more green products and services at affordable prices. Currently,

availing such products and services is a limited luxury. If green enterprises have to respond to mass aspiration, scaling up is the only solution.

Developing a scaling up framework: a brief review

A number of efforts have been made in the last decade to develop frameworks for scaling up social projects based on the case studies of community driven initiatives. For example, Binswanger and Aiyar (2003) and Binswanger and Nguyen (2004) examined the possible field-tested manuals, lack of scaling-up logistics, the obstacles to scaling up, and possible solutions. Hancock (2003) presents a checklist for thinking systematically about Scaling-Up impact. It is intended to help development practitioners and their partners think through key points related to scaling up impacts. Cooley and Kohl (2006) outline a three-step and ten-task framework offering a template for planning and for implementation. This model sees scaling up as a process that begins with good planning. Ideally planning starts with initial testing of the innovation. In this model, most of the work is done prior to any action to scale up. Important and useful frameworks have also been developed by Hartmann and Linn (2008, 2009) and Linn, Hartmann, Kharas, Kohl and Massler, (2010). Using these and similar frameworks a number of initiatives have been studied. A review of these studies show that the case studies of livelihood initiatives are fewer in number in India, the number is almost negligible. At the same time, most of these frameworks have been developed from donor's/grant makers perspective, not from practitioners perspective.

Key pointers for scaling up CDGLIs

UNDP India brought together nearly 15 organizations to share their experiences of scaling up successful livelihood pilots in different parts of the country (UNDP, 2012). Their experiences throw up a number of key insights which are being summed up below:

- Models can be scaled up if they adapt to changing social, economic and political conditions.
- Mere linear replication does not result in the sustainability of models. For beneficiaries of any scaling up model to stay with the model and continue its evolution, expansion and growth, there is a need to institutionalize a series of incentives that result in economic gains for the beneficiaries.
- Scaling up has to be people driven and any scaling up institution has to be an institution of the poor where they are able to understand effectively the process and dynamics of scaling up.
- Some of the points critical to scaling up are: intense social mobilization, institution building of the poor, dynamic and sensitive technical support, inducting young professionals to work with communities, a sensitive intermediary organization, strategic funding for the pilot stage, ownership by the government, availability of resources and a rights-based environment.
- Scaling up cannot happen in isolation and cannot be merely led by a single entity
- Partnerships with various organizations on the ground are important. So is the ability to retain large implementation teams. Partnerships also have to be piloted through various forms and capacity building patterns need to be designed such that they can be adapted to the needs of the partners.
- For scaling up to be effective, grassroots mobilization, especially of women and their systematic empowerment is an important consideration. Creating local structures that empower women have to work in tandem with existing local political structures that need to be convinced of the need for

women's empowerment. Ownership of land and other assets and their productive utilization by women in a campaign mode has resulted in the success of a number of initiatives.

- Oppressive working environments and conditions for workers need to change dramatically for livelihood scaling to progress.
- Mass media and interactive behavioral change communication tools play an important role in achieving scaling up.
- People-focused technology, gradual capacity building, involvement of women and grassroots community mobilizers and transparent operational and governance systems, all help in creating a successful recipe for scaling up.
- Government and other stakeholder participation (for example, religious groups) and the ability to manage this relationship in an effective way are important considerations for scaling up.
- There is a need for constant dialogue between the private sector and the government. It is important to understand the structure of how the government and the private sector dialogue in a transparent and seamless manner with mutual trust and cooperation for scaling up.
- For scaling up, the organization and the communities have to demonstrate a certain level of pragmatic risk-taking behaviour.
- Systems and processes need to be established which allow the organization to work effectively with governments, the trade and markets so that local people centred institutions own and manage the processes of generating livelihoods and scaling up.
- Key to developing a replicable and a scalable approach is the application of appropriate people-centric technology that is taken to the poorest of the poor.
- Capacity building at various levels of staff members for delivery of the programme, of local government machinery for behavioural change, etc., is important.
- Evolving a responsive organizational structure with local presence nearer to the people and a central support structure allowing for autonomous functioning of independent units.
- For rural producer communities, scaling up can take place through adopting a value chain based approach.
- People are the core asset for ensuring scaling up. Organizational and impact growth can only take place if people are available within the system to ensure commitment to scaling up.
- Human resources are thus an integral part of the scaling up strategy.
- Scaling up requires continuous presence in a particular geography through working groups which are able to create a second tier of visionary resources, both at the organizational and partner levels.
- Another project titled BIG GREEN, which attempted to develop a framework for scaling up CDGLIs (Kumar, 2015, Feb 13-14), in its early findings, noted that: scaling up needs internal expertise, management skills, quality consciousness, favorable legal frameworks, appropriate technology and adequate finances.
- dependence on dole/grants must diminish as scaling up moves up the ladder.
- organizational vision for scaling up is an essential prerequisite
- most of the grassroots institutions lack second line of leadership and is being run as a one man/woman show which would make it impossible to scale up.

But before scaling up is attempted, it is im-

portant to scout scalable initiatives. One such effort has been made for livelihood initiatives in Odisha (ACCESS Development Services, 2011). More such initiatives need to be undertaken in order to convert islands of excellence in to a phenomenon of continental magnitude.

Concluding thoughts

Development and democracy both remain a work in progress and availability, adequacy and quality of sustainable livelihoods stand as litmus test for their success. The poorest of the poor in India just not lack economic opportunities, they are entrapped in the 'vicious circle of inter-generational poverty and face simultaneous multiple deprivations ranging from social discrimination to alienation and in some instances just invisibility from the eyes of development practitioners (Bhogal, 2014). On the other hand, there is growing realization that extractive growth is not sustainable, but faces economic, ecological, social and political limits that will inevitably bring it to a halt (Saxer, 2013). The issue of livelihoods is inextricably linked with development which hinges on to participatory democracy. While right to livelihood is inseparable from right to life, right to right livelihood should be on the agenda. Right livelihood should be environmentally sustainable, economically gainful and socially just. There are multiple agencies engaged with livelihood promotion which includes the state, corporate and community based organizations. This paper discusses community driven green livelihood initiatives which are being incubated and supported by voluntary organizations. NGOs have been involved in livelihood promotion since decades. But their experiments largely remain as islands of excellence. There are enough social innovations related to livelihoods promotion at the grassroots. Finding such solutions and scaling them up is the *mantra* for taking the fruits of development to the teeming millions of this country. After all, a banyan in the bonsai form may look beautiful but only a big banyan can yield functional benefits of a tree.

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Disaster, Displacement and Rehabilitation A Case Study of Kosi Floods in North Bihar

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Abstract

The Kosi river, also called as the sorrow of Bihar, is notorious for flood. It causes devastating flood killing thousands of life and destroying property in billions. Many steps taken by the government to control flood of the Kosi river has been unsuccessful, as the river is known for changing its courses. In 2008, the river Kosi completely changed its course inundating areas which was supposed to be safe from floods. The flood of 2008 killed more than 50 thousand people and many more became displaced and homeless. Displaced people had to face various problems like lack of livelihood, loss of house and property, lack of health and hygiene, increase in violence etc. Post flooding, because of constrained livelihood opportunities, depressed economy and probability of future flooding event, many families have migrated to other parts of the country and many of the affected communities displaced from their land for long time. This study focuses on the extent of displacement caused by disasters in India as well as magnitude of displacement caused by Kosi flood 2008 and the government response for recovery and rehabilitation of the displaces. For this purpose, the satellite images of study area (North Bihar) were taken and the extent of flood and its impacts on the area were studied. For the analysis, data is compiled from field surveys and secondary sources, which give basic information on the problem. Data is also collected from different organizations and NGOs in the form of statistical tables, maps and reports. They have been used to understand the experiences of displaces and to evaluate the rehabilitation in the area after Kosi flood 2008.

Keywords: *disaster, displacement, rehabilitation, north Bihar, Kosi river*

Introduction

According to National Institute of Disaster Management (NIDM), disaster is "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources". Therefore, disasters result from a combination of risk factors: the exposure of people and critical assets to single or multiple hazards, together with existing conditions of vulnerability, including insufficient capacity or measures to reduce or cope with potential negative consequences. The United Nations' guiding principles on internal

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displacement stated that displacement may occur as a result of, or in order to avoid the effects of disasters.

Displacement includes all forced movements regardless of length of time displaced, distance moved from place of origin and subsequent patterns of movement, including back to place of origin or re-settlement elsewhere. This definition also encompasses anticipatory evacuations. Displacement involves physical eviction from a dwelling and the expropriation of productive land and other assets to make possible an alternative use. According to Cernea (1988), displacement can start before people are physically evicted from the residence by legally stopping construction, entrepreneurial investment, and public infrastructure investment. This makes households suffer economically before actual removal from their land/houses and eventually leads them into impoverishment. According to Cernea and Kanbur (2002), displacement can be experienced in many forms including the people who realise less benefit as a result of development process and those who face severe consequences and for those individuals and communities who involuntarily move leaving behind homes, networks, jobs, social capital and emotional ties to place.

Objectives of the study

This paper analyses Kosi floods with components like disaster, displacement and rehabilitation. This study was chosen since it is very recent incidence of disaster with massive displacement, where locals, NGOs and supporting agencies worked hard towards recovery and rehabilitation of the affected people. The objectives of this study are as follows:

1. to study the extent and magnitude of impacts and displacement by Kosi floods in the study area, and
2. to analyse the rehabilitation after Kosi floods in the study area.

Database and methods

The data used in this study were collected on the basis of field surveys conducted during August-September in 2009 and 2011. Questionnaire-based interviews were also performed at relief camp at Supaul, Saharsa and Madhepura by the first author. Five villages each from the above three districts were randomly selected. The 15 villages covered much of the affected lower Kosi region. The First author also visited 20 NGOs and Government Institutions located in these district headquarters and state capital Patna.

The secondary sources included published and unpublished materials available from Census Handbook, Gazetteers, Census Atlas, Statistical Handbook and Satellite Image of the affected Kosi region. Data on Kosi flood and information about displacement were collected from Flood Management Information System Cell (FMIS), Patna; Water Resource Department, Patna; Flood Control Cell, Patna; Disaster Management Department, Patna; Kosi Disaster Relief Forum, Patna; Kosi Flood Relief Committee, Patna; Kosi Inquiry Commission, Patna; Bihar Relief Committee, Patna; Bihar Relief and Rehabilitation Department, Patna; Ganga Flood Control Cell, Patna; Central Water Commission, New Delhi; National Disaster Management Authority, New Delhi; National Institute of Disaster Management, New Delhi; National Remote Sensing Agency (NRSA), Hyderabad and International Displacement Monitoring Centre (IDMC), Geneva.

Cartographic techniques including graphs and diagrams were used to analyse collected data for reaching at meaningful conclusion.

Study area

Bihar, embracing an area of 94163 sq. km with over 104 million population (Census 2011),is one of the most densely populated and overwhelmingly rural and agricultural lands of India

(Tirtha and Krishan, 2008). The state holds only 2.8 percent land of India but accounts for 8.7 percent of the total population of the country. The state has a population density of 1102 persons per square km. (Census 2011) which is quite higher than the population density of India (382 persons per square km), thus the state is overpopulated which is distinguished by high population density, low literacy, low per capita income, pronounced outmigration, low agricultural growth, low yield per hectare, low per capita income, high level of unemployment and hybrid disaster areas. The plains of Bihar are divided into North Bihar and South Bihar, separated by master stream the Ganga. The Ghaghara, the Gandak, the Kosi and the Sone are the notorious rivers for shifting their courses and degrading land. The Kosi is known as the "Sorrow of Bihar" for shifting changes in its course from east to west or vice-versa below Chatra. Other rivers are Burhi Gandak, Bagmati-Adhwara, Kamla-Balan, Buthi-Balan and Mahananda in North Bihar.

The North Bihar is criss-crossed by half a dozen big rivers which flow in different directions. The study area is characterized by meandering rivers with floodplains and *doabs*. Floodplains are interspersed with shifting channels and abandoned river beds extending between the Nepal border in the north and the river Ganga in the south. North Bihar includes 19 districts, *i.e*. West Champaran, East Champaran, Gopalganj, Siwan, Saran, Sheohar, Sitamarhi, Muzzaffarpur, Vaishali, Madhubani, Darbhanga, Samastipur, Supaul, Saharsa, Madhepura, Araria, Purnia, Katihar and Kishanganj. The entire plain is flat, never exceeding 75 meters above sea level. It is broken only by the diversities caused by fluvial action.

The Kosi plain is located east of the Kosi river, south of Nepal border, north of Ganga river and west of Mahananda river. It is a well defined sub-natural region with internal homogeneity (Singh and Singh 1997). The important districts in this sub-region are Supaul, Saharsa, Madhepura, Araria, Purnia and Khagaria. The sub-region is largely a *khadar* land formed by shifting channels and riverine ecology. Hence, this sub-region is easily distinguished into west Kosi plain and east Kosi plain. Geddes (1960) has also termed Kosi sub-region as plain of the Biharia which is criss-crossed by Kosi channel channels is geological part from east to west and west to east. Prasad and Thakur (2004) have suggested that the region is ploughed by Kosi from Mahananda in east to Kosi in the west.

Literature review

The findings of various studies point out that disaster displacement has caused the acute problem of displacement and in many cases, the rehabilitation measures are mechanical and inadequate. This exposes the affected people to drastic changes and in some cases prolonged sufferings. Therefore, a few scholars made an effort to assess the situation of displacement and rehabilitation.

Dhagamwar (1988) concentrated on displacement, he has accordingly made suggestions for the rehabilitation of persons displaced, who are affected by what are called acts of God or natural calamities. Many of these floods, droughts, landslides are caused because of human interferences with nature. Therefore, this paper identifies the main facts concerning displacement and rehabilitation. Then, it gives the background of demands concerning rehabilitation before presenting the main feature of a new national rehabilitation policy and analyse suggestions on it.

Goyal (1996) in "Economic perspectives on resettlement and rehabilitation" presents the case for a national policy on resettlement and rehabilitation and discussed different principles that have been proposed as possible bases for such a policy. She discussed the bargaining approach, which seeks to achieve voluntary re-

settlement based on collective bargaining between displaced persons and project beneficiaries. The central idea of this approach is that if the authorities are serious about providing a resettlement package which promotes or at least protects the standard of living of displaced persons that resettlement is in their interest. This non-coercive approach raises important institutional and other issues (cash compensation, land for land prices, the standard living approach, bargaining) but, it does seem to deserve further exploration. Barnabas (2002) has also discussed the resettlement and rehabilitation measures under various projects. He also explained that the various policies for rehabilitation of displaced persons due to development projects and disaster, as presently, operational are inadequate. Rehabilitation policies have kept changing, but some human concern seem to be emerging and vulnerable groups continue to be the worst sufferers.

Mishra (2008) has presented the rehabilitation of those people who were trapped in between the embankments of Kosi river. This number has swollen to 9, 88,000. Rehabilitation of these unfortunate people was not incorporated in the original plan of the project when the approval of the project was given in 1953. This paper peeps into many such questions and systematic denial of the rights of the people. It also looks into the avenues open for a possible solution.

As a conceptual framework in the research debate concerning forced migration even though there is a lack of qualitative data which gives the impression that the concept is somewhat incomplete. The typology is categorized in three types of reasons: displacement due to violence, development and disasters (Muggah, 2014, 7-8). Since the focus of this study lies on IDPs in the context of natural disasters, it will be concentrated on the latter category. The author further subdivides within natural disaster category. There are "dramatic climate events" such as floods, which are mainly seen as a cause of short- or long.-term displacements. As a second approach, the "long-term degradation of land" is taken into account, which is more focusing on long-term displacement and often results in relocation processes. This category is also recognized as having a possible link to development-induced displacement (Muggah, 2014, 8). According to the author, a strong contributing factor is the amount of vulnerability that has been existent before the disaster takes place. He refers to issues like the lack of maintenance of housing in poor areas or population density, just to name a few (Muggah, 2014, 10).

Stojanov et al. (2014) highlight additional factors that contribute to displacement due to disasters related to climate events. First of all, it is stated that there is a historic factor, evident by the fact that this kind of displacement has always been there. It is, further, found that there is a link to "social (political and economic) forces including poverty, food deficiency, conflicts, power relations, and social inequity". By looking at different typologies offered by other scholars treating this issue, it is emphasized that typologies should fulfil certain characteristics. Thus, the context needs to be taken into account when classifying a certain type of IDPs. For instance, the timeframe should be considered, namely, taking into account whether displacement is only a temporary or a long-term consequence (Stojanov et al., 2014, 514-516). Further, it is acknowledged that the whole area of migration related to environmental issues needs to be addressed on international, national, regional and local level.

Thus, Cohen (2009) uses the term disaster IDPs and argues that a special treatment is needed for this group (Cohen, 2009, 58-59). With a focus on human rights and protection of IDPs displaced by disasters, the international community is in particular being addressed. It is claimed that IDPs are either being excluded or the fo-

cus is not set sufficiently on this group. Moreover, it is stated that the use of the terms 'IDP' and 'refugee' is not clarified and used in a coherent way, which makes it even more difficult to protect these groups. The need for a new terminology that explicitly includes disaster IDPs is emphasized to ensure their claim on Human Rights.

Furthermore, there is research that clearly acknowledges the existence of environmental IDPs and the special situation they are facing. Bohnet, Cottier and Hug (2014), for instance investigated the link between environmental disasters and conflicts. They are taking the particular group of disaster IDPs into account and discuss their impact on conflict and security issues (Bohnet, Cottier and Hug, 2014). In reference to numbers of the IDMC and the Norwegian Refugee Council (NRC) from 2014, they point out the increasing relevance of natural disasters: "Each year thousands of people are displaced because of conflict. However, in 2013 almost three times more people were forced to leave their homes due to floods or other types of natural disasters" (Bohnet, Cottier and Hug, 2014).

Thus, the above review confirms that only a few studies have dealt with displacement rehabilitation issue caused by disaster, with a number of shortcomings observed and this was given prominence in this research.

Conceptual framework

Disaster-led displacement is never recorded after the initial dose of relief and rehabilitation assistance. One of the most serious aspects of the displacement belonging to this category has been the fact that the displacement has been silent but acute and frequent. In the past, forced displacement was usually the result of conflict and related human rights violations. However, people are increasingly being forced to leave their homes as a result of disasters.

The frequency and intensity of natural disasters are increasing. Sudden-onset disasters such as floods, storms, wildfires, earthquakes and volcanoes as well as more slowly developing disasters such as droughts, desertification, and extremes in temperature are uprooting a growing number of people around the world. No country is immune from the forces of nature. These disasters worsen the lives of many people in the developing world who are already living in vulnerable conditions. However, developing countries are not the only ones at risk: many rich countries have also been hit by severe weather conditions in recent years that have caused major damage and displacement. The vast majority of people displaced as a result of natural disasters stay within their home countries. As a result, they are considered internally displaced persons (IDPs) rather than refugees. Nevertheless, a minority of displaced people are forced to cross borders as a result of natural disasters. According to the International Displacement Monitoring Centre (IDMC, 2013), in 2010 alone, over 42 million people were newly displaced by sudden-onset natural disasters. In 2016, approximately 15 million people were also newly displaced for the same reasons in at least sixty-one countries, with the worst effects being felt in Africa and Asia. The majority of such displacements have been due to a small number of mega-disasters. Although mega-disasters are relatively rare, their results are devastating. Recent examples include the terrible combination of earthquake, tsunami, and nuclear catastrophe in Japan; massive floods in Australia and Pakistan; huge forest fires in Greece and Russia; droughts in China and East Africa; and a devastating earthquake in Haiti.

Disaster-induced displacement

Global data during the last few decades shows that the number of natural hazard-induced disasters and the number of people affected by them are on the rise. In the context of climate change, this challenge is expected to continue

to grow, as the frequency and intensity of extreme climate-related events increases, the patterns of their occurrence change. Climate-related disasters, primarily floods and storms continued to be the main sudden-onset triggers responsible for most of the displacement in 2009 to 2016. They caused the displacement of over 15 million people in 2009 and over 48 million people in 2016. However, all continents were affected, and beyond the largest events, disasters in a very wide range of countries displaced significant number of people. Large-scale disasters dominated the global figures and the world's attention (International Displacement Monitoring Centre, 2016).

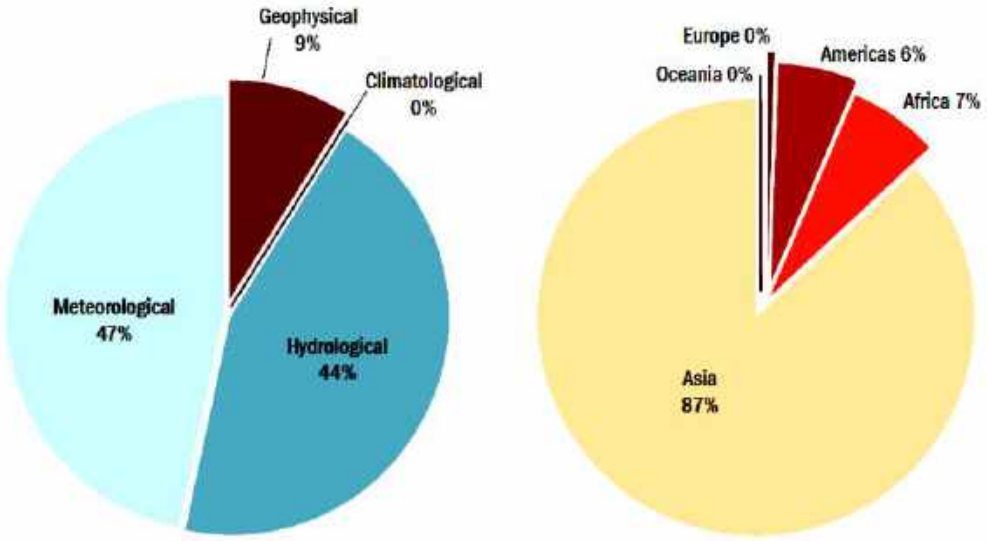

Fig. 1: Percentage of total displacement by hazards and continents

South Asia is the sub-continent where largest number of people have been displaced due to natural disaster. According to Asian Development Bank Report, 2010 titled Climate Change and Migration in Asia and the Pacific- India, Pakistan and Maldives face the greatest risk and most vulnerable countries. In the last six years, the eight countries in South Asia accounted for 36 per cent of the total number of people reported to have been displaced by disasters despite having only 23 per cent of the world's population. This reflects that there are more vulnerable people exposed to hazards in this region than in Africa, the Americas, Europe and Oceania. Displacement risk in South Asia, as evidenced by the historical displacement figures, has not changed dramatically since the 1970s. Absolute displacement risk within the region is concentrated in Bangladesh, India and Pakistan which rank among the eight most at-risk countries in the world (Figure 2).

The annual displacement estimates are depicted below in both absolute and relative terms. 'Magnitude' is used to refer to the total number of people expected to be displaced by disasters. The absolute magnitude measure provides the estimated number of people displaced per country, while the relative measure provides the estimated number of people displaced per million inhabitants of each country. Rankings between the eight countries in terms of absolute and relative expected displacement are also provided. Colour-coded representations are used in which green corresponds to least displacement risk and red the most (Table 1).

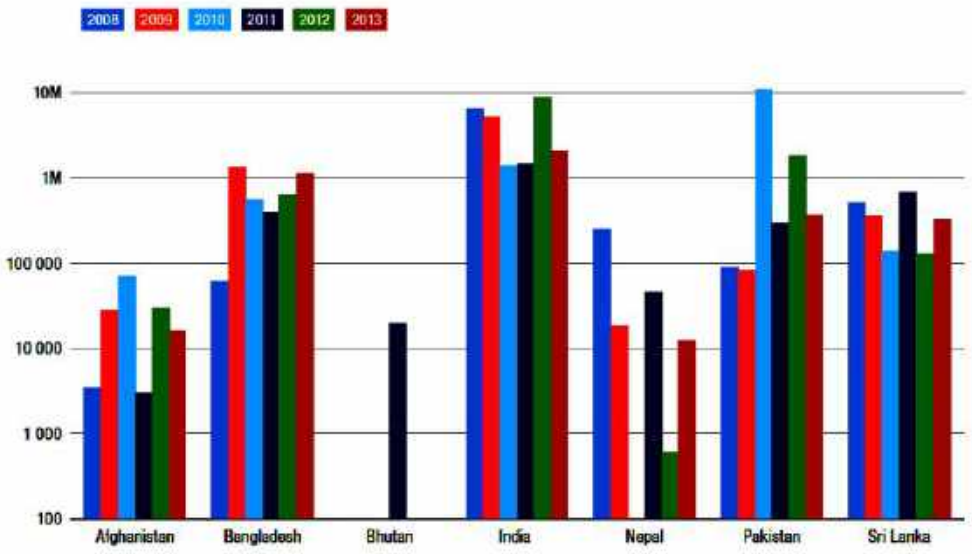

Fig. 2: Disaster-induced displacement in South Asia 1970-2013
Source: Internal Displacement Monitoring Centre (2013) Geneva, Switzerland

Table 1: Displacement risk estimates

Country	Population	Future Annual Displacement Risk (next 10 years)				
		Average Annual Displacement Risk	Regional Rank	Relative Annual Displacement (per 1 million people)	Regional Rank	Annual change in displacement risk
Afghanistan	35,516,224	137,000	5	3,900	7	2.4%
Bangladesh	156,536,136	1,486,500	3	9,500	4	4.8%
Bhutan	829,184	7,700	7	9,300	5	1.4%
India	1,292,502,640	5,314,400	1	4,100	6	4.2%
Maldives	311,724	3,700	8	11,900	2	3.3%
Nepal	32,054,000	124,100	6	3,900	7	3.1%
Pakistan	187,250,400	1,805,600	2	9,600	3	2.2%
Sri Lanka	21,529,024	325,800	4	15,100	1	2.4%

Source: Internal Displacement Monitoring Centre (2013), Geneva, Switzerland

Indian Sub-continent

Every year that passes, it is increasingly clear that the number of natural disaster rises. Very often, when a natural hazard strikes a vulnerable community, it transforms from a potential harmful events into a disaster that has catastrophic social and economic consequences. India was found to be the country in which the most people were newly displaced, as well as the location of the two single events which caused the most displacement in the year (Table 1). A huge storm in May displaced over 2.3 million people and floods in September displaced

another 2.5 million (International Organization for Migration, 2016).

Exposure to disasters in India has resulted in a displacement of tribal and other local people from their habitats and caused loss of traditional occupations. This displacement affects mostly the poorest section of the society consisting of Scheduled Castes, Scheduled Tribes and other economically weaker sections. The situation in flood-induced displacement is particularly wretched. In recent times, floods have claimed more lives than any other disaster in India. On an average, 37 million people are displaced by floods every year in India. Bihar is one of the most flood affected states of India. According to the *Rashtriya Barh Ayog* (1980), 16.5 per-cent of the entire flood prone area within the country is located in Bihar while 22.1 percent of the total flood affected population within the country resides in the floodplains of Bihar. Approximately, 68 per cent of India is prone to droughts, 60 per cent to earthquakes, eight per cent to floods and 75 per cent of coastline is exposed to cyclones. The most flood-prone areas are the Brahmaputra, Ganga and Meghna river basins in the Indo-Gangetic-Brahmaputra plains in north and northeast India, which carry 60 per cent of the country's total river flow (Central Water Commission, 1982).

India has the world's largest number of people, 632 million, living under poverty. By comparison, no other country has even 100 million people facing poverty. Disaster-related displacement in India is both an urban and a rural problem. Urban Indians' vulnerability to hazards is very high due to rapid urban growth, unplanned development and the large number of people without access to adequate housing, water, health and sanitation.

The 2011 census showed that in Mumbai, India's financial capital, 41 percent of its 20.5 million people live in slums. Located on reclaimed land in low-lying areas close to marshes, Mumbai's slums are prone to flooding during the monsoon season, especially when heavy rain coincides with high tides. Slums generally lack flood protection infrastructure. Since International Displacement Monitoring Centre (IDMC) began monitoring disaster-induced displacement in 2008, India - with 26 million people displaced - has experienced the second-highest number of displacement in the world, following only China. India's high risk is due to its large number of exposed and vulnerable people and high population density (Table 2). In 2013, monsoon floods displaced 1,042,000 people in the states of Bihar, Kerala, Uttarakhand, Assam, Andhra Pradesh, West Bengal and Uttar Pradesh, while Cyclone Phailin displaced another million people in coastal areas of Odisha and Andhra Pradesh (National Institute of Disaster Management). In 2012, monsoon flooding displaced 6.9 million Indians. The 1988 Nepal-India earthquake and

Table 2: Displacement Risk Profile of India

		Future Annual Displacement Risk (next 10 years)				
Country	Population	Average Annual Displacement Risk	Regional Rank	Relative Annual Displacement (per 1 million people)	Regional Rank	Annual change in displacement risk
India	1,292,502,640	5,314,400	1	4,100	6	4.20%

	Risk Configuration Index				Historic Displacement	
Country	Relative Physical Exposure (per 1 million people)	Vulnerability	Resilience	Risk Configuration	Average Annual Displacement, 2013 Trend level	Relative Annual Displacement (per 1 million people), 2013 Trend level
India	73,482	26	4.7	0.41	4,101,000	3,200

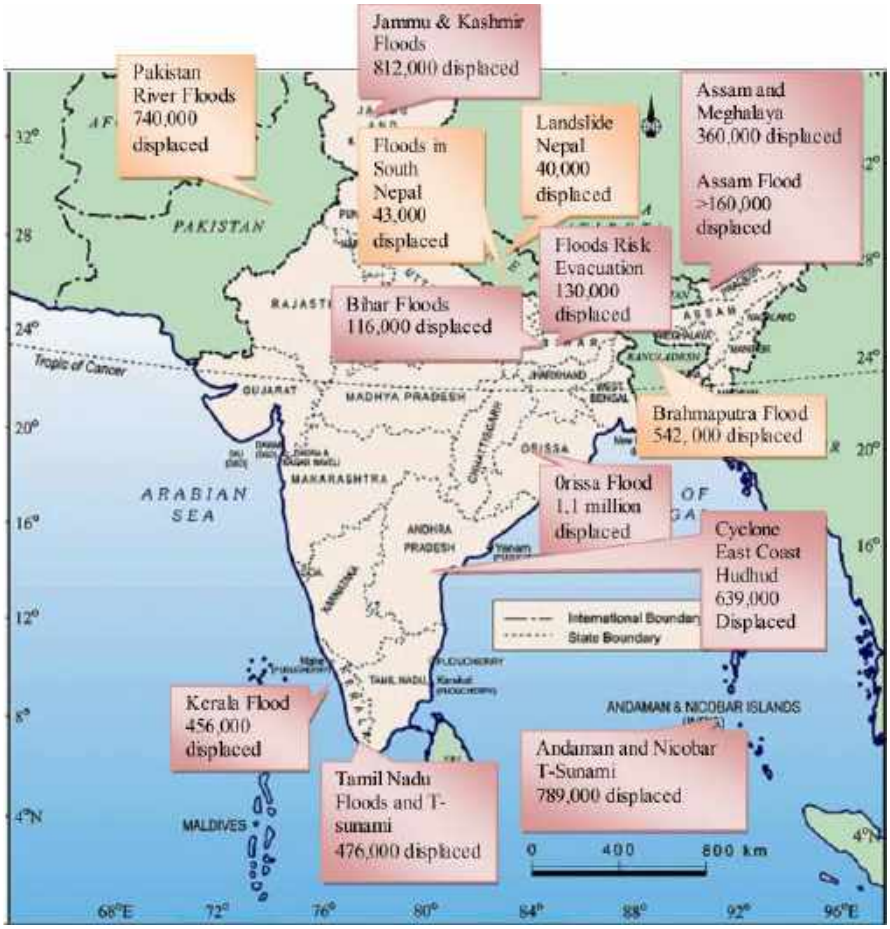

Fig. 3: Large displacement in India and neighbouring countries.

Source: Prepared by Author on the basis of data gathered from Internal Displacement Monitoring Centre, 2018, Geneva, Switzerland

2005 Kashmir earthquake were two of the largest disaster events over the past 40 years. The 2004 Indian Ocean Tsunami heavily impacted the Andaman and Nicobar Islands as well as the eastern coastline, displacing more than 382,000 people (www.internal-displacement.org).

There has been massive and recurrent displacement due to floods, cyclones and landslides. A report by the Centre for Science and Environment (1991) states that India is the most flood affected country in the world after Bangladesh and that over 30 million people are displaced annually. Flood affected areas shot up from an average of 6.4 million hectares a year in the 1950s to 9 million hectares in the 1980s (Figure 3). Government flood control measures mainly consist of dams and embankments. Over 400 km of embankments have been built annually since 1954 and 256 large dams with an average height of 15 meters and above had been constructed by 1986; 154 more were under construction. Yet, all these have failed to control floods and indeed dams are now cited as an important cause of floods, while embankments have disrupted the natural drainage system in

the floodplains.

Flood hazards in North Bihar

Flood means inundation of extensive land area with water for several days in continuation. Floods are considered to be associated with rivers and people conceive floods as the outcome of accumulation of huge volume of water coming out of the rivers through overtopping of river banks during peak discharge period (National Institute of Disaster Management, 2013). Floods have been a major aspect of man's interaction with his environment and epic stories of flood disasters are found in the traditions and literature of many ancient people. Every year the battle against flood reaches a crescendo and takes along with lives and property of the poor people who inhabit the riverbanks. The central and the state government tried hard to deal with the situation by building embankments. Part of the problem was contained, but it also resulted in prolonged waterlogging in many areas which were close to them.

According to Thakur (2003), Bihar is the region of super hazards susceptible to floods, drought, earthquake, heatwave and cold wave. A review by Kale (1997) indicates that the plains of north Bihar have recorded the highest number of floods during last 30 years. The area affected by floods has also increased during these years. Drained by two major rivers, the Kosi and Gandak, and several smaller system such as Burhi Gandak, Baghmati and Kamla-Balan, the plains of north Bihar have experienced extensive and frequent loss of life, property and displacement over the last several years. After analysing flood frequency and peak discharge, the Kosi river shows that the flooding would be more intense at the upstream station (Birpur) than at downstream station (Baltara). The Kosi being a typical fan system has a number of distributary channels in downstream reaches because of which flood peaks are attenuated between Birpur and Baltara (Sinha and Jain, 1998).

Thus, since 1990 Bihar has been facing flood regularly in many villages. According to the Department of Disaster Management, Government of Bihar, every year lacs of people were displaced from their houses and villages because of severe flooding in North Bihar affecting majority of districts. In 2017, the flood affected 19 districts of the state in which 194 blocks, 838 *panchayats* fully and 1154 *panchayats* were partly affected. 6405 villages, 90.91 lacs persons and 11.72 lacs animals were displaced from their places. 11,392 houses of *pucca* and 1,170,90 houses of *Kucha* make were fully damaged. 11,015 houses of *pucca* and 82,574 houses of *Kucha* were partly damaged.

This flood was the result of sudden increase in water discharge due to torrential rain in the foothills of the Himalayas in Nepal and adjoining areas in Bihar between August 12 and 20. It led to flash flood in various rivers-Gandak, Burhi-Gandak, Bagmati, Kamla, Kosi and Mahananda that was due to heavy rains in the catchment areas of the major rivers of North Bihar and Nepal.

The 2008 Kosi flood: An explicit view

During the last five and a half decades, at least 8 major floods in Bihar originated from Kosi- starting from the flood of 1954 followed by those in 1963, 1971, 1984, 1987, 1991, 1995 and the present flood in 2008, which was the most devastating so far. In 2008 flood, a breach was responsible for large-scale displacement, the reason being during the monsoon Kosi experiences floods almost every year causing considerable damage and disturbances to the local population. The jacketing of this river did not prove successful in guiding and controlling the upstream direction of the flow over 45 years. It was also becoming sorrow because of heavy siltation. The river carries heavy silt with it and in course of time the bed of the river rises above the field and this has been the reason of flood every year in this area. Unfortunately, all previ-

ous floods in Kosi happened due to breach in embankment downstream of the barrage, the 2008 flood carried out due to breach in the embankment near Kusaha located upstream of the barrage.

According to Department of Water Resources, Bihar (*Barh Prativedan*-2008), the sign of breach in this eastward upstream embankment was perceptible in the first week of August itself. The report also states that law and order situation in Nepal had undergone change and they were not getting required cooperation from the Nepalese authorities. They justified their alleged inaction by saying that when the team of engineers visited the site at Kusaha, they were not allowed to work and were forced to leave the site. Gradually, the spur near Kusaha worsened and, finally, breached on 18 August, 2008 at 12.80 kilometer point (Figure 4). The 18 August 2008 avulsion of the Kosi river recorded an eastward jump of 120 kilometer which is an order of magnitude higher than any single avulsive shift recorded in historical times.

This avulsed channel 'reoccupied' one of the palaeo-channels of the Kosi and took a path it had abandoned 200 years ago, 120 kilometer from its channeled course, nearly 80-85 percent flow of the river was diverted into the new course. Since the new course had a much lower carrying capacity, the water flowed like a sheet, 15-20 kilometer wide and 150 kilometer long with a velocity of 1 m/s at the time of breach drowning hundreds of villages and fields on its way. The roaring Kosi water, within hours inundated Birpur, Chatapur, Pratapganj, Raghopur and Triveniganj of Supaul district. Within a week, the water inundated 18 districts of Bihar, affecting 117 blocks, 751 *panchayats*, 2, 581 villages and a population size of 50, 517 lacs have been badly hit. As a result, a very large area remained inundated/waterlogged for more than six months after the breach. This single event affected more than 300 lakh people and there is still no reliable estimate of loss of life and property till the date (Department of Disaster Management, Patna, 2009).

Table 3: Flood inundation area in different Affected districts of Bihar after Kusaha Breach, 2008

District	Inundation area (ha)
Supaul	45,881
Madhepura	45,343
Saharsa	16,688
Samastipur	15,908
Katihar	15,210
Khagaria	14,050
Darbhanga	13,290
Patna	10,399
Purnia	9,599
Saran	7,917
Vaishali	7,528
Nalanda	6,538
Araria	6,174
Begusarai	4,804
Bhagalpur	4,659
Muzaffarpur	4,182
Siwan	1,150
Lakhisarai	1,092
Total	2,30,413

Source: Disaster Management Department, Government of Bihar, 2009

Magnitude of displacement

The Kosi floods have changed the whole view of 18 districts in Bihar, with over 35 blocks of five districts in the state badly in the grip of ferocious flowing Kosi water (Table 5), the magnitude of the problem is difficult to estimate. About 50 lakh people are trapped in different places and there is an urgent need to evacuate them, or also the state might lose them forever. (Disaster Management Department, Government of Bihar, Patna).

A rough calculation of the displaced based on the number of blocks and villages affected suggests that the state government would need to chalk out plans for relief and rehabilitation for over 1.2 crore affected displaces. Displaced people were brought in the public places like schools, temples, madrassa etc. on both sides of the main Kosi river. Most of the displaced people stayed in the camps with their families. Only few of those who had other options, for example, having home in other places or having relatives in other areas either went there or at least send their children and elder. People residing in the public places later shifted to proper camps with the support from NGOs and National Disaster Relief Force (NDRF). There were more than ten dozens of temporary camps and around 40 permanent camps (Disaster Management Department, Bihar, 2009). When displaces were relocated in the camps from the public places, different agencies and organizations started providing support, materials and facilities.

Resettlement and rehabilitation after Kosi flood

Reconstruction and recovery needs were enormous after Kosi flood 2008. The Government of Bihar was very proactive in relief operations in the immediate aftermath of the flood and also received support from Government of India. However, for reconstruction of infrastructure and rehabilitation of livelihoods, resources have been inadequate and as a result, reconstruction and rehabilitation needs have remained largely unfulfilled even after so many years. Poorer displaced groups are exposed to increased vulnerabilities during and post-floods. Some of the difficulties faced by displaces include loss of possessions, fear of extortion and separation from their social network etc. The poorer undertake different coping strategies to adapt the flood such as abandoning land or housing, salvaging house items, selling land or livestock, and moving housing or family members to safer places. This resulted in an increase in tension and domestic violence, particularly towards women. Thus, many NGOs and government organizations implemented flood relief strategies and executed restoration of their livelihood.

According to Bihar Government official estimates, and as confirmed by the Needs Assessment-1, housing damage is estimated in the order of 330,000 units. Significant damage to infrastructure including rural roads, culverts and bridges is reported in 412 *Panchayats* covering almost 2,581 villages. The Department of Agriculture estimates suggest that coarse sediment was deposited on an area. Needs Assessment conducted by the World Bank and GFDRR in close cooperation with Government of Bihar in May-June, 2010-11 area estimated are of 284,000 hactares in 1063 villages in 35 blocks of the five affected districts of the Kosi region. Generally, the deposits of sediments are deep, continuous and widespread in the northern districts (especially Supaul and Madhepura) and relatively shallow and patchy in other districts. The floods also caused severe damage to the East Kosi Main Canal and lower-order irrigation infrastructure in the Kosi Cultivable Command Area (CCA) scheme. The damage included serious siltation of the main canal and distributaries, breaches and siltation of smaller canals and water courses, and destruction of hydraulic and other structures.

After considering and analysing the impacts of Kosi flood 2008, the World Bank's Scoping Mission-2 phased approach, assistance with Government of Bihar and Government of India was initiated. The objectives of this approach were to provide timely and focused support to Bihar's reconstruction efforts in the short-term, while further developing a comprehensive long-term program of support for the state. Accordingly, it is proposed that the first phase address the immediate needs of the state for recovery

from the Kosi flood disaster, while the successive phases provide a comprehensive program of support for the states longer-term needs on overall disaster management, in particular for flood risk management and sustainable interventions in the areas of agricultural productivity and roads (United Nations Development Program, 2012). The objective of the Bihar Kosi flood recovery, reconstruction and rehabilitation project was to support the flood recovery as well as future oriented risk reduction through: reconstruction of damaged houses and road infrastructure; strengthening the flood management capacity in Kosi basin; enhancing livelihood opportunities of the affected people; and improving the emergency response capacity for future disasters.

The devastation clearly highlights the need and urgency to adopt an owner driven reconstruction approach for construction and resettlement of displaces. The scale of envisaged reconstruction alone makes owner driven reconstruction as the only viable option if houses are to be built in a time frame of 2-3 years. Further, though majority of houses are *kachha*, thatched, tin-sheeted, it is clear that displaces will prefer to have brick houses with RCC roof as status ascendancy factor was also crucial in determining people's aspiration for houses. On the other hand, bamboo is a viable option as good quality bamboo is available in relative abundance and enjoys high acceptance with people. Also, the available skill base in bamboo work is of high standard and in widespread use.

As per the recommendation given by National Disaster Management Authority (NDMA) in the National Disaster Management Guidelines-Management of Floods, it required that the houses in the flood prone areas should be made with flat horizontal roof which could be used as shelter by the family. Also either a permanent stairs system will have to devise or a ladder will have to be kept by the occupants of the house to use it for going to the roof at the time of the need. There were large number of options for wall construction such as solid walls (230 mm), solid concrete block (200 mm), compressed earth block (200 mm) and hollow concrete block of 200 mm width etc, however, in construction of reduction in cost and reduction of weight on the foundation a system of 230X230 brick columns with 115 mm width.

The Kosi flood affected regions and reviewing its impacts as widespread displacement, the envisaged scale of habitat development leaves owner driven reconstruction as the only realistic and viable option. The emphasis on systematic damage assessment in conjunction with enabling structures in place will catalyse demand and the prospect of relying on local material and skills suitably augmented by capacitating measures which fulfil demand. However, checks and systems need to be developed to overcome challenges of using financial instalments for consumption needs, ensuring timely availability of materials, sorting out land issues, building effective delivery mechanisms, honing of existing and imparting new skills as well as setting a realistic sunset clause (United Nations Development Program, 2012).

The availability of options and enabling people to take informed decision requires facilitation with regard to clearly setting forth the cost, area, technology and material availability implications that each house type entails. Supportive and enabling services should address issues related with the following:

1. Material banks- minimum 3000 bricks to all
2. Awareness and facilitation on safety features- engineer in each village
3. *Mistri* and engineer trainings
4. Support to *mistris* for workshops/livelihood
5. Third party technical audit

Table 4: Detailed analysis of displacement in fully affected districts of Bihar in Kosi flood, 2008

Particulars	Madhepura	Supaul	Saharsa	Araria	Purnea	Total
Number of Blocks Affected	11	5	6	4	9	35
Number of Panchayats	140	65	59	71	77	412
Number of Villages Affected	370	173	169	141	140	993
Number of Families Affected	374798	186661	130000	140895	41645	873999
Livestock Affected	303640	132500	161000	80000	35000	712140
Area Affected (Lakh Hectares)	1.59	0.51	0.38	0.45	0.47	3.4
Number of House Damage	168410	130207	26024	8439	7562	340742
Number of Persons Evacuated	335110	370000	115945	107937	35000	993992
Number of Human Death	187	15	34	2	1	239
Number of Livestock Death	1115	95	22	0	0	1232
Ranking on the basis of Severity of Damage and impacts	1	2	3	4	5	

Source: Disaster Management Department. Government of Bihar, Patna

6. Transparency of scheme and finance

According to Bihar Disaster Rehabilitation and Recovery Society (2010), it was suggested that the shelter package of Rs. 150,000 for each house to be built. Out of this Rs. 55,000 has been allocated for core house (accounting for a basic minimum with non-negotiable safety features with people themselves augmenting their housing with increased access to resources over a period of time); 25,000 for household services (water, sanitation and lights) and Rs.65,000 for habitat (*Tola*) infrastructure. Household services package also envisages setting up of dry-pit latrines (econ-san toilets), to avoid contamination of the groundwater; facilities for collection, storage and usage of roof rain water; and provisioning of Solar lanterns under TERI's Lighting a Billion Lives Campaign (LABL). The housing reconstruction package had three sub-packages which had overall upgraded the housing and living standards of displaces after Kosi resettlement and rehabilitation program. These three sub-packages are:

1. Package for housing reconstruction
2. Household services package - includes water, sanitation, energy
3. Package for community infrastructure

There is a story according to the displaces that the sea, where it receives the Ganga, personified as her husband and ask Goddess Ganga as to why she brings with her, all kinds of trees but never any bamboo? She explained that bamboo is the only tree that bows and touches her feet, while the others try to obstruct her path! During the flood, the water rise up to 6-9 feet inside the house, and water can sometimes be present for up to a month as it slowly recedes. These kinds of indigenous houses and lifestyle has built upon a sound understanding of sustainability, without a singular obsession for permanence. Whereas they require a constant engagement with respect to repair, maintenance and upgrading; they are also cheapest, and carry the smallest ecological footprints. State is creating enabling mechanism for displaces to build good quality and safe house themselves. This owner driven approach when executed well, has not only ensured safety and speed of reconstruction, but has also allowed greater choice to the people; it has allowed displaces to contribute to the process with their money and recycled materials. In the owner driven approach, all available materials including brick and RCC, can and

should form a part of the options. In the area a good quality bamboo house with a minimum area of 300-400 sqft can be built with assistance of Rs. 50,000/-. A household service package of Rs. 25,000/- will be able to provide roof water harvesting system, a dry pit latrines and solar lantern for each home (United Nations Development Program, 2012).

Conclusions

The analysis of disaster-induced displacement has revealed that the number of disasters in the Kosi region is rising. Also, when a natural hazard strikes a vulnerable community, it transforms a potential harmful events into a disaster that has catastrophic social and economic consequences. The study has indicated that a breach of the Kosi river embankment on 18 August, 2008 caused flash flooding that displaced about three million people from 2581 villages from North Bihar. After reviewing displacement risk at global and South Asian region, it was found concentrated in Bangladesh, India and Pakistan with displacement risk highest in India. The study has also highlighted that Kosi Administrative Division is highly flood prone and vulnerable in North Bihar, which has affected and displaced millions of population every year. The study has emphasized on the Kosi flood 2008 which occurred due to breaching of the eastern embankment in Kusaha displacing 3.5 million population from their ancestral homes. The study has examined the responses of displaces, types of relief activities employed, post-disaster situation concentrating on resettlement and rehabilitation of flood affected people and owner driven housing reconstruction and rehabilitation.

Our research indicates many constraints faced during data collection about the impacts of displacement, inadequate financial resources, systematic rehabilitation documentation and lack of literature and research work in the field of disaster-induced displacement. The analysis also reveals that no systematic attempts were made to formulate a need-based policy for displaces (affected and displaced by disaster) to restore their previous standards of living. It is also demonstrated that the government and institutions lacked means and skills to implement resettlement policy and there was total apathy towards social and community aspect of displacement and rehabilitation.

The study has contributed to the field of disaster and rehabilitation geography by examining displacement, impacts, resettlement and rehabilitation of locals negatively affected by the disasters in order to locate the global, regional and sub-regional experiences. Such empirical study may have profound hydrologic, ecological, developmental and social consequences. Further research needs to be carried on in the field of impact of displaced communities on the cost and availability of food, housing facilities and jobs. Hence, a better understanding and data of the disaster-induced displacement is needed to develop more effective and resilient solutions. The study area also needs empirical studies examining the impacts of displaced population, different phases of displacement, rehabilitation process and recommendations. Overall, this study provides support for the better management techniques of flood control and mitigation, especially construction of high dam on upper Kosi.

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Landslide Hazard Zonation in and around Litan Village along NH-202, Ukhrul District, Manipur, India

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Abstract

Hazard is multifaceted in nature which includes landslide that pose great threat to lives of people and properties especially in rugged hilly terrains like tectonically active Indo-Myanmar Range. Various ways of landslide susceptibility study have been taken up throughout the globe in order to minimize and mitigate the hazard. Systematic and scientific investigation is the only means to predict the vulnerability of landslides. Landslide Hazard Zonation can property demarcate the hazard prone slopes. The outcome of the present investigation reveals that more than 60% of the total study area falls under highly landslide prone areas.

Keywords: *hazard, landslide, himalayan region, landslide hazard zonation*

Introduction

Natural hazards have threatened the earth, which exceed the tolerable limit of magnitude, thereby resulting in catastrophic loss of life, property and impeding developmental activities. Certain initiatives have been adopted by the Government to minimise such hazards. The Indian sub-continent has been affected by different kinds of natural hazards like floods, droughts, cyclones, tsunamis, earthquakes and landslides. Recently, in Kerala, Himachal Pradesh, Uttarakhand, Manipur have experienced quite a number of landslides that even wiped out totally the local village leading to deaths and casualties. It has also been estimated that on an average, the damage caused by landslides alone in the Himalayan region costs more than one billion US dollars, besides causing more than 200 deaths every year, which overall is considered 30% of such types of losses occurring worldwide (Naithani, 1999). Sometimes it is difficult to calculate the economic losses from landslides as they often occur as a consequence of or in combination with other natural hazards such as seismic or flooding. In the Alpine countries losses due to winter storm induced snow avalanches are also significant.

The study area is an integral part of Indo-Myanmar Range (IMR) mobile belt. The area displays structural architectural complexities and unique geomorphic features. The area is tectonically very active, and seismically falls under the high risk zone IV. Ever-increasing anthro-

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pogenic activities, fragile lithology, structural complexities and heavy rainfall have aggravated landslides in the study area. This can be minimised through better understanding the factors governing landslides, mapping of the hazard zones, improved techniques to mitigate and responses to the hazards. Accordingly, a part of highway 202 (earlier 150) of Ukhrul district, Manipur (Fig. 1) is selected for the present study.

The present study endeavours to map the landslide hazard prone area in a part of highway 150, which runs across the eastern hills of Manipur. The term zonation is applied in general sense to categorize the land surface into areas and arrange them according to degrees of actual or potential hazard from landslides or other mass movements on slopes (Varnes, 1958). The Landslide hazard zonation (LHZ) map delineates areas of varying probability of slope instability, based on estimated causative factors inducing the latter's instability (Anbalagan, 1992). Various approaches of LHZ have been practiced by myriad individuals like Radbruch and Wen worth (1971), Brabb et al. (1972), Stevenson (1977), Carrara et al. (1977, 1978, 1991), Seshagiri et al. (1982), Brabb (1984, 1995), Kawakami and Saito (1984), Varnes (1984), Choubey and Litoria (1990), Gupta and Joshi (1990), Gupta et al. (1993), Gupta and Anbalagan (1997), Mehrotra et al. (1991), Anbalagan (1992), Pachauri and Pant (1992), Arya et al. (1993), Chung and Leclerc (1994), Djamaluddin (1994), van Westen (1994), Virdi et al. (1997), Nagarajan (1998), Lee et al. (2001), Hack (2002), Saha et al. (2002), Arora et al. (2004). Since these LHZ approaches are suggested for a specific terrain they have their own advantages and disadvantages, depending upon the terrain and climatic conditions it need to be modified if necessary.

Fig. 1: Location of the study area

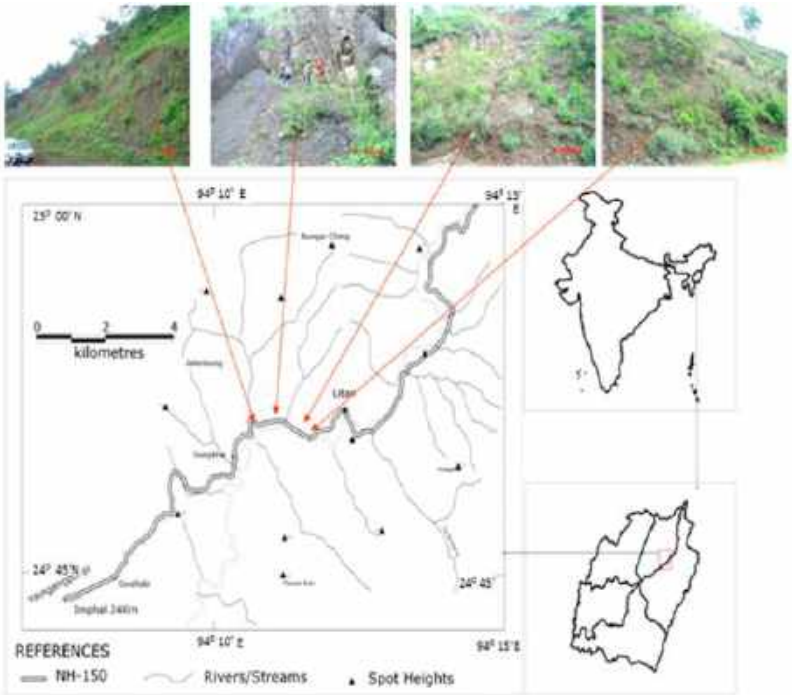

Fig. 1 : Location of the study area

Objective

The objective of this study is to

a) Map and decipher landslide prone areas and highlight its probable impact,
b) Fill up the gaps in the data already available and
c) Suggest requisite mitigative measures so that vehicular movement along NH - 150 become safer

Methodology

In the present study, guidelines of the LHZ mapping following Anbalagan, (1992) and BIS (1998) with some minor modifications (Okendro and Kushwaha, 2014) have been followed in order to meet the local conditions, e.g., lithology, climate and land-use/land-cover practices. LHZ map for the present area has been prepared on the basis of the geo-environmental factors, like lithology, structure, slope morphometry, relative relief, hydrological conditions, and land-use/land-cover patterns.

To meet the objective, the following maps have been prepared:

i) Facet
ii) Slope morphometry
iii) Relief
iv) Drainage
v) Lithotectonic
vi) Land use and land cover

Facet map

Facet is a polygonal area represented by uniform slope angle and direction in mountainous terrain. The hill slopes are divided into a number of facets, which are delimited by the ridges, spurs, gullies, rivers etc. Facet map (Fig. 2) represents a consistent slope direction and inclination of slope. These maps form the basis for the preparation of thematic maps in general and Landslide Hazard Zonation mapping in particular. Each individual facet is the smallest mappable unit having certain consistent geomorphological uniformity. Hence, the categorisation

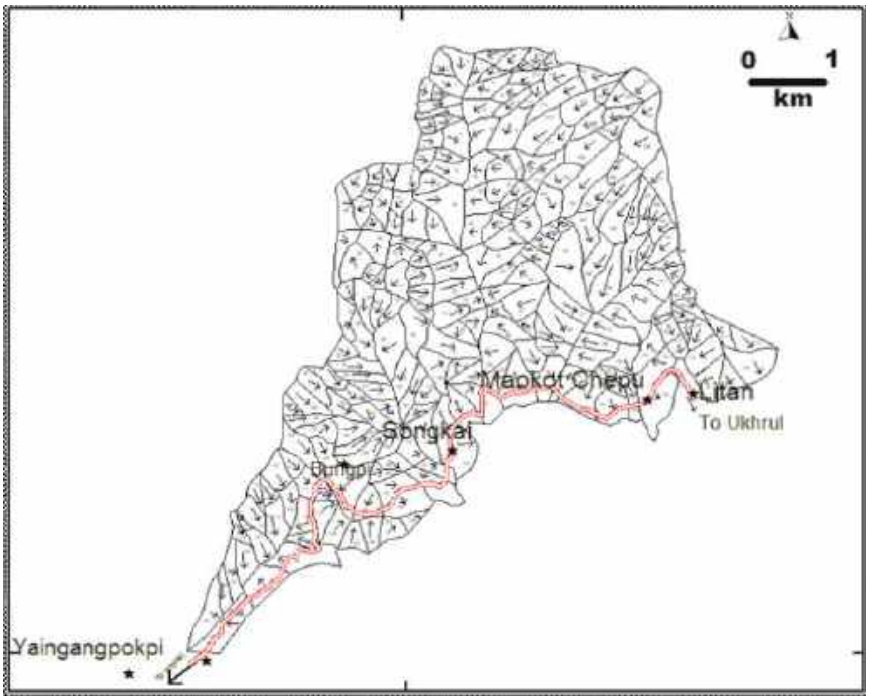

Fig. 2: Facet map of the study area

of a facet in this mode of study is the first and foremost importance.

Slope Morphometry

Slope morphometry map (Fig. 3) has been prepared on 1:50,000 scale using Survey of India topographic sheet 83L 1. Since the slope angle is considered to be an important geo-environmental parameter it can induce slope instability. The ratings awarded for sub-categories of slopes are furnished in Table 1.

Relative relief

Relative relief map (Fig. 4) represents the difference between the maximum and minimum heights (in metres) within an individual facet. It shows the major breaks in the slopes of the area. Relief map can be prepared from the slope facet

Table 1: Slope morphometry rating scheme (modified after Anbalagan, 1992; BIS, 1998)

No. of contours per cm of length in the facet	Slope angle	Category of slope	LHEF rating (out of 20)
< 7	<15	Very gentle	5
8 - 12	16 - 25	Gentle	8
13 - 18	26 - 35	Moderately steep	12
19 - 25	36 - 45	Steep	17
>25	>45	Escarpment/cliff	20

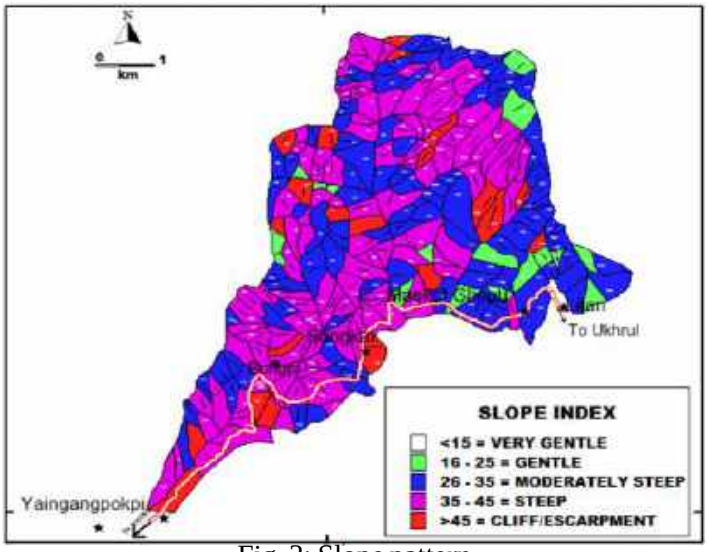

Fig. 3: Slope pattern

Table 2: Relative relief rating scheme (modified after Anbalagan, 1992; BIS, 1998)

Relative relief (m) (out of 10)	Relief category	LHEF rating
< 100	Very Low	2
101-200	Low	3
201-300	Moderate	6
301 - 500	High	8
>500	Very High	10

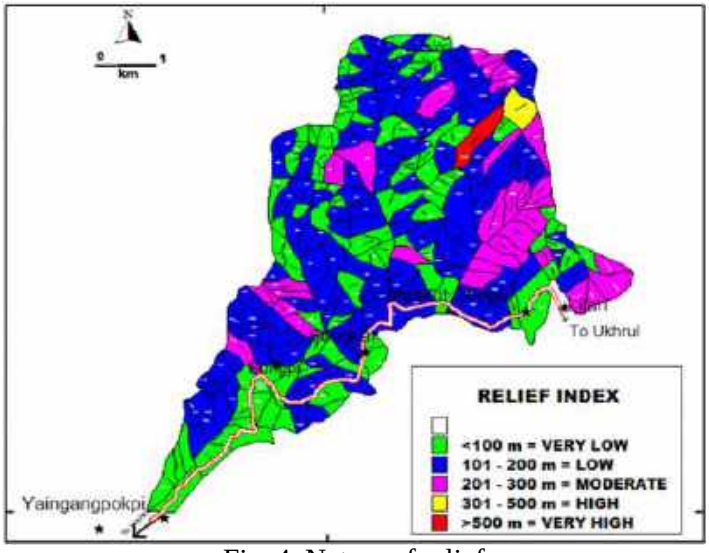

Fig. 4: Nature of relief

map by subtracting the lowest contour value from the highest contour value in a facet. Table 2 shows the ratings assigned to the different categories of relief.

Drainage

The hydro-geological condition of the study area can be considered from the drainage density of the area. The following table indicates the classification of facet in order to find out different mode of drainage density.

Drainage density is ratio between the total lengths of all the stream segments in a drainage basin to the area drained by them or it can be defined as the measure of the length of stream channel per unit area of drainage basin (Horton 1945).

Dd= L/A,

where, L=Total length of all the stream segments of a basin and A=Area of the basin.

The spatial variation in the drainage density

Fig. 5: Drainage pattern

is related to precipitation (Melton, 1957), vegetation index (Chorley, 1957) and permeability of the terrain (Carlston, 1963). It is, because of the low porosity of rock types, steep slope and sparse vegetation, run off rate in the hilly area is very high, while in the plains due to unconsolidated recent alluviums percolation is very high and run off is low.

Table 3: Drainage density rating scheme

Stream frequency	Drainage density Category	LHEF rating (out of 10)
1 - 2	Very Low	2
2 - 4	Low drainage	4
4 - 6	Medium drainage	6
6 - 8	High drainage	8
> 8	Very high drainage	10

Lithology

Landslide Hazard Evaluation Factors (LHEF) rating for the subcategories of lithology has been assigned as 20, keeping in view, the susceptibility of the rocks to the processes of weathering and erosion. The study area is exclusively covered with Disang Group of Tertiary rocks. Thin intercalations of shales, siltstones and/or sandstones pose great difficulty to map the individual litho-units on 1:50,000 scales. An attempt has also been made to identify the weathered zones as far as practicable. The following rating scheme (Table 4) for lithology is followed for the present purpose:

Table 4: Lithological rating scheme (modified after Anbalagan, 1992; BIS, 1998)

Lithology units	LHEF rating (out of 20)
Sandstone	0.7
Sandstone-shale	0.8
Shale-sandstone	1.0
Siltstone-shale-sandstone	1.2
Shale	1.3
Siltstone	1.35
Crushed soil	1.4

The correction value for the rock types based on the degree of weathering is given as: Highly weathered rocks, C1 = 1.5, Moderately weathered rocks, C2 = 1.25 and Slightly weathered rocks, C3 = 1.0.

Structure

The structures in the area include bedding planes, several sets of joints, faults and folds. The relationships between the direction and inclination of slope and disposition of structural discontinuities have important bearing on the stability of slope. According to Anbalagan (1992), there can be three categories of relationship among these variables.

i) Extent of parallelism between the directions of the discontinuity or the line of intersection of two discontinuities and the slopes.

ii) Steepness of the dip of discontinuity or the plunge of the line of intersection of the two discontinuities.

iii) Difference in the dip of the discontinuity or the plunge of the line of intersection of the two discontinuities to the inclination of the slope.

If the discontinuity or the line of intersection of two discontinuities tends to be parallel to the slope, the risk of slope failure increases. With increasing dip of discontinuity or the plunge of the line of intersection of two discontinuities, the probability of failure increases. If the inclination of the slope is more than the dip of discontinuity or the plunge of the line of intersection of two

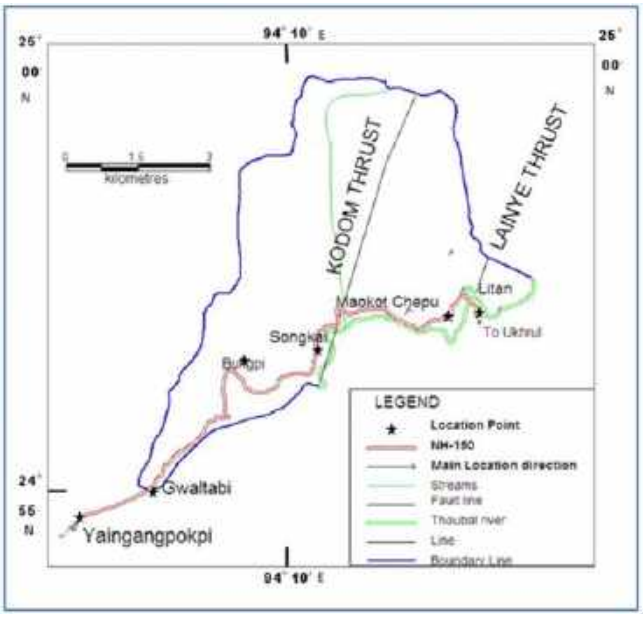

Fig. 6: Litho-tectonic structure

discontinuities, the failure potential remains high.

LHEF ratings for various stability conditions have been assigned according to the approach followed by Romana (1985). The LHEF ratings of Anbalagan (1992) and BIS (1998) guidelines for structure has been proportionately changed considering maximum as 20 for this factor (Table 5).

Table 5: Structural rating scheme (after Anbalagan, 1992; BIS, 1998)

	Relationship of discontinuity with the slope	Ratings		
1.	Relationship of parallelism between the slope and the discontinuity	I	>30	2
		II	21 - 30	2.5
		III	11 - 20	3
		IV	06 - 10	4
		V	< 5	5
2.	Relationship of dip of discontinuity and inclination of slope.	I	> 10	3
		II	10 - 0	5
		III	0	7
		IV	-10 - 0	8
		V	> -10	10
3.	Dip of discontinuity	I	< 15	2
		II	16 - 25	2.5
		III	26 - 35	3
		IV	36 - 45	4
		V	> 45	5

Both the lithology and structure of the area have been incorporated in the Litho-tectonic Map (Fig 6).

Land use/land cover

The nature of land use/land cover is an indirect indication of the hill slope stability. Vegetation cover generally checks the action of climatic agents and protects the slopes from weathering and erosion. Land use/Land cover map of the area (Fig. 7) has been prepared on the basis of visual interpretation of IRS-1D geocoded sheet of the area corroborated by field checks. On the basis of the land use/land cover pattern, the area has been subdivided into the following six categories (Table 6).

Table 6: Land use/Land cover rating scheme (after Anbalagan, 1992; BIS, 1998)

Category of land use	LHEF Rating (out of 20
Agricultural land/populated flat land	6.50
Thick forests	8.50
Moderate forest cover	10.20
Sparse forest cover	10.50
Jhum/terrace cultivation/barren	10.80
Road cut, human settlement, quarrying on 25° slope and natural/ artificial undercutting of hill slope, avalance area.	20.00

The land use/land cover map and table reveal that the major part of the area fall under moderate forest cover, followed by sparsely vegetated area, *jhum* cultivation and human settlement.

Landslide hazard zonation

Finally, the landslide hazard zonation (LHZ) map of the area has been prepared, based on the distribution of Total Estimated Hazard

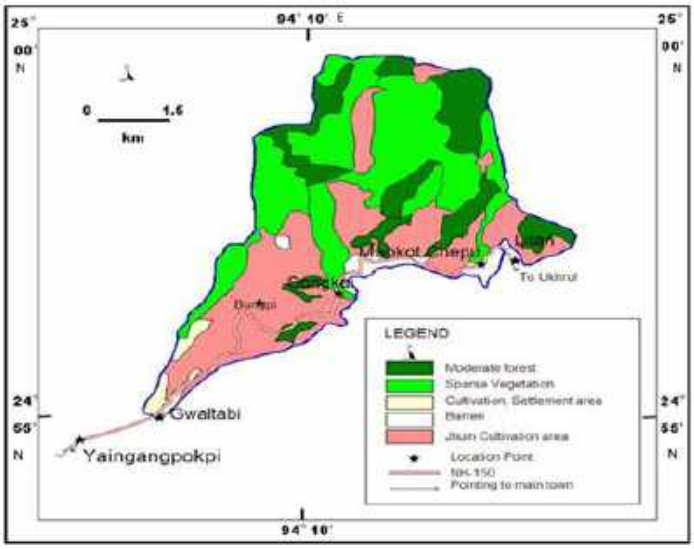

Fig. 7: Landuse/ Landcover

(TEHD) values of each facet, dividing into five zones of hazard (Table 7) namely: very low hazard (VLH), low hazard (LH), moderate hazard (MH), high hazard (HH) and very high hazard (VHH) zones.

Table 7: LHZ rating based on TEHD (modified after Anbalagan, 1992; BIS, 1998)

Zone	TEHD value	Description of zones	Percentage
I	< 35	Very Low Hazard (VLH) Zone	Nil
II	36 - 50	Low Hazard (LH) Zone	1.45
III	51 - 60	Moderate Hazard (MH) Zone	30.84
IV	61 - 75	High Hazard (HH) Zone	65.51
V	> 75	Very High Hazard (VHH) Zone	2.18

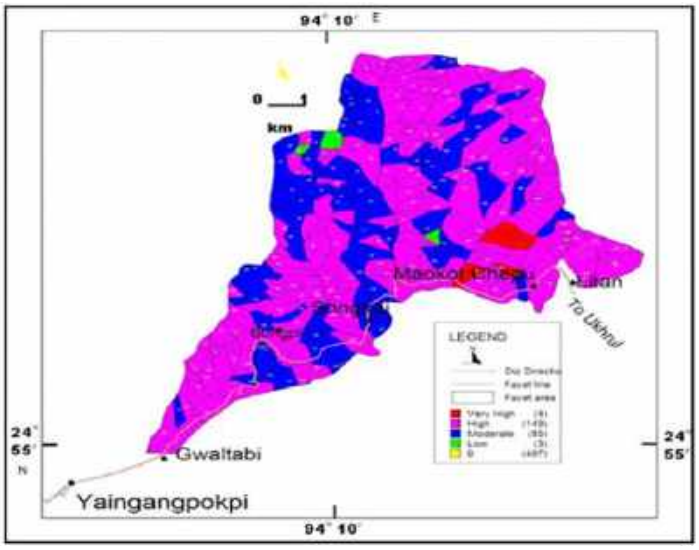

Fig. 8: Landslide hazard zonation

Conclusion

The majority of the area under the present investigation falls under high hazard zone covering 65.51 percent of the total area. Moderate hazard covers 30.84 percent followed by 2.19 percent of very high hazard zone and 1.46 percent of low hazard zone. High hazard zone is vulnerable to landslides and slope instability that require due attention during the planning and execution of any type of developmental projects. The fragile litho units of young sedimentary rocks with complex structure, rugged hilly terrain and high rate of precipitation aggravate the vulnerability of landslides. The explosion of population demands the increasing anthropogenic activities along the slope and threatens the stability of the slope. Excessive and unsystematic quarrying is the most common problem in study area.

Following mitigation measures can be taken up in order to reduce or minimize the slope instability. Construction of retaining walls, tie beams, etc. but not heavy structures because the load itself may further threaten the slope

stability. Changing the terrace cultivation pattern in and around the highway by other mode of cultivation is required so that the long retention of water affects the slope stability. Afforestation is necessary in order to arrest the slope from sliding. Giving awareness to the general public is matter of the prime importance to control and remedy such hazard.

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Resource Use and Conservation of Kabartal Wetland Ecosystem, Bihar

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Abstract

Wetlands are one of the most productive systems and play a significant role in the ecological balance. Kabartal is ecologically most important wetland and considered as one of the largest fresh water oxbow lake in the country. The lake is very rich in biodiversity and was declared protected area in 1986 and as a bird sanctuary in 1989. The purpose of this study is to analys the resource base and major problems of the largest fresh water lake of Bihar. A total of 160 respondents from all sample villages have been covered to collect information on income, fishery, agricultural practices, firewood and fodder requirement. Land and water constitute the major resource of the area. The major positive changes were recorded in built-up area and vegetative cover, whereas, water bodies, swampy land and agricultural land recorded decreasing trend. The total inflow of water in the lake was estimated at 4250 cusecs and outflow about 2769 cusecs. Water quality index value oscillates around 58. It clearly reflects that the water quality of lake is gradually deteriorating because of discharge of domestic waste from surrounding villages, consumptive and non-consumptive use of lake, excessive use of chemical fertilizers and pesticides in the agriculture field. To conserve the lake, it is necessary to initiate proper awareness and education programme in the lake catchment area.

Keywords: *Ramsar site, water quality index, land-use/cover, Begusarai*

Introduction

Wetlands are most productive and life support systems in the world. Wetlands are multidimensional and cross-boundary resources. They provide a range of interrelated environmental functions and socio-economic benefits, which support a variety of livelihood options for different members of the local community (Adger and Luttrell, 2000). Wetlands also nurture and provide sustenance to biological diversity and it is evident from the concentration of birds especially waterfowl and as well as countless plants that they support. Another is their association with open landscape, wildlife, local traditions etc. (Nambian, 2000). They are biologically diverse ecosystems which cannot be replaced by other ecosystems. Wetlands are the transitional zones between permanently aquatic and dry terrestrial ecosystems where the water table is usu-

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ally at or near the land, is covered by shallow water (Parikh, 2003).

Wetlands are often biodiversity "hot spots" as well as function as filters for pollutants from both point and non-point sources and being important for carbon sequestration and emissions. The value of the world's wetlands are increasingly receiving due attention as they contribute to healthy environment in many ways. Wetlands perform a wide variety of functions from simple to complex as a result of their physical, chemical and biological attributes. Most wetlands perform functions such as flood retention, water filtration, bird and wildlife habitat and tree growth Ambastha, et. al., 2007). Overall, wetlands play a vital role in maintenance of cultural, economic and ecological health of the ecosystem but due to fast pace of disappearance from the landscape is a matter of great concern. Panwar (1992) stated that an interdisciplinary approach merging social, economic and environmental forces to achieve the goal of conservation has more importance in India where the use of natural resources has been the part of traditions and culture of most of the rural population.

Kabartal (Kawar Lake) is an example of wetland of national importance due to its rich biodiversity. The lake is exploited for fodder, fuel and other purposes. The lake is under threat from anthropogenic activities such as land-use/cover change, extension of agricultural activities and excessive removal of biomass by the local community. Increasing demands and pressure on wetlands without understanding their nature and dynamics have often led to their degradation and threatening livelihood of local community.

The Kabartal wetland

Kabartal is ecologically most important wetland and considered as one of the largest fresh water oxbow lake in the country. The lake is very rich in biodiversity and was declared protected area in 1986 and as a bird sanctuary in 1989. The lake is surrounded by the Budhi-Gandak and spread over 6400 ha in district Begusarai, Bihar. It serves as major habitat for many resident and migratory birds. The lake is situated at 25º 35´N longitude and 86º 10´E lotitude is a residual ox-bow lake formed by meandering of the Budhi-Gandak river which falls in the mid Indo-Gangetic bio-geographic zone (Kumar, 2013). Eleven villages have been situated in the vicinity of the lake with population having 78347 persons. The Kabartal has been classified as wetland type 19 due to presence of habitat (Scott, 1989).

Traditionally, the wetland has been used for water supply for irrigation and domestic purposes, fishing, netting of migratory waterfowl, harvesting of wild rice, and gathering of edible mollusk (Pilaglobosa). More than 41 species of commercially valuable fish have been recorded (Anon, 2004). The average rainfall in July was 274mm during 2006-10. The maximum and minimum temperature ranges from 21.57ºC to 35.83ºC and relative humidity varies from 56 to 81%.

Objective

The purpose of this study is to analyze the resource base and major problems of the largest fresh water lake of Bihar.

Data base and methodology

The present study has been based on both primary as well as secondary data sources. Primary data has been collected through interview, personal observation and structured questionnaire survey. The secondary data were collected from survey of India topo-sheet, population census, district agriculture census, and satellite imagery.

For household survey, stratified random sampling of population of all caste groups has been undertaken. 6 villages from 160 respondents have been covered to collect information on income, fishery, agricultural practices, firewood and fodder requirement. Demographic profile of sampled villages such as total population, lit-

eracy rate, density and occupational pattern were collected from census handbook.

Land-use/cover mapping of the area in and around Kabartal lake has been done with the help of satellite imageries for the year 1992 and 2005. A buffer of 5 km has been considered as the study of catchment area of the lake. Satellite imageries were re-sampled and then supervised classification was carried out using the maximum likelihood algorithm. A reconnaissance survey of the field was carried out for the accuracy assessment and finally a fivefold land-use/cover classification of the lake has been done.

Results and discussion

Land-use/cover analysis

The land-use/cover statistics are presented in Table 1. The whole area has been grouped into 5 categories. Water spread area includes those which are completely under water termed as permanent water area and other area which is dried during summer termed as swampy area. The built-up area was 1.6% in 1992 and 7% in 2005. The agriculture land was 41% in 1992 and 38.5% in 2005. Water body was 12% in 1992 and 8% in 2005. Vegetative cover was 34% in 1992 and 39% in 2005 (Table 1).

The major land-use/cover change analysis of Kabartal wetland area is presented in Table 1. The major positive changes were recorded in built-up area and vegetative cover, whereas, water bodies, swampy land and agricultural land recorded decreasing trend. From 1992 to 2005, water bodies have been changed about -32.73%. Swampy areas in the wetlands are decreasing drastically during time from 1992 to 2005. Swampy area has been decreased -32.42% during this period. high percent 41% of the land is used for agricultural purposes. From 1992 to 2005 about -6.79% agricultural land has been changed. In 1994, land survey has been completed and subsequently the area has been restricted for agricultural use. Built-up area has been significantly increased during 1992-2005. built-up areas have increased 333% during this period. The settlements are situated near by wetland. Growth of population, increasing road connectivity and availability of fertile land are the main reason for this increase. Vegetative cover of the area has increased about 14.64% from 1992-2005. Sparse vegetation has also been seen on water body itself.

Changes of land-use/cover of the Kabartal wetland are important drivers of soil and water pollution. Good regment of wetland area has been converted for agricultural purposes and are excessive chemical fertilizers and pesticides for more production. This creates large scale pollution in the area.

Hydrological regime

The hydrological regime of Kabartal wetland has covered outflow and inflow of water, sediment, source of water and flooding in the nearby river.

Table 1: Land-use/cover of Kabartal wetland area in 1992 and 2005

Land-use/cover	Area (1992)		Area (2005)		Variations (1992-2005)
	(ha)	(%)	(ha)	(%)	(%)
Water body	996	12.2	670	8.2	-32.73
Swampy land	882	10.8	596	7.3	-32.42
Built-up land	130	1.6	563	6.9	333.1
Agriculture land	3373	41.3	3144	38.5	-6.79
Vegetative cover	2785	34.1	3193	39.1	14.64
Total	8167	100	8167	100	

Morphometric analysis

Morphometry deals the measurement of significant morphological features of the wetland. The wetland has maximum length and width of 8.3 km and 4.6km, respectively. The total surface area of the Kabartal and total area of adjacent lake is 63.24 sq. km and 31.28 sq. km. The values of lake permanence index of 1.5 reflect certain degree of stability of the lake against susceptibility to the extinction forces. The value is not satisfactory and indicates ageing status of the lake. The depth of Kabartal wetland varies from 1.5 to 2.1m (Table 2).

Table 2: Morphometric analysis of Kabartal wetland

Parameters	Values
Total Area	63.24 sq. km
Total area of adjacent lake	31.28 sq. km
Total area of Kabartal always submerged	20.24 sq. km
Maximum length	8.3 km
Maximum width	4.6 km
Total volume of water	3.036 x 107 m3
Maximum depth	2.1m
Mean depth	1.5m
Length of shoreline	51.76km
Index of lake permanence	1.5

Inflow and outflow of water

The Kabartal wetland is fed by rainwater or by overflowing the river Budhi-Gandak and Bagmati during rainy season. Therefore, rainfall is the main source of water for Kabartal wetland. At present, water comes into the Kabartal from its catchment area. At the time of flood it comes through drainage made amidst meandering course of the Chanha river. The depth of the canal is 3.5m and width is 14m. Therefore, drainage canal helps in the outflow of water from the Kabartal. During flood the water comes into Kabartal at the rate of the 500 cusecs per second and goes out of the same rate but during lean months its rate is not more than 25 cusescs. The total inflow of water in the lake was estimated at 4250 cusecs and outflow about 2769 cusecs (Kumar, 2013). But presently, outflow has been stopped due to the siltation and proliferation of the weed in the drainage canal. Inflow of silt through the runoff from the surrounding area has occurred in Kabartal. About 3cm of silt is deposited in the Kabartal. The problem of sedimentation is more pronounced in the reservoir, resulting in the reduction of their water holding capacity and decrease in lake area.

Water quality

The range of water quality observed in Kabartal with respect to temperature, PH, DO, BOD, Nitrate, TC, FC and is presented in Table 3.

Table 3: Water quality parameters of Kabartal wetland, 2010

Parameters	Mean value
pH	7.7
Electrical conductivity (µmho/cm)	343
Temperature (0C)	25.3
DO (mg/l)	6.8
BOD (mg/l)	2.8
Nitrate (g/l/)	1.12
Faecal Coliform (MPN/100ml)	2329
Total Coliform (MPN/100ml)	5467

Source: CPCB Report, 2010

The mean value of pH and electrical conductivity are 7.7 and 343µmho/cm but both the values are under permissible limit. The mean temperature of the water is 25^0C. This is very much close to the atmospheric temperature. The maximum dissolved oxygen values ranged from 6.8 to 7.4 mg/l, whereas, minimum from 6.4 to

6.5 mg/l. The mean value of DO is 6.8 mg/l which is slightly higher than permissible limit 5mg/l. After 2003 local administration launched forestation programme through which it control agricultural practices in near to lake area than it maintain the healthy status on this parameters. Mean value of Nitrate in the lake water is 1.12g/l. The excessive and uncontrolled use of chemical fertilizers and pesticides in the agricultural filed constitutes the most important cause of agricultural pollution in the lake. The mean value of BOD in the lake water is 2.8 mg/l that is very near to permissible limit. This shows that the health of the lake water is good. Faecal coliform mean values in the Kabrtal is 2329 MPN/100ml. The total coliform value is 5467 MPN/100ml. It is clearly indicated that the total coliform value is exceeding the permissible limit. This is due to untreated domestic sewage, grazing of livestock etc.

The water quality index was calculated to know about the water quality status for its suitability for human consumption and other aquatic organism. Water quality index value oscillates around 58. It clearly reflects that the water quality of lake is gradually deteriorating because of discharge of domestic waste from surrounding villages, consumptive and non-consumptive use of lake, excessive use of chemical fertilizers and pesticides in the agriculture field.

Conflict between stakeholders

The lake bed is encroached by the rich farmers. There is no boundary demarcating the bird sanctuary and lake area. This encourages illegal poaching in the wetland area. The rich farmers deliberately widened the outlet canal so that water could not stay for long periods and they could practice agriculture. This resulted in social conflict between the communities. This lake is important for the fishing community because they depend on this lake for their survival. But the rich farmers are increasing their agricultural land because the land is more fertile. Therefore, the two different land use practices create a conflict between two communities.

The other conflict is between local people and government, regarding ownership rights of the land. Due to the immense pressure for subsistence, fishing community has been leaving their traditional job and looking for the alternate livelihood resources.

Conservation measures

Government has enacted number of laws for protection and conservation of wetland *i.e.*, wetland conservation and management laws, National environment policy, 1986 and 2006, and national wetland management programme etc. Further, Government of India declared this protected area in 1986 and bird sanctuary in 1989. Government has initiated several activities for the conservation of lake and allotted Rs. 322 lakh for its conservation.

Number of NGOs are working for creating awareness among the people not only local but also amongst urban people also. "Save the Soul" compain for the Kabartal wetland has been launched in 2010 and initiated number of awareness programme such as *Jan-Jagarn Shiveer*, School painting competition etc.

Environmental awareness

For conservation of wetland, different types of awareness programme have been conducted. Forest department, government of Bihar set up hoarding near the lake area mentioning about the importance of lake. Local media also played a very important role about awareness drive. There is a need of number of training programme to be organized for skill development of local community. Other activities like painting competition, quiz competition, and essay competition should be encouraged for creating awareness among the people. Forestation programme should be also started to conserve the lake. Proper awareness and education programme should be started in the area.

Green belt area development

Green belt should be considered the first line of defense against pollution-laden runoff water and buffer against the upland activity. Setting of green belt around the wetland area is required. With the active participation of government, local people and NGOs about 20,000 tree saplings were plated around the lake area. With the help of the green belt, non-point pollution may be checked and this can maintain the water table in the wetland area.

Traditional ecological knowledge

People surrounding the lake area are well equipped with indigenous knowledge. For the conservation of the wetland, their local ecological knowledge must be incorporated in any conservation programme and policy making.

Coordination amongst different stakeholders

Kabartal wetland is the common property and numbers of stakeholders have been involving for achieving the objectives. Fishing community, agriculture farmers and other people who are directly or indirectly benefited from the lake be involved in any conservation programme. The area is whiteness for resource use conflicts; therefore a cooperative society should be farmed to resolve the conflicts. With the help of forum, coordination among the stakeholders will be easily obtained and will be also helpful in conservation of wetland.

Capacity building programme

Capacity building is a major tool for conservation, without this any conservation activity is not successful. For this we need good infrastructure, trained people to teach values and functions of wetlands in an integrated and multi-disciplinary manner. Right now, it needs capacity building through which it can be listed in the Ramsar convention.

SWOT analysis

SWOT (Strength, Weakness, Opportunity, Threats) analysis has been used for assessment of natural resource which helps in assessing the existing legal policy, project and economic decision. This analysis will be attempted to identify new strategies for better management of the area. This can be facilitating the process of making decisions in multi-criteria framework in natural resource management.

Table 4: SWOT analysis of Kabartal wetland area

STRENGTH		
	1.	Source of income and employment
	2.	Protection of flora and fauna
	3.	Providing platform for household task
	4.	Development of tour ist site
	5.	Development of bird centre
	6.	Have very fertile land farm
	7.	Have a bird sanctuary
	8.	Listed in protected area
WEAKNESS		
	1.	Limited income through employment
	2.	Loss of access to some areas
	3.	More weed prevent in pisciculture develop ment
	4.	Lack of awareness of local people for their benefits
	5.	Overland flow and sedimentation
OPPORTUNITY		
	1.	Improve awareness and education on en vironment

	2.	Increase local community involvement
	3.	Improve better community and government relationship
	4.	Project as ecotourism site
	5.	Efforts for listing this as "RAMSAR SITE"
THREATS		
	1.	Listed the bird in IUCN red data book
	2.	Conflict between community and government for compensation
	3.	Limited involvement of local people in decision making
	4.	Conversion of wetland area into agricultural land
	5.	Decreasing number of migratory birds
	6.	Illegal bird trading and trapping

Conclusion

Wetlands are one of the most productive systems and play a significant role in the ecological balance. Wetlands are one of the important water resources used for irrigation, drinking, fishing, and flood control purposes. It also provides habitat for invertebrates, fishes and aquatic birds. The Kabartal wetland is one of the important wetlands for water fowl and supporting large number of various species of migratory and resident avifauna. The land-use/cover analysis shows that there has been an overall decrease of water bodies, swamp land and agricultural land but the other hand built-up area increased significantly during 1992-2005. The anthropogenic activities in the area such as overgrazing, use of chemical fertilizers and pesticides and other developmental activities accelerate soil erosion and hydrological alteration and consequently ecological instability. Water quality status has come under the poor category on the basis of water quality index in 2010. Trend clearly indicates that the lake water is deteriorating gradually. Number of measures has been taken by the government but it has no impact on the lake ecosystem. Therefore, there is a need of cooperation of all stakeholders to conserve the lake. Adaptive management creates stronger linkages between the local people, planner, institution and ecosystem. It helps in the decision making for rational use of the resources.

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Women and Natural Resource Management A Conceptual Analysis

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Abstract

Conflicts over natural resources are endemic to developing countries. As conflicts over natural resources reach new heights, newer forms of interest groups make their presence felt. One such group has been that of women whose daily lives are closely interconnected with natural resources and their preservation. Today, they, on their own as well as due to development efforts, have been in the forefront of debate on natural resource. Women's relationship with Natural Resource Management (NRM) has been well-established in the development literature though there still exists a lot of confusion regarding the exact nature of such relationship. A holistic understanding of exact nature of linkage between women and NRM remains a mirage due to the tendency of different disciplines to treat the issue from their respective narrow perspectives. A holistic understanding of this relationship would require nothing less than putting women at the centre of the discourse on NRM without regards to the disciplinary boundaries. A feminist perspective has analytical strength to provide an avant-garde understanding of women's relationship with NRM. In view of this, the paper begins with a discussion of the concept and thrust areas natural resource management followed by a critical examination of women relationships with NRM. Finally, the paper tries to locate the role of women in the NRM processes.

Keywords: *natural resource management, gender, resource conflict, ecofeminism, sustainable development*

Introduction

With ever-increasing numbers and intensity of conflicts over natural resources, newer forms of interest groups are making their presence felt. One such group has been that of women whose daily lives are closely interconnected with natural resources and their preservation. Today, they, on their own as well as due to efforts of the governments and development organizations, have come to the forefront of debates on natural resources. Women's relationship with Natural Resource Management (NRM) has been well-established in the development literature though the exact nature of such relationship still remains a point of debate. Scholars coming from the background of geography background look at it from a spatial and ecological perspectives, economists look at it from a developmental perspective and sociologists from a point of view of social change while political scientists look at it from a policy perspective. Research in all these

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disciplines has enhanced our understanding of relation between women and NRM. This has led to increase in number of literatures on the issue.

In these literature women have been portrayed either as victims of environmental degradation or as mothers. Their managerial capabilities are suspected. It is primarily because of such articulation of women concerns in feminist theories on NRM that gender issues were either completely overlooked or were put superficially in NRM processes. In this context, the paper seeks to provide a critical analysis of relationship between women and NRM. Using a feminist perspective, the paper intends to critically examines various approaches to the study relationship between women and NRM in the developing countries. It begins with a discussion of the concept and thrust areas of natural resource management followed critical examination of women's relationships with NRM. It also tries to locate the role of women in the NRM processes.

Concept of NRM

At the most applied level, the term management refers to a set of decisions to deal with a situation by directing the people and the process towards a positive goal. Management essentially involves decision-making to achieve certain goals, which are well-defined and predecided. In this sense, natural resource management represents actual decisions concerning principles that guide policy as well as practice regarding the utilization and allocation natural resources. NRM becomes significant as it involves decision-making with regards to resources that are very basic to the survival of human beings. These resources are not manmade but are natural such as land, water, forests, livestock and fisheries. Resources management refers to a set of technical, economic and managerial practices by which stocks are converted to resources for the purpose of satisfying man's utilitarian needs and wants under prevailing socio-economic and technological conditions (Conacher, 2003: 51). This definition broadens the concept of NRM to include extraction, manufacturing, marketing, waste disposal and recycling of resources. It would be pertinent here to understand the various aspects of NRM.

As a concept, NRM differs from 'environmental protection' as it seeks to regulate the behavior and activities of various stakeholders with a view to maintain, protect, preserve, regenerate and utilize the natural resources. It seeks to involve various stakeholders which may include individuals, communities and non-governmental and governmental institutions. Participation of all the stakeholders at all steps is necessary for success of NRM. Therefore, NRM appreciates and greatly values roles and responsibilities of all the stakeholders. As a paradigm, NRM seeks to see all stakeholders having their basic needs fulfilled from the local resources. It also seeks to ensure that all stakeholders get equal share in access, control, decision-making, benefits etc. Stakeholders are not mere recipients in this process. Rather, NRM aims at ensuring rights and entitlements of all the stakeholders. This might mean positive discrimination, training, handholding and skill-building in favour of the marginalized groups, such as women, Scheduled Castes, Scheduled Tribes, etc. Central to NRM is the roles played by the various stakeholders in planning and development of the resource management framework. What is also very significant to NRM is its emphasis on indigenous knowledge systems. It is due to this, local and indigenous leadership is valued in the NRM framework.

As a practice, NRM also puts premium on the concept of sustainable management. Sustainability refers to management of resources to satisfy human needs without degrading the

environment or the natural resource base on which resources depends. The main objective of NRM should be to provide maximum benefits to all stakeholders with minimum destruction of natural resources. NRM aims at sustainable development of natural resources for guaranteeing inter and intra-generation equity in availability and accessibility of natural resources.

Thrust areas of NRM

In developing countries such as India, NRM has primarily focused upon the natural resource themes such as integrated water and watershed management, land resource management and forest management. Integrated water and watershed management refers to the management of land and water resources for the primary purpose of securing the best quantity and timing of water flows for irrigation, and quality of water for the benefit of farmers and rural citizens, particularly the poor. It also includes management of water as habitat for living aquatic resources for rural livelihood enhancement. Land resource management indicates the policies and practices in relation to land resources and related flora and fauna to enhance sustainable agricultural production. It also aims to prevent soil nutrient depletion, declining physical properties of soils. Management of forest environments points towards rural livelihood enhancement, including social forestry as well as through sale and personal consumption of forest outputs, including, but not limited to fruits, nuts, oils and other forest products.

Women and NRM

There are ample instances to make us believe that women have not only been involved in issues of NRM but have led movements and initiatives for local resource management. One of the most famous examples of this is the Chipko Andolan (Jain, 1984). A more recent one is the APPIKO, a movement started in 1983 in Uttara Kannada district of Karnataka in response to tree-felling in the Kalase Forests (Hegde, 1989). The slogan of Aapiko Movement is Ulisu (Save), Belasu (Grow) and Balasu (Sustain). Such instances could be found in other parts of the world as well. The Kenyan Green Belt Movement started by late Wangari Mathai is a case in point. It has been internationally known and celebrated as a women's movement for planting millions of trees throughout East Africa in order to provide sources of fuel, food and a way to stop soil erosion and environmental degradation.

The question that has been often asked is whether there is something inherent and spiritual that draws women to be associated with natural resources or is it out of practical necessity that they come to associate with movements concerning natural resources? The answer to this question still remains a point of debate. The present section looks into different approaches that have attempted to answer this question.

A starting point has been provided by the ecofeminist approach that symbolically associates women with nature while men with culture. It believes in the essential interlinkage of oppression of women and that of nature, and relates this to the patriarchal control of nature.

Ecofeminism sees an interconnection between the domination of women and the domination of nature. This interconnection is typically made on two levels: ideological-cultural and socio-economic. On the ideological-cultural level women are said to be 'closer to nature' than men, more aligned with body, matter, emotions, and the animal world. On the socio-economic level, women are located in the spheres of reproduction, child raising, food preparation, spinning and weaving, cleaning of clothes an houses, that are devalued in relation to the public sphere of male power and culture (Reuther, 2005, p. 91).

In line with ecofeminist ideas, the Women, Environment and Development (WED) approach, that draws upon the Women in Devel-

opment (WID), also attempts to establish connections between women and natural resources. For WED practitioners, the connection is essentially based on women's heavy dependence on the natural resources rather than any innate or natural reasons. This has been the earliest developmental approach to challenge women's exclusion from NRM. As per WED, women were seen as having specialist knowledge, abilities and responsibilities of NRM as they were the main users and managers. They were also seen as the main victims of depletion and degradation of natural resources. To put it briefly, the above two approaches believe that:

- Women's lives are related closely and in a special way to natural resources in terms of their use & conservation;
- Women are chief victims of depletion and misuse of natural resources;
- Women possess specific and specialist knowledge and skills in relation to the use and conservation of natural resources;
- Women have better (than men) managerial abilities in relation to natural resources.
- NRM programmes and projects should aim at catering to the special needs of women.

Though these approaches helped to provide a corrective to gender-blind and androcentric environment-development policy, they also provided enough reasons for trapping 'women' into a sort of gross essentialism. In other words, above arguments resulted in a notion that women have fixed caretaker roles which could lead to policy planning that bases itself on reified 'roles' of the women that are disassociated from wider relationships and webs of power (Rocheleau,1991; Leach,1992; Leach, 2007). Besides, it has also been argued that there is a need to contextualize women as they dynamically respond to complex environmental realities, and to consider how they enter into and engage in social relationships with men within the institutions of their natural resource-dependent societies instead of just focusing on perceptions on women's roles (Rao, 1991). Ecofeminism has a tendency to essentialize women as one undifferentiated category while in reality they occupy multiple locations as they belong to different caste, class, region and ethnicity and this in turn entails their differentiated interests in caring for or protecting nature (Raju, 2014: 360)

In reaction to these approaches, economist Bina Agarwal (1977) developed 'feminist environmentalism'. It sought to give a different viewpoint of about relationship between women and NRM. Such a viewpoint is based on more of a materialistic and pragmatic political approach that raises broader issues about gender relations in natural resource management strategies and stresses the role of customs, laws and social structures in determining women's relationship to their environment. As per this perspective, the different forms of relationship to the environment are seen as caused by different forms of interaction between human beings and their material interests (Agarwal, 1997).

Thus, there have been debates regarding the very nature of the concept of 'woman' within these literatures. If, on the one hand, there are streams that focus on an reified image of women equating them with earth mothers, there are strands that have sought to focus on the unequal gender power relations, and therefore argue for a re-conceptualization of the development process and practical needs and strategic interests of women.

The Gender, Environment and Sustainable Development (GED) approach, in line with the Gender and Development (GAD) approach, that is currently in fashion is not only concerned with women, but with the social construction of gen-

der and the assignment of specific roles, responsibilities, and expectations to women and men. It looks at gender as a critical factor in determining human relationships with the physical environment and sustainable development. The focus shifts to access and effective to control over natural resources of good quality, such as land, water and forests rather than a fixed 'mother' image of women. The GED looks at the use and management of the resources and concentrates on how this is done by women and men differently owing to their gender roles. It, however, also brings into its discussion wider issues such as access to and control over other means of production, including income and credit, appropriate technology, training and education, housing, active participation and involvement, decision making power and social status. In brief, GED along with 'feminist environmentalism' focuses mainly on the following issues:

- It recognizes women as critical agents of change;
- The complex power relationships are focused rather than a simple and fixed image of women in relation to NRM;
- It looks at male-female relationship in terms of both cooperation and conflicts rather than only as conflictual;
- It emphasizes that the NRM Programmes and projects should use gender analysis rather than focusing only on women's role.

As the debate evolves into newer stages, there are certain points on which there is a consensus. These consensuses are mostly related to the existence of gender differences in relation to NRM. First, there exist gender differentials in vulnerability to natural resource scarcity. Studies suggest that women experience greater vulnerability and hardships as survival resources become scarcer and their already weaker rights are further eroded (Agarwal, 1994; Sharma, 2003). Second, there are gender differentials in roles and responsibilities in relation to NRM. Feminist literature is replete with examples of gender stereotypes that determine the place of women and men in the society, polity and economy. Such gender stereotypes are found with regards to NRM practices as well. Women's identities as family nurturers/mothers/caretakers get reflected here. Traditionally, women, because of with their gender location (private), have been collectors and preservers of natural resources while men with their gender location (public) have been more into the marketing of these resources. Third, men and women have different and yet unique knowledge and skills in relation to natural resources. Women are generally closer to natural resources owing to their roles as collectors and preservers. It has been found that they possess better and sometimes unique knowledge and skills relating to processing and storage of resources. Fourth, one finds gender inequality in targets of most NRM programmes. Men and women are differently targeted in government sponsored NRM programmes. It is seen that women who are often ignored in such programmes. Fifth, there exists gender inequality in benefits from NRM. Women and men get different benefits from NRM primarily owing to the gender stereotypes within which they operate. Finally, gender differentials in access to and control over resources are clearly visible. Women have limited and conditional access to natural resources. They enjoy little control over NRM decision-making while men are usually the decision-makers both at household and community level.

Given this, there is a need to draw attention of policy makers and progarmme implementers towards the need for gendered NRM practices. Gender sensitive NRM Practice should have the following as the main focus.

- Need to analyze the impact of existing power relations within the community.

- Need to examine and understand the gendered nature of local institutional aspects of NRM.
- Need to focus on the decentralization of local resource utilization, i.e. community-based resource planning.
- Need to develop capacity-building through the use of information and communication technologies.
- Need to develop women's networks.
- Need to teach women to develop effective partnerships.
- Need to improve women's bargaining power within the social institutions.
- Need to promote sustainable NRM.

In the final analysis, the policy makers and programme implementers need to realize that these above components are important in NRM not only because they help women to improve their status but the very presence of women enhances the likelihood of success of NRM programmes.

Conclusion

Though women's relationship with NRM makes an interesting subject to read and discuss, a more significant question invariably arises regarding the need to bring women into the NRM discussion. Do women really make a difference in NRM? If so, how do they make a difference? The question arises because of the way women have been portrayed in discussions on environment as either victims (to be pitied) of degradation or (in reified roles) as mothers, it is only pertinent to doubt their managerial capabilities. It is because of such articulation of gender concerns in feminist theories that gender issues were either completely ignored or were put in the backburner with regards to NRM planning.

Faced with criticism of ignoring gender elements, most NRM programmes are deliberately integrating gender components these days. But, in many cases these are done just for the sake of it. As a result, gender issues are incorporated unevenly into the development programmes. Also, the understanding of gender varies from person to person even in the same development projects. Therefore, the benefits of the NRM have not accrued to women. In fact, in many NRM projects women were found to be at the receiving end. It has been found that the targets as well as benefits natural resource management programmes varies across gender. What is significant is to recognize the fact that women's association with NRM practice has distinctive meaning than to that of men. As has been discussed, women have distinct roles and responsibilities in relation to NRM that has been responsible for their closeness with the resources. Further, women possess distinct knowledge and skills in relation to processing and storage of natural resources. It is this skill and knowledge which would be enriching additions to natural resources if women are given space. Moreover, women's close relationship as collectors and preservers could make them effective managers of natural resources.

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Estimation of soil loss sensitivity in the Jinari river basin using the Universal Soil Loss Equation

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Abstract

Soil erosion hazard is an environmental problem in diverse geographical areas and oftentimes has repercussions that are felt in downstream areas. This study assesses various aspects of soil erosion in the Jinari River basin in Assam, India using the Universal Soil Loss Equation (USLE) in a GIS environment. The average rainfall erosivity index is found as 165.2 MJ mm/ha/yr and soil erodability factor K varies between 0.56 - 0.43. The LS factor was computed using Digital Elevation Model (DEM) data, while the C factor was computed from Normalized Difference Vegetative Index (NDVI) values derived from Landsat TM data. In the Jinari River basin no supporting practice was observed, thus the value of 'P' has been taken as 1. The average annual soil loss estimated in the watershed using USLE was 1.76 ton/ha/yr and 0.95 ton/ha/yr for 2007 and 2011 respectively.

Keynote: *USLE, soil loss, river basin management*

Introduction

Soil erosion is the result of the interplay of several complex parameters such as slope, rock type, relief, rainfall, as well as land use and land cover. It is a phenomenon which consists of detachments of individual soil particles from the soil mass and their transportation by erosive agents like running water and wind. Soil loss is the net mass of sediment removed from a particular portion of the slope (Kalita & Sarmah, 2016). Soil loss can be an environmental problem when it happens due to the strong force of water action. Several studies have used Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE) models to identify soil loss sensitivity zones (Sen et al., 2001; Wang et al., 2003; Dabral et al., 2008; Karaburun, 2010; Prasannakumar et al., 2011; Ghosh et al., 2013; Farhan et al., 2013; Jaiswal et al. 2014).

Jinari River and its environment

The Jinari River is a south bank tributary of the Brahmaputra River, Assam. It lies in between the East Garo Hills district of Meghalaya

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and Goalpara district of Assam. The locational extent of the basin is 900 20/ 0 // E - 90 0 42 / 30// E longitude to 260 8/ 30// N - 250 44/ 0 // N latitude. It is surrounded by Dudhnoi-Krishnai sub basin on the east and south and the Jinjiram sub basin on the West and by the Brahmaputra to the north. The river basin covers an area of 432.9 km2. The catchment areas that lie within the state of Meghalaya are mostly hilly barring a few narrow floodplains along its course. In the Goalpara district of Assam, the catchment is mostly along level lowland stretches barring a few hill sections portion on the south of the National Highway No -37.

On October 7 of the year 2004, a flash flood in Jinari river of Assam was triggered by a cloudburst over Meghalaya that caused great havoc in the downstream areas in Assam. This sudden event wiped out about 20 villages over an area of about 4 sq. km, killing 250 people. A similar cloudburst occurred in 2014 killing 40 people (Report, 2017). As the shape of the Jinari basin is elongated therefore surface flow has a low lag time, thereby creating flash flood in the downstream areas. However, due to lack of rain gauges inside the basin, proper documentation of the cloud burst events are missing. The Jinari basin has a long history of climatic and geomorphic disaster and therefore understanding the physical parameters is necessary. This present study aims to quantify the nature of soil loss in the basin with the help of proven model USLE.

Data and Methods

USLE has been used in the study area to investigate the long term average soil loss of concerned field area for the year 2007 and 2011 using Landsat TM data to identify the specific crop-cover management practices that underlie the erosion processes.

The general USLE model is as follows:

$$A = R*K*LS*C*P$$

where, A is average annual soil loss (t ha?1y?1); R is the rainfall and runoff erosivity

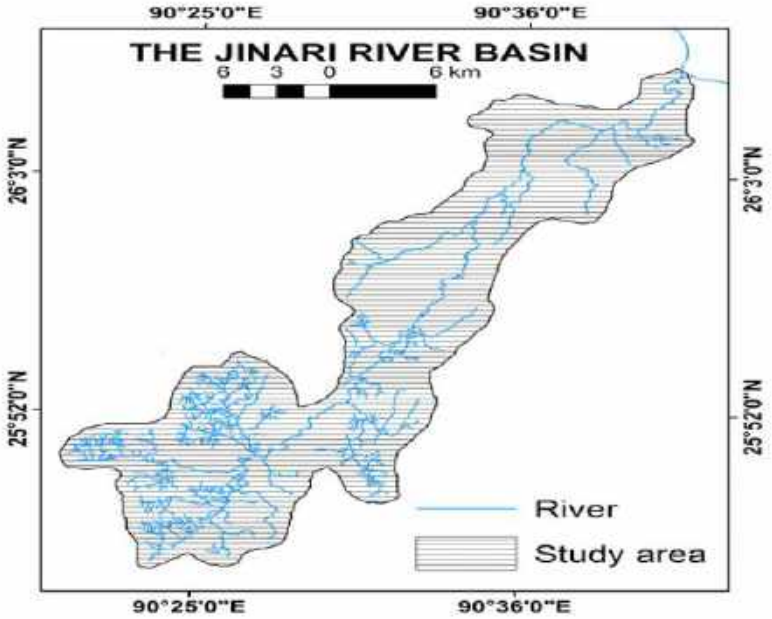

Fig. 1: Location of the study area

index (in MJ mm ha-1hr-1); K is the soil erodibility factor (in ton/MJ/mm); LS is the slope and length of slope factor; C is the crop-cover management factor; P is the is the supporting conservation practice factor. For the calculation of these factors, the data were collected from various sources. The rainfall data was obtained from the Water Resource Department, Government of Assam; the soil data for the calculation of K was collected from Agricultural Department, Government of Assam; while a Cartosat Digital Elevation Model (DEM) was used to generate terrain data in the area of interest and finally Landsat TM satellite imagery of 2011 was downloaded from the USGS website. The following is a schema of the workflow employed in the present analysis (Fig. 2):

Rainfall and runoff erosivity factor (R)

The rainfall-runoff erosivity factor (R) quantifies the effect of raindrop impact and reflects the amount and rate of runoff likely to be associated with rain. It is a numerical description of the ability of rainfall to erode soil (Wischmeier and Smith, 1978). The R values can also be obtained by 'iso erodent' maps, tables as well as historic data of the area concerned (Renard et al., 1997). The following equation is used in estimating the R factor in the Indian context which is given by Singh et al (1981).

$$R = 79 + 0.363 * P$$

Here, R is the annual R factor; P is the average annual rainfall in mm.

Soil erodability factor (K)

The soil erodibility (K) values are computed from the soil map data prepared by the Department of Agriculture, Government of Assam. Since, K factor value is mainly related to soil texture, thus in computing soil erodibility factor soil properties that were collected from the technical bulletin on soil series of Assam as well as soil samples collected through field investigation were used.

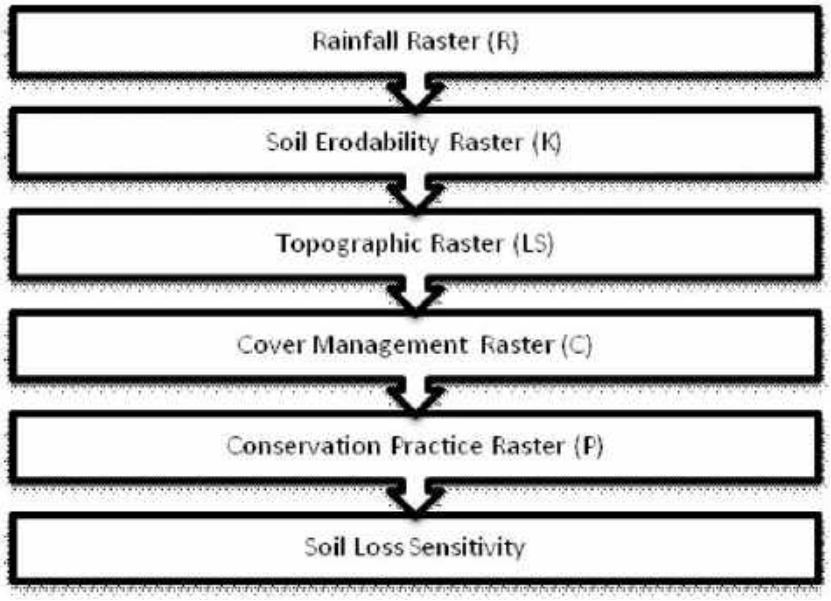

Fig. 2: Flow chart of steps followed in the soil loss sensitivity assessment

Table 1: Values of erodability factor based on soil types and per cent organic matter content in soil (Foster et al. 1981)

Textural class	K based on % organic matter content in soil		
	0.5%	2%	4%
Fine sand	0.36	0.31	0.22
Very fine sand	0.94	0.81	0.63
Loamy sand	0.27	0.22	0.18
Loamy very fine sand	0.98	0.85	0.67
Sandy loam	0.60	0.54	0.42
Very fine sandy loam	1.05	0.92	0.74
Silt loam	1.07	0.94	0.74
Clay loam	0.63	0.56	0.47
Silt clay loam	0.83	0.72	0.58
Silt clay	0.56	0.51	0.43

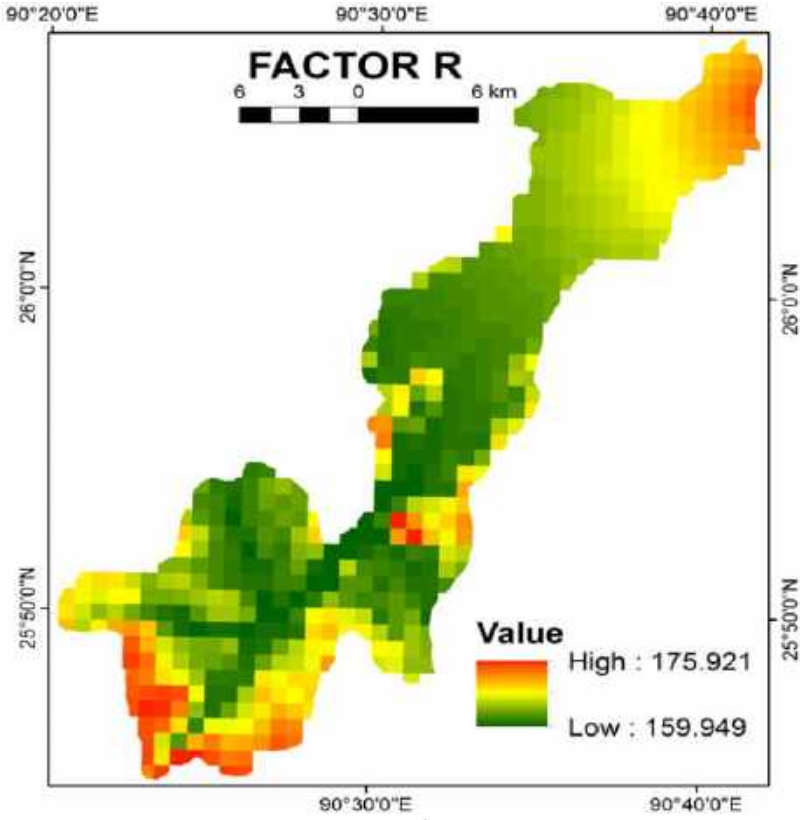

Fig. 3: Rainfall-runoff erosivity factor (R)

Table 2: Calculated K values on the basis of textural classes

Soil code	Soil Textural Class	Calculated k values
AS 57 (Typic Udifluvents)	fine loamy (clay loam)	0.56
AS 55 (Typic Fluvaquents)	Fine silty clay	0.43
AS 80 (typic haplaquepts)	fine loamy	0.56
Aquic eutrochepts	Fine loamy	0.56
Typic haplaquepts	Silt loam	0.51
Typic kandiudults	Fine loamy (clay loam)	0.56
Dystric eutrochrepts	Fine loamy (clay loam)	0.56
Umbric dystrpchrepts	Fine loamy (clay loam)	0.56
Typic udorthens	Coarse loamy (sandy loam)	0.54
Dystric eutrochrepts	Fine loamy	0.56

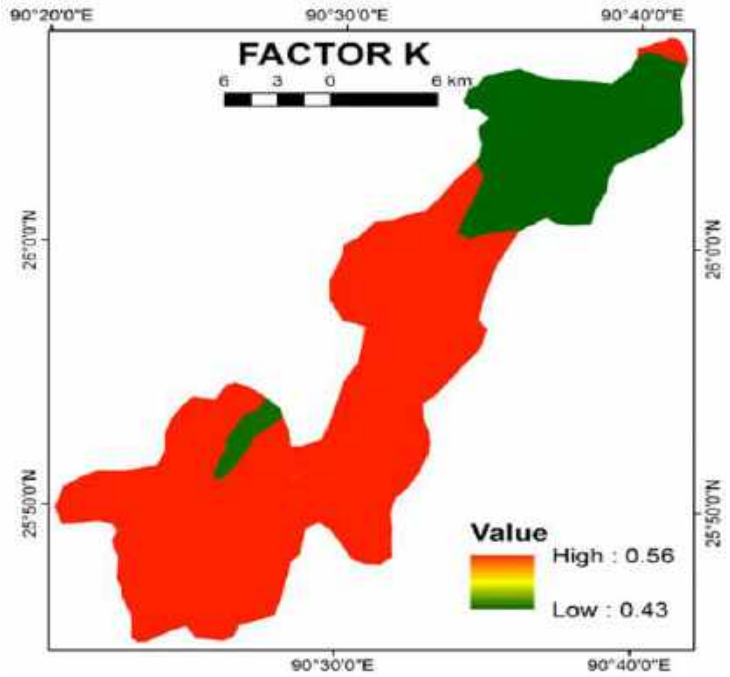

Fig. 4: Soil erodibility factor (K)

Topographic factor (LS)

In the present study the LS factor is computed with the help of a DEM. The DEM of the study area is of 9 meter resolution and the slope layer was derived from the former. The formula used for calculation of LS factor was proposed by Moore and Burch (1986) , Zeng et al. (2009) and Silva et al.(2012).

LS=(v/22.13)0.4 (Sin ?/0.0896)1.3

Here, LS is slope length and slope steepness factor, V is the product of flow accumulation and cell size, ? is the slope in degrees (Silva et al. 2012)

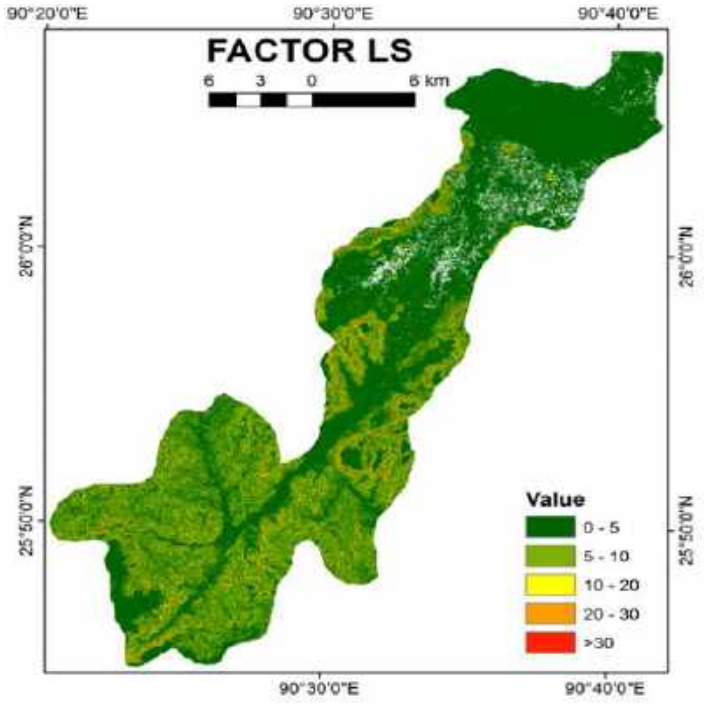

Fig. 5: Length and steepness factor

Cropping management factor (C)

This represents the effect of soil-disturbing activities, plants, crop sequence and productivity level, soil cover and subsurface bio-mass on soil erosion (Prasannakumar et al., 2012). The C factor reflects the effect of cropping and management practice on soil erosion rates, and is the factor used most often to compare the relative impacts of vegetation cover and management options on conservation tactics (Renard et al., 1997). This C factor has a close connection to land use and land cover types and also anthropogenic interventions on the soil erosion processes (Jaiswal et al., 2014). Currently, due to the variety of land cover patterns with spatial and temporal variations, satellite remote sensing data sets were used for the assessment of C-factor (Karydas et al., 2009; Tian et al., 2009).

Conservation practice factor (P)

In the study area of Jinari River basin no supporting practice such as strip cropping , terracing, contouring etc are witnessed thus the value of 'P' taken as 1.

Results and discussion

The river basin is characterised by both lowland and hill topography and erosion is equally significant in both types of terrain. This is possibly since erosion depends not only upon the action of fluvial processes but also results from the action of splash erosion. The average annual soil loss estimated in the watershed using USLE was 1.76 ton/ha/yr and 0.95 ton/ha/yr for the years 2007 and 2011 respectively (Fig 7, Table 3. & Table 4.). In 2007 the tropical dense forest areas had high erosion rates and it accounted for 36.1 percent of total erosion of the basin. On the other hand in 2011 the settlement classes had the maximum erosion rates accounting for 49.4 percent of total erosion. This is due to the conversion of dense forest areas into settlement

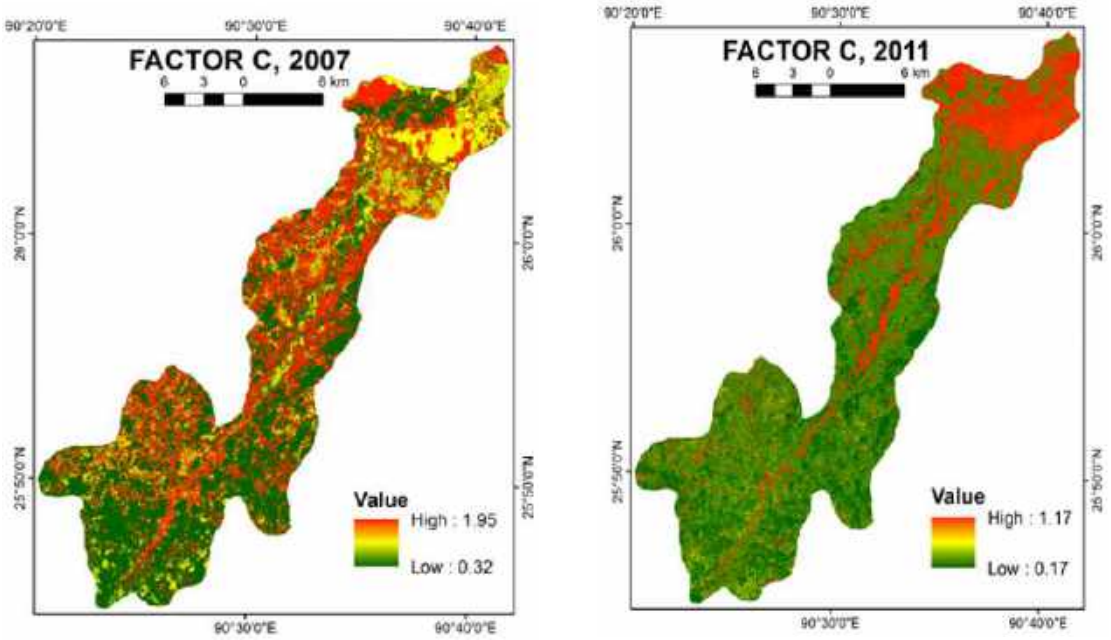

Fig. 6: Cropping management factor of 2007 and 2011

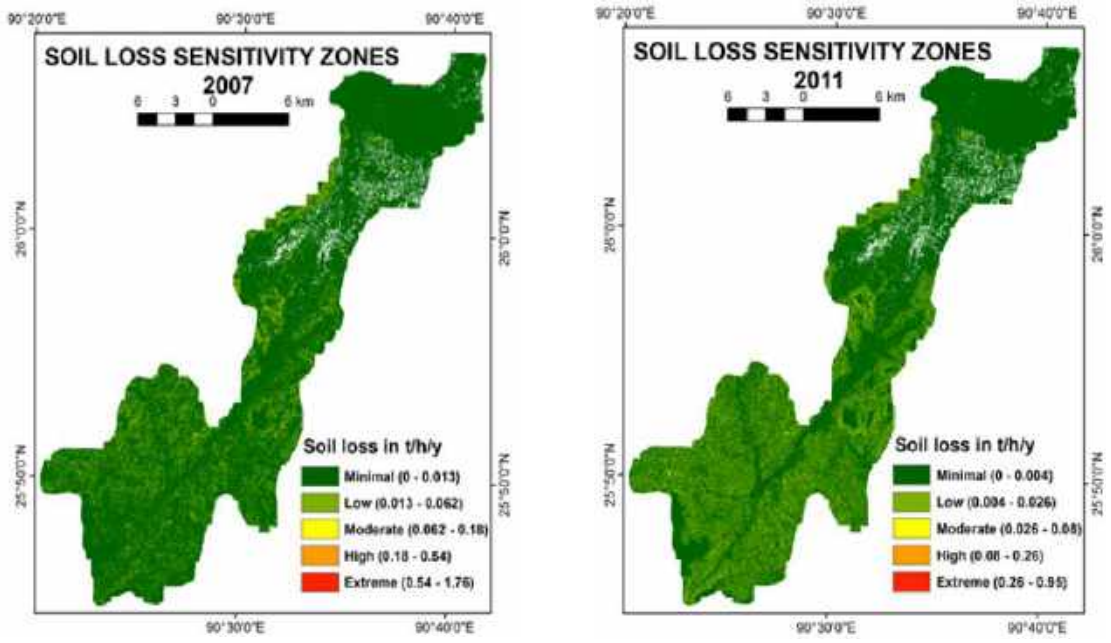

Fig. 7: Soil loss sensitivity classes of 2007 and 2011

areas and because of that the amount of splash erosion is relatively high in such areas. The basin experiences more or less similar rainfall conditions and thus the soil loss of the area is dependent upon the LS, K and C factors.

Table 3: Soil loss sensitivity classes, 2007

Soil loss (t/h/y)	Soil erosion sensitivity zone	Area (sq. km)	Percentage
0- 0.013	Minimal	357.15	89.57549
0.013 - 0.062	Low	36.18	9.074173
0.062 - 0.18	Moderate	04.88	1.223935
0.18 - 0.54	High	00.48	0.120387
0.54 - 1.76	Extreme	0.024	0.006019

Table 4: Soil loss sensitivity classes, 2011

Soil loss (t/h/y)	Soil erosion sensitivity zone	Area (sq. km)	Percentage
0 - 0.004	Minimal	310.85	77.99836
0.004 - 0.026	Low	83.45	20.93924
0.026 - 0.08	Moderate	3.92	0.983605
0.08 - 0.26	High	0.29	0.072767
0.26 - 0.95	Extreme	0.024	0.006022

The soil loss data recorded in the table 3 & 4 revealed that although erosion in the basin has increased considerably, yet it is hard to relate it with the nature of disaster in the basin. However increasing clearance of the dense forest for other land use has triggered soil erosion in the basin. It is interesting to note that tropical dense forest and degraded forest category contribute significantly to the total estimated soil loss in the basin (Table 5).

When compared the average annual soil loss data with Belsiri basin records (Kalita and Sarmah, 2016) it was found higher soil loss rates existed in the Jinari river basin. The catastrophic

Table 5: Percentage distribution of land use and statistical of soil loss using USLE during 2007

Landuse	Area		Estimated soil loss (ton)		
	sq. km	%	Maximum	Mean	SD
Agricultural Land	20.5	4.7	14351	0.2	27.5
Tropical Dense Forest	156.1	36.1	16969	64.3	207.4
Mixed Vegetation	37.8	8.7	8277	3.1	47.7
Degraded Forest	65.5	15.1	23033	27.5	190.5
Barren Land	4.1	0.9	14389	4.2	84.1
Water body	34.8	8.0	41329	12.7	204.7
Settlement	113.8	26.3	76292	166.4	758.5

Table 6: Percentage distribution of land use and statistical of soil loss using USLE during 2011

Landuse	Area		Estimated soil loss (in ton)		
	Km2	%	Maximum	Mean	SD
Agricultural Land	12.5	2.8	1774	0.05	4.3
Tropical Dense Forest	26.4	6.1	6988	8.0	58.7
Mixed Vegetation	84.6	19.5	8932	26.6	117.8
Degraded Forest	47.0	10.8	28247	14.4	167.5
Barren Land	16.5	3.8	10985	8.7	81.9
Waterbody	31.7	7.3	41329	8.1	166.3
Settlement	213.8	49.4	19090	56.8	197.9

flood occurrences of the basin are inextricably linked to unusually high soil and water discharge rates of the basin. To formulate a realistic and effective disaster management plan for the basin it is imperative to take into account the soil loss specifics that are at work, as evidenced by this analysis.

Conclusion

USLE are useful in assessing soil loss parameters in a given area. In the Jinari river basin in Assam, India a unique set of factors are at work in shaping and influencing soil loss and rapid land-use/land-cover changes have accentuated soil loss. Unfortunately, this aspect is often lost sight of by planners and governmental stakeholders. However, in order to minimize future loss of lives and property the factors underlying high soil losses need to be factored in.

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Deteriorating Scenario of Lakes A Case Study of Ramgarh Lake, India

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Abstract

Lakes are an important part of our ecosystem that provide not only direct benefits like, drinking water, irrigation, fishes, aquatic crop production, recreation etc. but also indirect benefits like, regulation of hydrological cycle, local climate control, maintenance of ecological biodiversity etc. But now, lakes are being contaminated through various pollutants as a result of urbanization in recent decades. The deterioration problem of lakes is seen from global to national and regional level. This study focuses on the severe depleting factors, impact of depletion and controlling practices. A case study of Ramgarh lake which is an ox-bow lake situated in the eastern part of Gorakhpur city, Uttar Pradesh is carried out to study the status of the lake at present. Water quality and quantity of Ramgarh Lake are changing with passing time dramatically like other water bodies. The changing pattern of utilization of the lake resulted degradation of water quality and hampered the livelihood. The quality of Ramgarh lake was good, as per local people, up to 1980s, but thereafter, within 38 years, human impact has pushed the lake at the edge of depletion. During 1922 to 2018 about 234.94 hectare area was encroached by people. This drastic alteration was happened due to rapid unplanned urbanization and dumping of solid as well as liquid wastes in to the lake. This action initiated uncontrolled growth of hyacinth, eutrophication and sedimentation, which have changed lake's morphology, depth, volume and quality of water. Some measures are being taken towards the stewardships of this lake in recent decade but more conservational steps on ground are essential to be taken to ensure the better future of this lake.

Keywords: *lake ecology, importance of lakes, eutrophication, siltation, sewage disposal, encroachment, restoration practices*

Introduction

Water is an essential component of an ecosystem. It sustains life on earth. A community depends on water for its domestic, agriculture and industrial needs (Barnwal, et al., 2015), Availability of water has been a factor in the development of various civilizations near lakes and rivers. A lake is an area filled with water, localized in a basin that is surrounded by land, apart from any river or other outlet that serves to feed or drain the lake. (wikipedia.org). Lakes are known to be the ecological barometers of the health of a city. They regulate the micro climate of any urban center. Water quality, habitat structure, flow regime, energy source and biotic in-

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teractions are the major environmental factors that determine water resource integrity. Indian Vedas explored the scientific aspect of water and rain which depict the importance of lakes, ponds and tanks. Significance of lake is told that 'a person who constructs a lake attains 100 million times more excellence than those who perform the ritual of Ashwamedha yagya and goes directly to heaven' (Ramachandra, et al., 2014). Lakes are important for preservation of sound ecosystem and biodiversity on our planet. On the earth sufficient amount of water available, two third areas are covered by water bodies in which 97.2 percent is found in the oceans and remain 2.8 percent is lie as freshwater. Of the total amount of freshwater 68.6 percent occupied by continental ice cap, 30.1 percent in underground aquifers and 1.3 percent found in lakes and rivers. Lakes specially covered less than 87 percent of whole part of freshwater, 2 percent river and 11 percent swampy land (NCERT, 2005).

Lake has three essential features commonly integrating nature, long retention time and complex dynamic response. Integrating nature of lake refers mixing of some inputs within a lake in which resources and interruption are disseminated throughout in the volume of whole lake. Lake retention time refers to slow change in homeostatic mechanism in lake while complex dynamic response system denotes that, water storage in lakes generates concentration of nutrients excessive growth of flora that abrupt the food chain or trophic status of lake (International Lake Environment Committee, 2005). The above features are found together in lake only which reveals the lake ecology affected by geology, morphology, environment, social effects and government policies etc. in a particular region. Lakes play a vital role in hydrological cycle with the impacts on economy and micro-environment of a region. It provides goods, livelihood and environmental services for both poorer and richer people. It recharges the ground water and control the flood problem during rainy season. Lake water is used as drinking water supply, irrigation, power generation and other uses. Lake is the home to many aquatic animals and plants. It is the source of storage of ground water which is fruitful for dwellers. It fulfills recreational and aesthetic enjoyment requirement of the people. Water of lake has a high capacity to control temperature of surroundings by keeping fairly constant and enable to support life. A balanced ecosystem of lakes promotes healthy plants and animal communities. Clean water of lake increases secure animal nesting and resting places. Aquatic ecosystems worldwide are being destroyed at a greater rate than any other time in human history and faster than they are being restored. Some of these losses occur through intentional exploitation of resources. Other losses occur cumulatively through lack of knowledge or fragmented approach in resource management (Kumar and Ramachandra, 2005). Lakes are the most beautiful feature of a landscape. They are often explained as the "Eye of the Earth". A pristine lake expresses the beauty and joy around it, but a polluted lake choked by callous and severe dumping of waste is like a blind eye. Unfortunately, now, many of our lakes have been blinded and polluted through over-exploitation and reckless dumping of human/ recreational and industrial waste, therefore, we must remember that we are the custodians of the Earth and its natural resources. Unless remedial measures were taken we would be guilty of depriving future generations of the beauty, the grandeur and the bountiful benefits of nature" (Patil, 2007).

Yadav, et al., (2013) analyzed physio-chemical characteristics of Mahil pond, located in Orai in Jalaun district of Uttar Pradesh. This study explained that the pond was just below the level of eutrophication. Zutshi, (1985) compared and analyzed limnological feature of nine lake sys-

tem of Himalayan region from Kashmir to Arunachal Pradesh and revealed the causes of eutrophication. Pant, et al., (1985) analyzed chemical, microbiological and biological aspects of pollution in Lake Naini. Little, (1975), described about exploitation and conservation of aquatic flora. Hosper, and Meyer, (1986) analyzed the control of phosphorus loading and flushing as conservation and restoration methods for Lake Veluwe in Netherland. They also toward high nutrient loading in Lake Veluwe suffered from permanent bloom of the blue-green algae Oscillatoriaagardhii Gomont. Mahapatra, et al., (2010) revealed the algal Photosynthetic dynamics in urban lakes under stress conditions and computed algal growth, community structure, primary productivity and their composition for three major lakes (T G Halli, Bellandur and Varthur lakes) under contrast and intense levels of anthropogenic influences. Vyas, et al., (2006) focused the environmental impact of idol immersion activities in lakes of Bhopal. The immersion of idol of Lord Ganesh and Durga during Ganesh Ustav and Navratri festival was a major source of contamination and sedimentation in lake water. International Lake Environment Committee Foundation (2005) described about managing lakes and their basins for sustainable use. ASVA (Association of Summer Villages of Alberta, 2006) created the lake stewardship Reference Guide to take positive action towards improving the condition of lake's environment and their ecology by having a better understanding of lake stewardship issues, involving people at all and by making better decisions about land use practices. Ramchandra, (2008) stated about characterization and restoration aspects of Varthur Lake based on hydrological, morphometric, physical, chemical and socio-economic investigations for period of six months covering post monsoon seasons. Mahapatra, et al., (2011) explained the role of Macrophytes in maintaining the level of nutrient pollution as a result of prolific growth of invasive species like hyacinth (Eichhorniacrassipes) in urban water bodied.

Sharma, (2001) analyzed morphology, economic use and factors of deterioration of Ramgarh Lake, induced by urbanization of surrounding areas of Gorakhpur town. Tiwari, F., (2013) analyzed that all the physio-chemical parameters were high. The lake is gradually attaining eutrophication. Bharati, and Pandey, (2015), analyzed water quality of the Ramgarh Lake for various physio-chemical and biological parameters i.e. pH, TDS, turbidity, acidity, alkalinity, total hardness, Cl, DO, BOD, COD, fecal coli form, in the month of January-2015 to June-2015. Pandey, and Prakash, (2016) analyzed monthly change in physio- chemical parameters of Ramgarh lake's water. Kumari, and Singh, (2017) examined the biochemical and hematological changes due to pollutants in fishes in Ramgarh lake, Gorakhpur.

Objectives

The objectives of this study are to explore the socio-economic and ecological impotence of lakes, factors and impacts of lake deterioration with a case study of Ramgarh Lake, Gorakhpur. The case study analyzes the utilization status, depletion scenario, impacts of depletion and stewardship practices operated in Ramgarh Lake.

Data source and methodology

The study based on the primary as well as secondary data obtained from different sources such as, books, theses, reports and web sources. Ramgarh lake, Gorakhpur is taken for the case study of its changing scenario since 1922 to 2018. For the primary survey surrounding area of the Ramgarh Lake covering about 500 meters around the lake is taken. Primary information were gathered from 100 households from Taramandal, Padleyganj, Kuraghat, Jharkhandi and Maherva ki Bari (fishermen's village) through an interview schedule. Water quality

was analyzed for temperature, pH, conductivity, TDS, salinity, BOD, DO, orthophosphate, nitrate, chloride and chlorophyll through lab experiments in June 2018. Amount of encroachments in the Ramgarh lake by the surrounding people from 1922 to 2018 is also explained. The toposheet NG 44-8 of Gorakhpur on 1:250,000 scale is used to know the position of lake in 1922. Images of the lake region are collected from Google Earth (www.googleearth.com) for the period of, 2003, 2005, 2008, 2010, 2012, 2017 and 2018. To analyze the encroachment in these years computer software such as MS Excel, Arc-GIS and ERDAS are used. Land use transformation depicted through buffer analysis of encroachment is done on the image of 2003 and 2017 in GIS environment. Depth of lake was measured through stadia and bamboo sticks. Sewage samples are collected from sewage entering point of Kuraghat Nala and about 100 meter away in open lake from this point. Maps are drawn with the help of Satellite images, Google Earth images and toposheets by above computer software.

Importance of lake

People lives in surrounding area execute many activities like, cultivation, fishing, irrigation, cattle bathing, recreational activities, tourism and other daily life related activities. Lake have consumptive economic values like, availability of gravel, sand, peat, reeds, wood, mushroom, willow branches, fish, birds, frog benthic invertebrates etc. and non-consumptive use like tourism, bird viewing, boating, education and research and aesthetic attraction. Lakes are also used for irrigation, domestic water supply and hydroelectric power generation etc. Thus, Lakes are premium source of water today and future along with cultural and historical importance. Human activities directly and indirectly affect the lake ecology. Lakes are used for water extraction for daily use in human life, development of commercial fisheries and aquaculture, paddy and vegetable cropping and grazing, disposal of sewage waste, facilitate recreational and tourism activities and promote some religious and cultural uses whereas lake catchment basins are used for livestock grazing, human settlement, forestry, road network, hotels, restaurant, parks for tourism development etc. But at the same time lake basin areas region become paved surface which alter the hydrological regime, reduce in width of drainage that creates excessive flood in Lake Zone and hamper flora and fauna. Dumping of wastes, expansion of residential colonies, loss of shoreline due to lack of proper embankment and deforestation, siltation due to soil erosion in lake areas force the lake to be depleted that adversely affect livelihood of lake surrounding people due to increasing contamination in lake.

Deteriorating factors

Construction activities such as residential zone, commercial hub, administrative building, park, playground, theatre, restaurant etc. are made in catchment area of lakes that altered in topography. Freely and uncontrolled dumping of solid wastes, untreated sewage water, industrial effluents are filling the lake bed. Removal of shoreline vegetation for construction in the lake zone has threatened urban wetland. Pollution in lake area due to excessive traffic, tourism and recreational activities and lack of co-ordination between government policies and their execution bodies on ground level have created unhygienic environment to the flora and fauna of lake (Ramachandra, et al., 2015). Lakes act as factor of climate change, specially due to sediment transport and carbon cycling in lake catchment area. Climate change in lake ecology is depicted through alteration in composition of stratification, shift in seasonal algal production, change in lake retention time, alteration in lake basin morphology etc. (Taner, et al., 2011). Thus, climate change produces some problems like, increase in temperature as well as in evaporation

from lake surface and extensively affect the living organism in lake basin. Accumulation of phosphorus in soils affect freshwater ecosystem. Over enrichment of nutrients causes excessive growth of flora (Bennett, et al., 2001). Sewage waste water let into lake freely without treatment that increases eutrophication problem (Mahapatra, et al., 2011). Eutrophication in lake increases growth of flora, change phytoplankton to algal-bloom forming species that make lake water an anoxic, inedible and toxic, which decrease the transparency of water, imbalance the odor, taste and other water quality of lake. Moreover decline in oxygen concentration and depletion of fishes is occurred. (Carpenter, et al., 1999). Uncontrolled anthropogenic eutrophication is major problem in recent times for inland water bodies under influence of large dense populated area in the world (Dokulil, and Teubner, 2011).

Freshwater (lake, river, reservoir, pond etc.) ecosystem has limited water resource on the earth surface. Increasing population, urbanization and climate change abrupt accessibility of freshwater. This limitation degrades lake ecology quickly. The supply of usable water decreases due to pollution and increases the cost of purifying it. Some pollutants like chlorinated organic compound or mercury contaminate aquatic biota and affect supply of food. Lakes are essential part of ecosystem and their depletion is dramatically creating problem for human existence (Plenitz and Vincent, 2000). Increasing imbalance in freshwater system dramatically alters the hydrological cycle in the world. Many regions are already facing limitation for water quantity and quality. In the world, 20 percent fish species of freshwater are extinct and threatened. Some scientific evidences highlighted that more than half of freshwater surface globally is used by human beings. Almost 1×109 people currently are not in access to potable drinking water. After increase in evapotranspiration, irregularity in seasonal variation and some intense alteration in biogeochemical cycle, lake water quality significantly decreases as seen in Bangalore (www.theguardian.com). The lake Bellundur, burned for 12 hours and left behind a sinister black patch in the core area due to untreated sewage entered into lake catchment area that created a fertile toxic environment for disaster such as foam and fire. In Bengaluru city, rapid expansion of urbanization from 1973 to 2016 increased 100 percent concrete surface and reduced 88 percent vegetation cover in city region whereas water bodies' area encroached by 85 percent from 2000 to 2014. In Bengaluru, 98 percent lake area encroached through commercial building, apartments, slum dwellers etc. (www.theguardian.com). A field survey of lakes (in 2014-2015) revealed that approximately 38 percent area covered by slums, 82 percent loss of catchment area and 90 percent of lake area faded by sewage water. (Ramchandra, and Aithal, 2016). This city is called city of lake. In 1990 there were 285 lakes that fulfilled water requirement but in 2016, only 194 lakes were remained and were unable to meet the people greed. About 43 lakes in Bengaluru have lost their entire characteristics through construction of many apartments, playgrounds, administrative buildings, workshops etc. (Ramchandra and Aithal, 2016).

Control practices

The increasing demand of freshwater raises an urgent need of interdisciplinary research for water management. The problem of eutrophication can be mitigated through phosphorus input in to the lake water according to varying state of eutrophication because reduced phosphorus input controls the eutrophication according to their retention time with their complex dynamic response and integrating nature characteristics (Carpenter, et al., 1999). Some steps can be taken for better regulatory mechanism for stewardship of lake. Control on land grab-

bing with non-bailable offence, to force implementation of 'polluter should pay' principle, restriction on construction works in the lake region, ban on diversion of lake inflow for another purpose, decentralized treatment of solid waste and sewage and ban on entry of untreated waste water in to Lake zone may be some measure to implement for lake management. Moreover, impediment of pollution and proper treatment of point source pollutant are essential before enteringin catchment area of lake (Ramchandra, et al., 2015). Harvesting of macrophytes through mechanized way of de-weeding, afforestation of native flora in catchment area to interrupt the entry of silt trough run off in lake, lake shoreline embankment with bricks or stones to control erosion of shoreline, reducing in sediment load rain water to downstream area to make infiltration trenches in Lake Zone, protection and management of buffer area vegetation in lake zone are some measures to mitigate lake degradation (Ramachandra, 2009). During recent decades, remote sensing data are used to analyze the current status of depletion, set constraints and determines the strategies for stewardship, and finally, describe and select the best ideology and scenario of restoration and management of Lake Basin area (Alexandridis, et al., 2007). Fencing keeps livestock out of stream and protecting existing grassed areas and trees from erosion. Trees and shrubs can slow the wind and reduce erosion. Proper treatment of domestic wastes and safe application of fertilizers reduce nutrients entering into the lake that keep harmful pollutants out of water. The lake management techniques include Dredging (removing excess sediments) can eliminate nutrients and aquatic weed growth, deepen areas for recreational uses and remove toxic or other contaminated substances; Alum Treatment (adding aluminium sulphates to lakes) can control algae; Shoreline Stabilization- (stabilizing lake shorelines) can decrease sediment loads and turbid conditions in lakes; Harvesting (mechanical removal of excessive aquatic plant growth) can increases areas available for recreation, navigation, irrigation and helps in removing the source of nutrients released by decaying plants, which can in turn, decrease algal blooms; Aeration and Circulation (adding oxygen to a lake through aeration devices) can prevent fish kills, create conditions unfavourable for algal blooms and improve the taste and colour of drinking water (www.epa/gov/own). Specific research for individual lakes for further protection and management of the lakes are needed.

The conditions of some major lakes in India like, Chilka, Powai, Pushkar, Bellundur, Ramgarh etc. are not good regarding their morphological characteristics, ecological health and deterioration controlling practices for stewardship of lake. Lakes are touching at varying level of deterioration condition related to siltation, eutrophication and encroachment due to tremendous population pressure. Lakes are depleted through point source pollution such as nutrients pollutants let into through municipal waste and domestic effluents, industrial effluents enter in the form of organic, inorganic and toxic pollutants. Silt occurs from urban expansion, agricultural areas, deforestation, road construction and other land disturbances in Lake Region. After application of bio-remedial measures in Powai lake, Ooty lake etc. had been unable to revive their proper equilibrium and ecology. Hyacinth growth in lake results endemic disease that can be seen in the Loktak, Sukhna, Ropar and Bhopal Lake. Cultural siltation through idol immersion in India has been serious source of heavy metal in lakes. Furthermore, uncontrolled tourist activities have disturbed the flora and fauna of lakes. For better management of lakes, pollutant sources must be controlled so that deterioration could be taken place. In-Lake treatment includes dredging the lakes, hyacinth removal, cleaning of bio-products, introduction of composite fish culture, me-

chanical sea water flow into lake to maintain salinity, revival of traditional drainage of the lake and harvesting of aquatic weeds for livelihood of local people, Shoreline management is also essential to protect the lake from the animal grazing and encroachments so that soil erosion can be checked. Further, special attention is required to take for awareness of the people related to importance, values and function of lakes. A comprehensive and collaborative action is needed by the Government, private entrepreneurs, NGOs and local people together for conservation and restoration of lakes.

Case study of Ramgarh Lake

Ramgarh Lake (260 42' 30" N to 260 45' N and 830 24' 20" E to 830 25' 20" E) - an example of deteriorating lake due to several urban impacts (fig.1) - a large, perennial, eutrophied lake, exists in the south-east part of Gorakhpur city having luxuriant aquatic plants and animals. Several macrphytes, planktons and aquatic fauna, water hyacinth (Eichhornia) and Vallisnaria, Ceratophyllum, Pottamogeton etc. are surface as well as submerged weeds. Among fishes, Wallagoattu, Murrel, Mystus seenghala etc. are common while a number of insects like, Nepa, Ranatra, Cybister, etc. are present in the lake. Disposal of municipal solid wastes is deteriorating the water quality of lake and enriching eutrophication and siltation, that resulting contraction of the lake basin area.

Utilization status

Fishing is the most important activity in the lake which is carried out by a fishery society. This society has a large number of family members employed in pisciculture normally for 8 months in a year from November to June. They catch mostly carps, wallagoattus, labeorohita and catla fishes mainly in the areas of Jharkhandi Mahadev, Mohaddipur, Mahervakibari, Bhawanika and Ramgarh village. The production of fishes depends on rainfall as well as amount and quality of fish seeds nurtured in the lake (Sharma, 2001). Water of the lake is used in agriculture for irrigation purposes. One water lifting pump is placed near Mahervakibari for lifting in a canal that waters the farms of mahervakibari and other adjacent villages but it is now out of order. Cows, buffaloes, boars, goats, etc. graze in grasses around the lake and about 3000 of them drink water in the lake daily. Ramgarh lake is an attractive place to the tourists not only as a water body but its relation with a historical city. It is said that the Ramgarh (situated at the south-eastern bank of the lake) was the capital of the Koliya kings 2500 years back. Mahamayadevi, mother and Yashodhara, wife of the Lord Buddha were princesses of the Koliya family. Many Buddhist centers like, Lumbini (118km), Kapilvastu (96 km), Sarnath (223 km), Kushinagar (53 km), Sansika (350 km), Kausambi (308 km) and Shravasti (175 km) are linked with the city. A Ramgarh lake project is being developed by the Gorakhpur Development Authority acquiring 486 ha area of the older lake between western dam along the lake and Padaleganj, Indra Nagar, Deoria bypass road. The project includes a Buddhist Complex, Research Center, Library, Deer Park, Five Star Hotel, Tourist Bungalow, Circuit House, Health Center, Water Sports Club, Planetarium, Aquarium, Children's Park, Shopping Center, Japanese Garden, etc. Thus, the beautification of the lake has continued to develop as a source of income through tourism (Sharma, 2001).

A very dramatic change (Table1) from natural utilization pattern to commercial use of Ramgarh Lake is seen due to excessive human interferences. Lake water was used for drinking purpose up to 1980; for washing up to 1998; for traditional boating up to 2004; for vegetable cropping up to 2005 and cattle bathing up to 2011 but with the increasing population pressure lake is being used more and more for fishing, recreational activities and dumping sites. These ac-

Table 1: Change in utilization status

Activities	Current status
Fishing	Incessantly Continue
Irrigation	Incessantly Continue
Vegetable Cropping	Up to 2005
Washing	Up to 1998
Recreational Activities	Incessantly Continue
Religious Activities	Incessantly Continue
Dumping Sites	Incessantly Continue
Cattle Bathing	Up to 2011
Drinking Purpose	Up to 1980
Traditional Boating	Up to 2004

Source: Based on people's responses during Field Survey (February 2017)

tivities are still continuing from the beginning. But due to increasing pressure of these activities the lake is forced to be deteriorated and the surrounding people have been forced to suffer for livelihood.

Depletion scenario

Sewage generated in urban households is finally let into Ramgarh Lake through sewer network. Nutrient enrichment in the lake has become one of the major environmental .concerns in rapidly urbanizing city of Gorakhpur. The sustained inflows of sewage, urban runoff, etc. are the drivers of lake quality deterioration. According to the report of Gorakhpur Environmental Action Group, around 800 quintals of wastes are being dumped into the lake every day from colonies of lake area. It caused foul smell near the lake area (www.rainwaterhar-vesting.org). Sewage water enter into the lake from several drains such as Kuraghat Nala, Tura Nala, Mohaddipur power house Nala, Jharkhandi Nala, Padleyganj Nala, Maharva ki bari Nala etc.

The physical and chemical parameters of water are the typical components of a water resource. They include temperature, dissolved oxygen, pH, hardness, turbidity, concentration of soluble and insoluble organic and inorganic matter, alkalinity, nutrients and an array of toxic substances which may have simple chemical properties or their dynamic, complex and changing nature. In aquatic ecology, the disturbance is most commonly conceived as being due to physio-chemical and biological factors. The alteration in the physio-chemical characteristics of aquatic ecosystem is the result of inputs of pollutants from point and non-point sources. (Kumar, and Ramachandra, 2003).

Physio-chemical properties of Ramgarh lake's water and entering polluted water through sewage at Kuraghat nala were tested in June 2018 (Table 2). The pH value (intensity of acidity and alkalinity) was found 7.33 of open lake area and 7.68 of sewage water near Kuraghat which indicate that open lake water has pH within the standard value. Sewage water increases pH of water which can damage the gills and skin of aquatic organisms. Conductivity is a measure of the ionic activity in water and their content and also is affected by level of TDS. As the level of TDS increases conductivity also increases. The conductivity of open lake area and sewage water near Kuraghat was 652 µs and 460 µs respectively while the TDS were found 803 NTU and 621 NTU of both places which indicate that open lake water and sewage water has conductivity and TDS within the

Table 2: Physio-chemical properties of Ramgarh Lake

Parameters	Open lake water	Sewage water near Kuraghat	Unit	BIS 1991	Analytical method
Temperature	32.80	33.98	º Celsius		Thermometer
pH	7.33	7.68	…..	6.5-7.5	Multi-parameter Tester
Conductivity	652.00	803.00	µs	>1200	Multi-parameter Tester
TDS	460.00	621.00	NTU	>700	Multi-parameter Tester
Salinity	221.00	285.00	g/kg	…..	Multi-parameter Tester
BOD C	21.09	80.48	Mg/L	>5	5 Days incubation, 21º
DO	3.39	0.80	Mg/L	<5	Winkler Method
PO43- (orthophosphate)	17.22	82.36	Mg/L	.....	Spectrophotometer
NO3-	13.29	46.40	Mg/L	45	Spectrophotometer
Chloride	124.25	64.05	Mg/L	250	Argentometric Titration
Chlorophyll	122.62	40.50	Mg/L	…..	Spectrophotometer

Source: Tested by authors in laboratory of Department of Botany, Banaras Hindu University, June 2018

standard value of BIS but, sewage water carries more pollutants due to industrial and domestic effluents than the open lake water. They can breakdown the surviving system of flora and fauna in lake water due to their ionic effect. Salinity is important and affects dissolved oxygen solubility. The salinity was 221 g/kg in open lake area and 285 g/kg in sewage water near Kuraghat which indicate that salinity is high in sewage water than the open lake water. The higher the salinity level, lower the dissolved oxygen that can disturb the life of biota in lake. BOD is the demand of oxygen for decomposing the nutrients inflow (phosphate, nitrate etc.) through bacteria. It reflects the needs of oxygen by living organism (flora, fauna, microbes, etc.) for their survival in water-bodies. In open lake area biological oxygen demand was 21.09 mg/L whereas 80.48 mg/L of sewage water which indicate that open lake water has B.O.D surpass the standard value. Thus, the condition shows huge requirement of oxygen for microbes to decompose the pollutants, but, sewage water has hampered the surviving condition of biota in lake. The important water quality parameter is dissolved oxygen. Its presence is necessary for survival of aquatic life. The amount of Dissolved oxygen in lake water was 3.39 mg/L in and 0.8 mg/L of sewage water which indicate that open lake area water has D.O surpass the standard value. The sewage water has become anoxic and lake water is also reaching this level. In open lake water, orthophosphate (nutrient pollutant) let into lake from residential area and found 17.22

mg/L whereas in sewage water it was 82 mg/L which is very high and support the prolific growth of hyacinth which rupture respiration system of fishes and other fauna. Nitrate was found 13.29 mg/L in open lake area water and 46.2 mg/L in sewage water which indicate that open lake water nitrate is within limit but sewage water has crossed the standard limit. This condition has caused hyper-eutrophic condition in lake and anoxic, toxic, anaerobic condition of sewage water where growth of biota is impossible. The chloride was found 124.25 mg/L of open lake area and 64.05 mg/L of sewage water near Kuraghat which indicate that open lake water has chloride within the standard value. It is toxic for aquatic life and hampered their ecosystem. Chlorophyll was 122.62 mg/L of open lake area water due to excessive algal bloom after the presence of nutrients but 40.05 mg/L found in sewage water due to diminishing of biological (flora and faunal) activities influence hence, water is in anaerobic condition. These above all parameters range support the eutrophication condition of lake.

Encroachment in the lake catchment area is not a common but ecologically hampering activity. Due to over pressure of population encroachment in the lakes for residential and waste disposal purposes is increasing day by day and creating several problems specially in urban areas. Total area under encroachment (Table 3) was 235.94 hectare during 95 years from 1922 to 2018 (Fig.1). This encroachment was very huge because, normally, this much area can form an area of another lake that means a lake size area was depleted for fulfillment of the greed of human being with shameful manner.

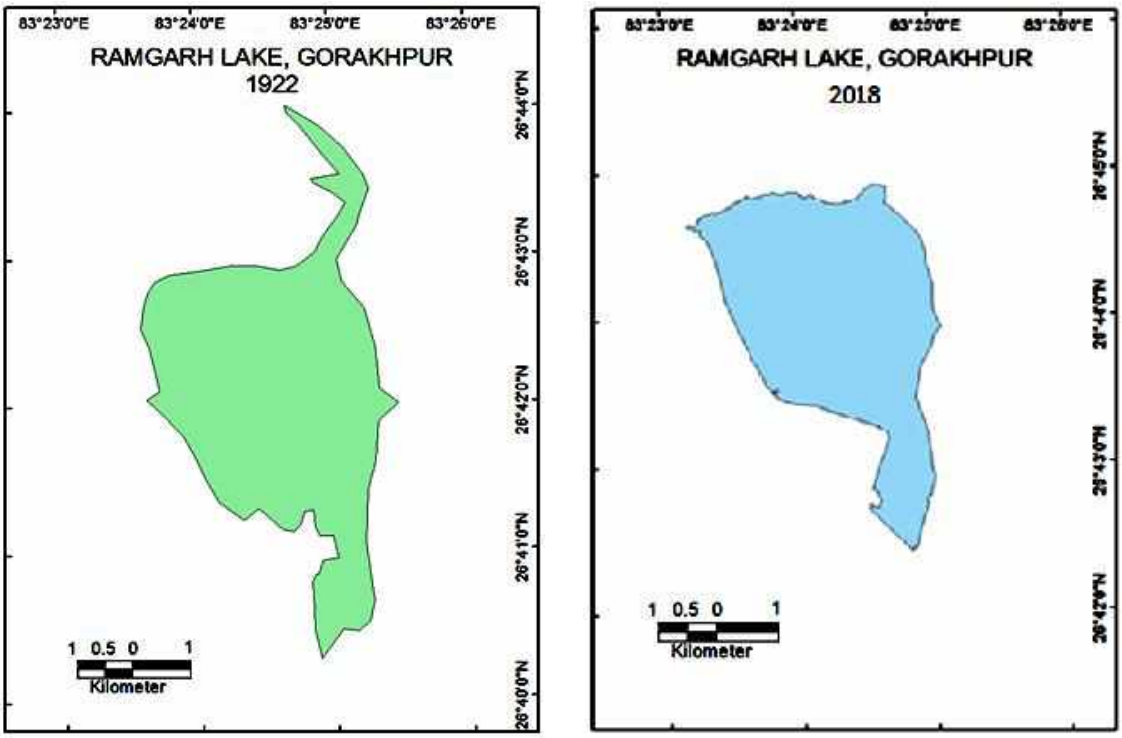

Fig.1: Reduction in area of Ramgarh Lake (1922 to 2018)
Source: Toposheet NG 44-8 (1922) and Google earth images (2018)

Table 3: Changing Area of the Ramgarh Lake (1922-2018)

Year	Area (Hectare)	Change in area (Hectare)	Rate of annual change (Hectare)
1922	964.02	---	----
2003	756.83	207.19	2.58
2005	750.14	6.69	3.35
2008	743.19	6.95	2.32
2010	738.78	4.41	2.21
2012	733.42	5.36	2.68
2017	729.98	3.44	0.69
2018	729.08	0.90	0.90

Source: Calculated by authors from toposheet NG 44-8 (1922) and Google earth images in GIS environment.

In 1922, the lake area was 964.02 hectare that was decreased to 756.83 hectare in 2003. Thus, encroached area is 207.19 hectare with a rate of 2.58 hectare per year due to increasing population. After that, with the passing time in 2005, the lake area encroached with an increasing rate of 3.35 per year than past scenario due to attraction of people for residential purposes to get their basic and luxuriant amenities. Up to 2010, the encroachment rate was declined by

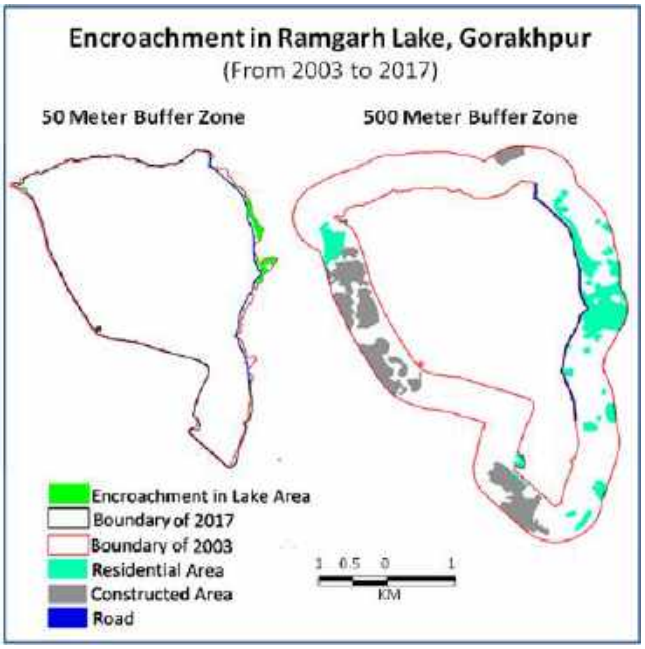

Fig.2: Buffer zones of encroachment

Source: Mapped by authors from Google Earth images in GIS environment

2.32 and 2.21 per year in 2008, 2010 respectively due to policy of government bodies to control dumping of wastes and filling pattern of lake basin areas. Government took action for restoration and conservation of lake by making concrete road in the west side of lake and some kachha and pacca embankment to demarcate and maintain the shoreline area of the lake in 2011. Due to lack of proper boundary, the lake water area fluctuates in rainy and summer seasons and people try to encroach in to the area of lake for their residential and livelihood purposes. Government steps for stewardship of lake depicted through decline rate of encroachment of 0.69 hectare per year in 2017. Again in 2018, encroachment rate was increased to 0.90 hectare per year with 729.08 hectare of lake area. About 234.94 hectare area was encroached from 1922 to 2018 and it is still continuing but, now, concretizing of shoreline of lake may make the lake free from any further encroachment activity of human being.

Aquatic ecosystem is a vital concern for living beings as it provides habitats for a variety of flora and fauna, recharges ground water, augments and maintains stream flow, recycles nutrients, purifies water etc. The components of aquatic ecosystem and their working pattern are highly dependent on the catchment structure, morphology and land use pattern in the catchment of lake area.

In 50 meter buffer (Fig.2), the total coverage area is 71 hectare in which encroached area is 8.04 hectare (including roads, residential and other constructed areas) in the image of Google earth 2017. In 500 meter buffer (Fig.2) the total coverage area is 745 hectare in which encroached area is 21.74 percent (161.98 hectare) including residential area 40.37 percent (65.40 hectare), and other constructed area such as administrative, commercial and other infrastructural development 57.21 percent (92.68 hectare) and roads cover 2.40 percent (3.90 hectare). These encroachments depict the crowed, congestion and pressure of population surrounding the lake area through uncontrolled, unauthorized and unplanned city development.

Table 4: Change in depth and thickness of silt

Year	Depth (meters)	Thickness of Silt Deposition (meters)	Rate of Siltation (Meter/Year)	No. of fish species
1998	4.50			28
2006	3.80	0.70	0.088	18
2018	2.56	1.24	0.103	10

Source: www.rainwaterharvesting.org and People's responses during field survey, 2018

Alteration in topography disturbs geological stability of lake that cause soil erosion and lead to siltation in the lake. In 1998 the depth was recorded as 4.8 meters and in 2006, depth was 3.8 meters (www.rainwaterharvesting.org) that mean 0.7 meter silt is deposited in 8 years at a rate of 0.088 meter per year. After 12 years in 2018 the depth was measured as 2.56 meters which is further decrease of 1.24 meter from 2006 at a rate of 0.103 meter per year (Table-4). Thus, the rate of siltation has continued increasing trend. This will lead the lake to be depleted in next 25 years at the present rate of siltation. The human impacts on biological processes reduce reproductive rates or change competitive ability of organism that can result in reduction in the floral as well as faunal species. In 1998, there were about 28 varieties of fishes in Ramgarh lake which reduced to 18 in 2006 and 6 to 10 species were remained up to June 2018.

Impact of depletion

Various anthropogenic activities have drastically changed the physio-chemical and biological processes within the lake aquatic system. Accumulation of silt and pollutants are two important reasons for the lake's depletion. These are entered from several drains such as Kuraghat Nala, Tura Nala, Mohaddipur power house Nala, Jharkhandi Nala, and Padleyganj Nala etc. Refuses from industrial area, whole N.E. Railway establishment such as loco-shed, loco workshop, hospital of railway and large number of residential quarter are drained into Gurudhia nala and finally entered into the lake. Disposal of non-decomposable materials is most severe problem because it never participates in the recycling process. Increasing recreational activities near the lake and new mushrooming of apartment and administrative buildings have made the lake in critical stage. Loss of various functions of Lake Ecosystem lead to depletion of lake that directly affect humans, for example, the reduction in area and depth by siltation affects the amount of water storage, suck of flood water and groundwater recharge. Thus, anthropogenic activities (agriculture, urban settlements, recreational activities etc.) have increased amount of sediments, nutrients, toxic substances that enter into the lake with runoff. Increased pollution through nutrients in lake water, siltation, habitat loss of many organisms, reduction in area due to encroachment and decrease in water quantity and quality have badly affected the functioning of lake ecosystem.

Control practices

In spite of all some positive changes are recognized very recently which have improved water quality of the lake. Some sewage treatment plants are set up along the bank of lake to treat the polluted water. Upto the month of August, 2017, the sewage water was freely entered into the lake but now, some barriers (bamboos and cemented pits) have been made to stop direct entrance of polluted water into the lake. But, this step is not enough to revive the quality of water and their ecology because sewage water gets mixed into the lake water through internal seepage. So, some suggestive plans are needed to revive the lake ecology. The Uttar Pradesh Jal Nigam had submitted a proposal to the state government for extension of the sewerage system in the city. Besides, the Lake Conservation Department of Government of India is implementing a project for cleaning and beautification of the Ramgarh lake. It is being partially funded by both central and state governments. As part of the project, two sewage treatment plants (30+15 MLD) are going to be installed for treatment of waste water discharged by six drains into Ramgarh Lake. (www.acccrn.net). The former MP of Gorakhpur Mr. Virbahadur Singh announced the Ramgarh Taal Tourist Complex Scheme in 1987. From June 1987 to July 1988, Gorakhpur Development Authority worked on this project that was developed by the state government to incorporate large number of activities like, Water Sports Complex, Buddha Museum, Planetarium, Tourist Bungalow and Champa Vihar Park around the area. But in the course of time, the area began to lose its charm and condition of the lake became bad. For conservation and restoration purpose, the Central Government has sanctioned Rs. 124.32 crore for Ramgarh Tal Project. (news.webindia123.com) but released 8.70 crore only, therefore, encroachment problem is still continue.

Conclusion

Lakes provide many uses of different values to humans in form of water for drinking, agriculture, industry and livestock uses and energy generation; they become storage for floods water; they provide sinks for sediment and contaminants to protect downstream areas; they provide habitat for important flora and fauna. Many people surrounding of lakes are heavily

dependent upon lake biota and natural lake process for their water, food and livelihoods; as population grow, lake resource come under increasing pressure. (International Lake Environment Committee, 2005). In addition to restrictions in the utilization of water bodies as sources of drinking water, or other uses, contamination of fresh water can also have a multitude effects on human beings such as disruption of community and traditional activity, economic and nutritional hardships. It is, therefore, of overriding importance to find and improve means of monitoring and evaluating water quality and pollution levels in order to remedy and prevent harms to human beings and their environment. (Benjamin, et al., 1996). Ramgarh Lake is a boon for Gorakhpur city because it provides many direct and indirect economic, recreational and ecological benefits but now the lake is facing so many limno geographical problems. Ramgarh Lake is of immense ecological and economic value, but eutrophication and sedimentation in the lake, reduction in area, depth and volume of water have led to a significant deterioration of the lake. The positive steps taken to rejuvenate of Lake Scenario but these are very few for the ecological maintenance of these above levels of depletion; therefore, urgent measures are required to identify the pollution loading into the lake, to determine the existing position of deterioration and to understand the responses of the lake to pollution loading. Deterioration can be checked by placing sewage treatment plants, proper disposal of wastes, management of inflow-outflow of water, removing sediments and checking encroachments in the lake. A joint effort including the participation of government agencies, non-government organizations research institutions and the public is needed to overcome the lake deterioration problems.

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Rural Environmental Characteristics: A Case Study of the Selected Central Himalayan Villages

R.C. Joshi[1] and Masoom Reza[2]

Abstract

Biotic and abiotic components co-exist systematically and are mutually interdependent having a bearing on the quality of life of the inhabitants. Less modern infrastructure, dependence on the agriculture and symbiotic relationships with nature are typical rural environment characteristics. Rural characteristics and their spatial variation are influenced by physiography for example in the study area agriculture crop production varies because of physiographic and micro climatic conditions. The variations can be perceived on the basis of their tone of language due to change in their physical landscape. In mountainous area it is common saying that in every 10-20 minutes' walk of distance there is change in the language.

Village Information System (VIS) is a process which incorporates the spatial and non-spatial information of a village in a GIS platform for this work ten villages are selected from the Outer and Lesser Himalayan domain. Using collected information from satellite data, census 2011 and field survey, a detailed analysis is carried out i.e. landuse/cover (LULC), soil characteristics, rainfall, spring water discharge, road and other infrastructural facilities have been collected. Socio-economic survey of each household is also conducted. All collected information is stored in a digital cadastral layer using GIS technique. This work is very important for planning and management of village resources and creation of infrastructure for the sustainable development.

Keywords: *Himalayan village, geology, rainfall, springs water discharge, soil characteristics, cultural and economic environment*

Introduction

Rural environment characteristics of villages in study region are diverse in context of physical and cultural characteristics. Physically the landscape is comprised of ups and downs with an elevation ranging from 851 m to 2615 m. The potential areas for settlements and agriculture occupied by the dwellers are distributed unevenly. The most part of the area has good road connectivity with surrounding towns. People commute daily for their day to day activity to nearest urban centres mainly to Nainital and Haldwani. Commuters are farmers, employee

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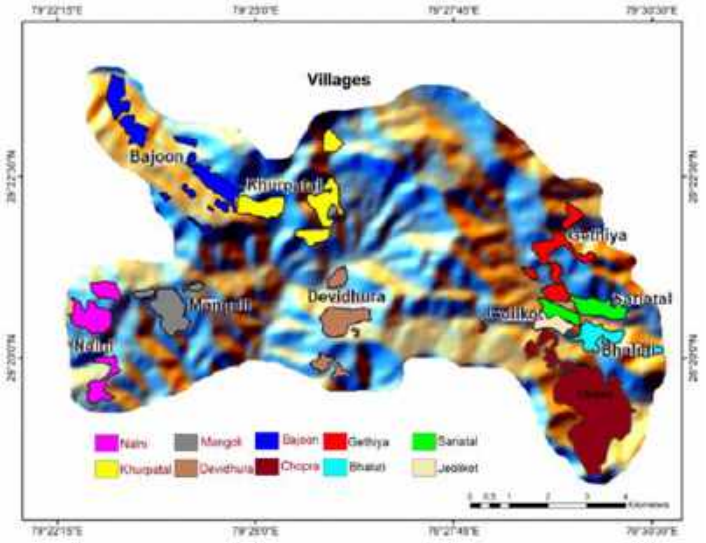

Fig. 1: Location of study area

and students. Villagers have to depend for their daily needs on the surrounding towns.

Some villages are near the urban centres while others are very far. This leads to migration to road sides or nearby towns. Village level digital data base is very important and helpful to the planner and administrator as it can be easily updated Joshi and Reza (2018). So in this study, an attempt is made to identify the major rural environmental characteristics including physical and cultural aspects.

Physical characteristics

The altitude of the area ranges from 851m

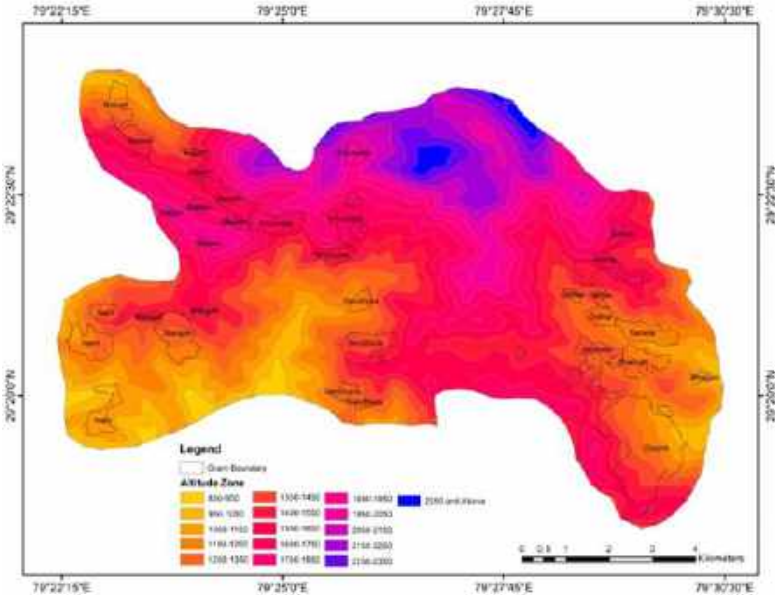

Fig. 2: Altitudinal zone

to 1899m (Elevation within *Gram Panchayat* boundary) Ups and downs are most important physical characteristic that dominantly affects everything comes under it. It may be agriculture, water table, soil fertility, vegetation, temperature, precipitation, humidity, atmospheric pressure etc. In the study area variation of 5-6 degree temperature is recorded in winter as well as in summer from valley to top of the hills. The difference in temperature and rainfall with varying altitude results variation in soil moisture contents having impact on the decomposition process. It also affects the soil chemical properties with changing altitude (Saeed, et. al. 2014).

Geologically study area includes the Middle Siwalik and Lesser Himalayan parts. The Main Boundary Thrust (MBT), a major and active thrust, separates the Siwalik and Lesser Himalayan rocks. MBT, a wider zone, having many associated faults in the region, forms highly vulnerable area for landsliding and soil erosion. In this zone many natural springs are also found. MBT zone carry high volume of water with fluid pressure in groundwater flow and ooze out in the form of natural springs (Gudmundsso, 2000). The water quality of springs is very good as it contains many important metals that are favourable for agriculture growth and production. Major portion of study area falls in the Siwalik region.

Rainfall data has been collected using rainfall data logger installed in a village with an altitude of 1560m (the average height of study area). It collects the data with an interval of 1 minute. The data have been collected for 1 year to understand the precipitation variation and pattern during pre and post monsoon season. It is found that the rainfall received by area dominantly occur in monsoon having small amount in the remaining months. Rain gauge and automatic data logger is Installed on the roof of the residential building in Bajoon Village. Occasional rain is very helpful for agriculture but rain with hailstone damages the crop. The villagers from the area are mostly agriculturists and the agriculture is the sole occupation for their livelihood.

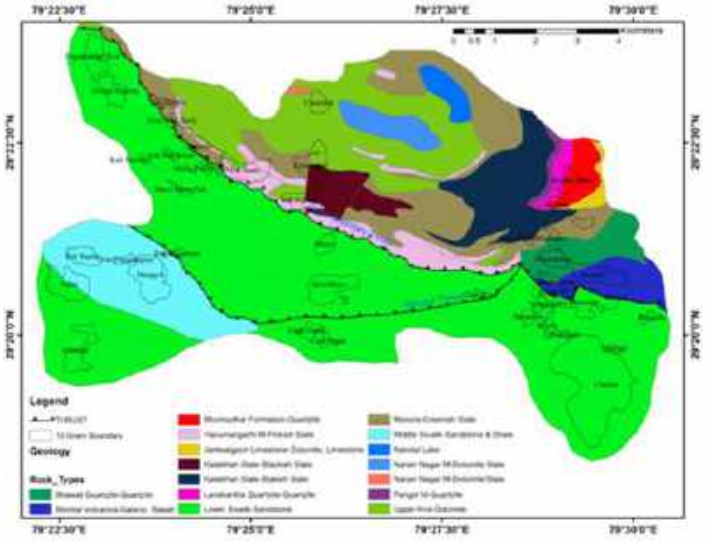

Fig. 3: Geology

As per rainfall data recorded so far the driest months of study area are October, November and December with 0 numbers of rainy days. The number of rainy days recorded is 125

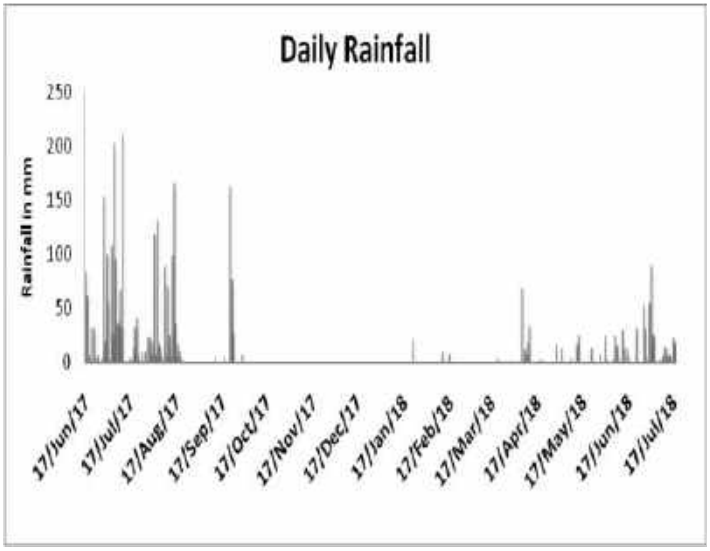

Fig. 4 : Rainfall pattern

mostly in the month of June and July, but occasional rainfall is recorded in August and September. The maximum rainfall recorded in Monsoon is 210mm in the month of July. The maximum intensity of rainfall recorded after monsoon is 161.6mm. As compare to 2017, the rainfall data shows there is a deficit of 153mm of rainfall in the month of June of current year and in the month of July 372.8mm of rain deficit recorded till 18th July 2018. The total deficitis of 38.9 % and 56.9 % of rainfall recorded in the month of June and July, respectively.

Spring water discharge

More than 28 perennial natural water springs scattered in study area fulfil the water needs of villagers. One water spring discharge is monitored from each village. Annual water

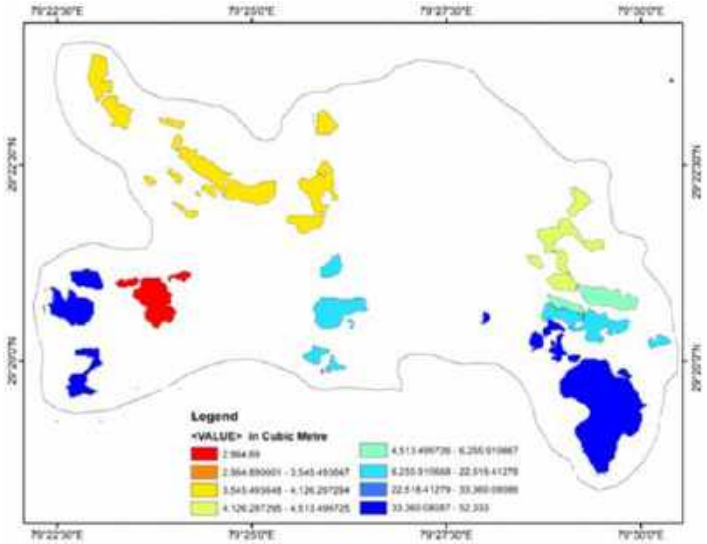

Fig. 5: Annual water discharge of perennial springs

Table 1: Chemical characteristics of soil

Sl. No.	Village	Average of five soil samples					
		pH	O.C %	Available N Kg/h	P2O5 %	K2O %	EC dS/m
1	Mangoli	6.76	1.300	350.000	0.00490	0.00930	0.07980
2	Devidhura	7.36	1.832	266.180	0.00530	.02140	0.1010
3	Sariatal	8.00	2.396	316.610	0.00612	0.01706	0.08460
4	Khurpatal	8.10	2.996	282.736	0.00554	0.01186	0.12600
5	Nalni	6.40	1.152	321.388	0.00340	0.01498	0.07880
6	Bajoon	7.16	2.486	352.478	0.01896	0.02130	0.07640
7	Chopra	6.96	1.256	317.868	0.007260	0.01188	0.0674
8	Bhaluti	7.64	1.452	359.26	0.00978	0.01824	0.08272
9	Jeolikot	7.38	2.498	312.346	0.00646	0.03024	0.12940
10	Getiya	7.40	3.144	271.452	0.00538	0.01900	0.15680

discharge is shown in the map. Water scarcity is felt by people as all spring water is not taped properly.

Chemical characteristics of soil

In hilly region, the soil erodibility is common phenomenon due to heavy showers and steep slope. Slope is one of the factors that accelerate the soil erosion that we cannot stop (Haiyan, et. al. 2014). The physical properties of soil of study area are varying from highly sandy to clayey soil (Joshi, and Pant, 2014). Five soil samples are collected from each village and chemical analysis is carried out at Uttarakhand Tea Board Lab. Bhawali. The sand percentage is upto 70-80 and clay percentage is 20 (Kharkwal, and Rawat, 2010). The chemical analysis of soil includes Nitrogen, Organic Carbon, Phosphorus, pH and Potassium content. Availability of Nitrogen in study area is ranging from 130 to 265 kg/hectare. The maximum amount of concentration of nitrogen found in the Lesser Himalayan villages *i.e*. Bajoon, Khurpatal, and Gethia. Organic carbon is one of the important soil chemical properties which helps in good agricultural growth. Analysis shows it ranges from 0.63 to 4.37. In the Siwalik villages *i.e.* Nalni, Mangoli, Chopra and Bhalyuti it is ranging from 0.63 to 1.89. Remaining villages which have maximum area in the Lesser Himalaya O C value ranges from 1.89 to 4.36. Soil pH of the area is ranging from 5.6 to 7.9 and forming alkaline to moderately acidic. It is found that Bajoon, Bhalyuti and Chopra Gram Panchayat have both Alkaline to acidic pH values. The concentration of Phosphorus and Potassium in soil is almost equal in whole area but, it is slightly higher in the some parts of higher elevation area in comparison to low altitude area. The value of phosphorus ranges from 0.002 to 0.01 whereas potassium values are in between 0.004 to 0.05. The spatial variation of E C is almost same except Bhalyuti viallge.

More than 28 perennial natural water springs scattered in study area fulfil the water needs of villagers. A small concrete tank is built at the mouth of the springs to store adequate amount of water for supply. In some villages the water from storage tank is also being supplied through pipeline to households for drinking purpose. The villagers also utilize spring water for the cultivation of vegetables where there is

sufficient amount available. The spring water is channelized through concrete canal all over the fields.

Cultural characteristics

Total population of study area of all *gram Panchayats* is 8315 persons. The average density is 734 persons/ sq km. The geographical area is 11.32 sq km. The geographical area of *gram Panchayat* includes all revenue comprising registered land parcels whether it is for commercial or personal. The reserve forest area is excluded from the *Gram Panchayat* boundary. In most of the villages, houses are built beside each others. However, in some hamlets (*Tok*) villages houses with a distance with each other can be seen.

The population distribution of hills is very less diverse in context of race and religion but

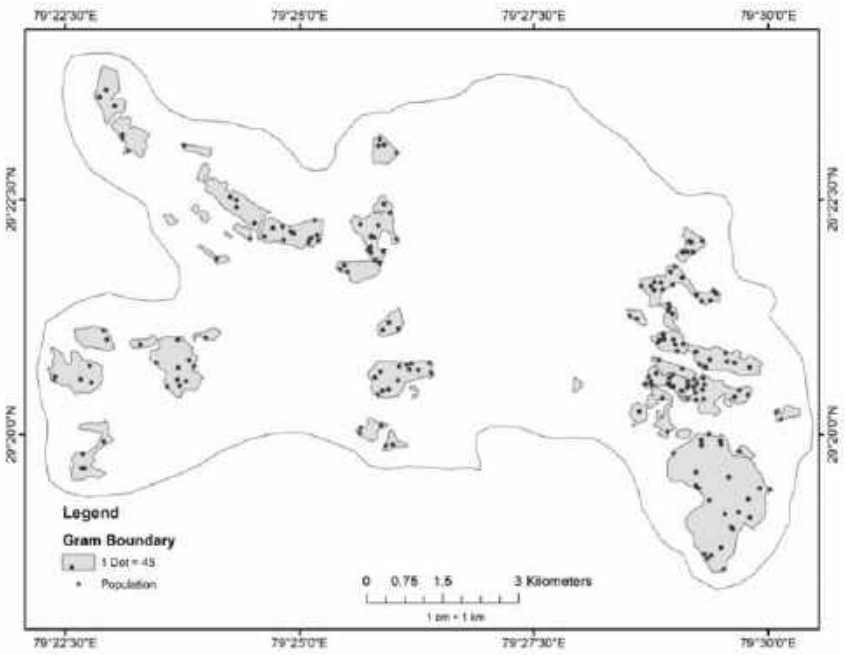

Fig. 6 : Population distribution

diversity is there in caste (Brahmins, Kshatriyas, Vaishyas and Shudras). They all live together with peace and harmony. A small part of population of all villages is mobile because they are engaged in business and other activity for which they have to commute daily, weekly and monthly to nearest urban centres.

Because of heavy tourist flow to hill station Nainital, the road connectivity is good. These roads are passing through villages of study area. Some people have settled along these highways but in a few villages or hamlets (*Tok*) there is no road facility available. People walk for long distance upto 1-2 hours to reach nearest town for marketing.

If we consider other infrastructural facilities each and every village (except hamlets) has schools, dispensary, dairy etc. Total numbers of houses in all *gram Panchayat* are 1731. Out of which maximum 347 and minimum 79 houses are in Gethia and Nalni *Gram Panchayat,* respectively. House construction material includes stone, bricks, tin, mud, cement concrete etc.

All *gram panchayats* have connections with government water supply schemes. Even then, villagers are using natural spring's water

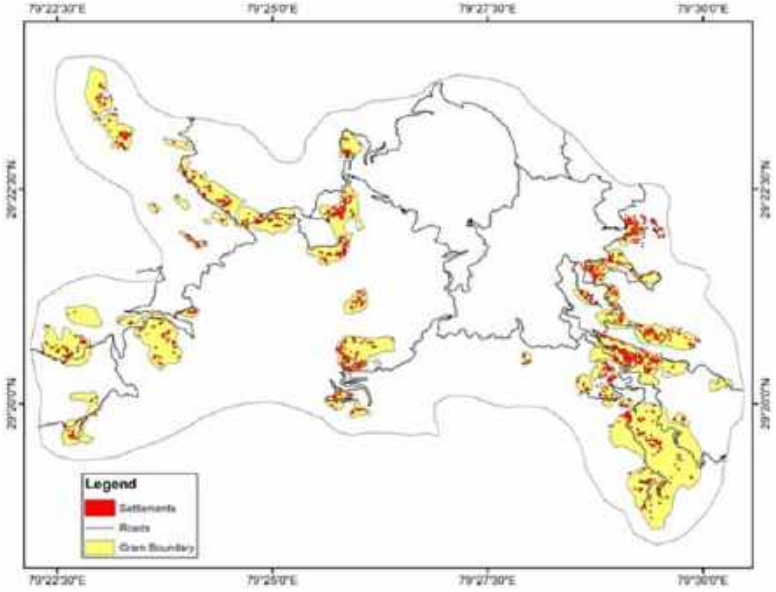

Fig. 7 : Distribution of settlements and connectivity of Roads

for drinking and cooking purpose. In Uttarakhand Himalaya the street language is Hindi and it occupies major area of vocal communication. Besides many languages such as Kumauni, Garhwali and other tribal dialects are also spoken by people. In the study area, older generation still use mainly Kumauni language whereas, young generation prefers to speak in Hindi. Mostly people are having faith in Hinduism and worship all hindu Gods and Goddesses but they also believe in many deities and super natural power. The local festivals are Harela (Celebrated before rice and Maize cultivation), Ghughutiya, Ghee Sankranti, Khatarua (begin-

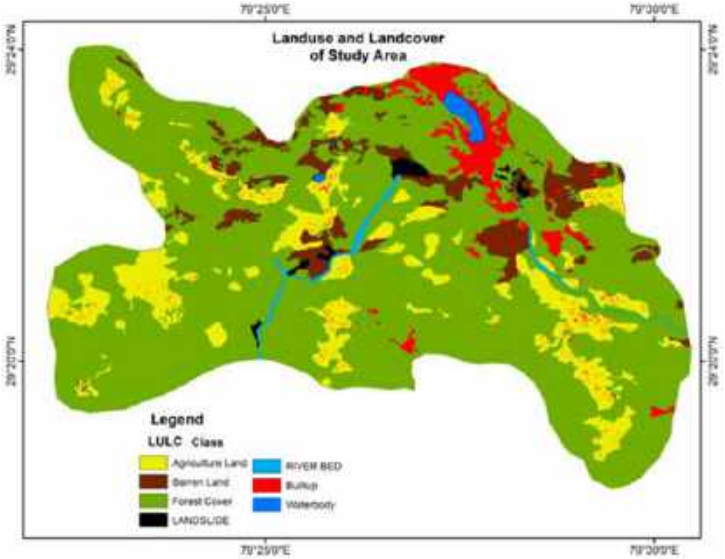

Fig. 8: LULC of study area

Table 2: Villagewise LULC class

Aria by LULC Class (ha)						
Gram	Agricultural (ha)	Barren (ha)	Built-up (ha)	Forest (ha)	River bed (ha)	Water body (ha)
Bajoon	74.5	5.6	2	53.4	-	-
Bhalyuti	35.2	0.93	0.62	15.4	-	-
Chopra	141.8	-	3.5	164.2	-	-
Devidhura	70.5	-	2.9	16.3	0.05	-
Jeolikote	12.5	-	3.5	58.6	-	-
Sariatal	43.3	-	1	14.8	0.02	-
Mangoli	68.4	-	0.46	10.2	-	-
Nalni	66.4	-	1.2	43.9	-	-
Khurpatal	111.7	1.8	2.4	15.9	-	0.2
Gethia	12.5	5.8	3.5	59.6	0.7	-

ning of winter), Phool Dei Chamma Dei (beginning of springs) etc. Common Hindu festivals are also celebrates such as Holi, Dusshera, Dipawali, *Vasant Panchmi*, *Makar Sankranti* etc. In addition, a small numbers of Christians and Muslims are also residing in the area permanently and Christmas and Eid are also celebrated in the Locality.

Agriculture is main occupation of the people. People cultivate variety crops according to season and climate. Some crop especially Pea is cultivated twice in a year. Settlements are surrounded by moderate to dense forest.

Poverty is high in this region as a good number of dwellers fall in the category of Below Poverty Line (BPL). Agriculture is the main source of income of the family in this region. Peasents grow, carrot, reddish, pea, eggplant, wheat, rice, okra, green bean, cucumber, chilly, ginger etc.

Mostly people of this region earn their livelihood through agriculture, private jobs etc. Out of 1264 families 64 % (810) family have their annual income below Rs. 50,000. Among all *gram panchayats*, 89.6 % of families of Bajoon are having annual income of below Rs. 50,000 and minimum 32 % in Sariatal and Bhalyuti, respectively. Only 6.5 % families belong to taxpayers group which have income above Rs. 4.5 lakhs. Mostly, it includes government employees and a small number of business class.

Table 3: Household (family head) income

Income (Rupees)	Name of Villages									
	Bajoon	Bhalyuti	Chopra	Devidhura	Jeolikote	Gethia	Khurpatal	Mangoli	Nalni	Sariatal
<50,000	112	32	164	50	37	175	128	45	49	18
50,000-1,00,000	0	20	8	0	12	33	43	10	7	2
1,00,000-2,00,000	10	14	32	12	15	2	25	2	3	27
2,00,000-3,00,000	3	6	12	8	3	34	7	1	4	4
3,00,000-4,50,00	0	4	4	0	1	3	0	0	0	1
>4,50,000	0	22	1	0	17	2	26	3	7	4
Total	125	98	221	70	85	249	229	61	70	56

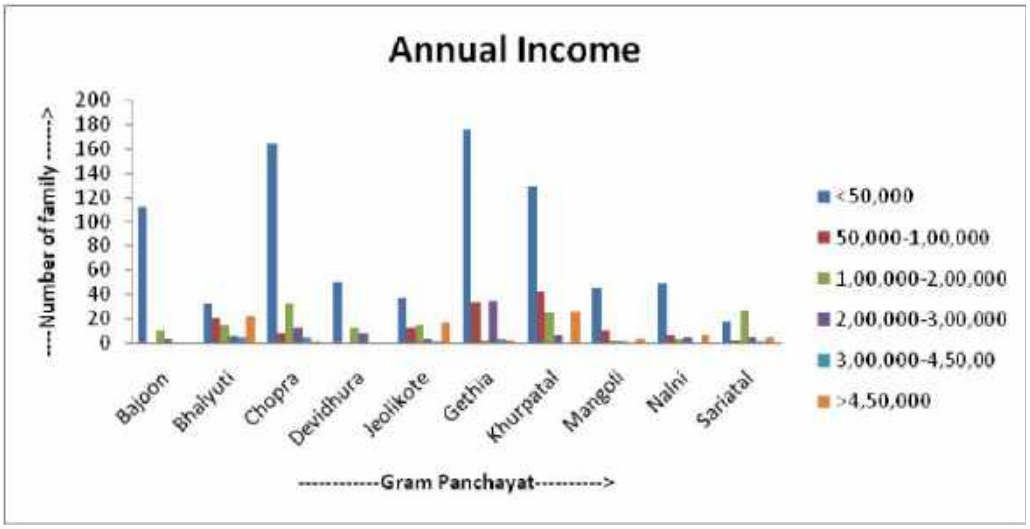

Fig. 9 : Income of household

Agriculture finds a major place in econonmic occupations followed by private jobs, government, daily wages worker (labour) and so on. The 38 %, 25 %,15 %, and 6 % belong to agricultural group, from private jobs in local and nearest urban centres, job holders are from government sectors, and daily wages worker, respectively. Out of ten *Gram Panchayat* the maximum number of agriculturists are from Bajoon (81.25 %) and 0 % from Jeolikote. Maximum number of government job holder is from Bhalyuti having 25.48 % and minimum from Bajoon *i.e.* 4.68 %. (Table 3 and Fig 10)

Table 4 : Occupation structure

Occupation	Name of Villages								
	Bajoon	Bhalyuti	Chopra	Devidhura	Jeolikote	Gethia	Khur-patal	Mangoli	Nalni
Agriculture	104	22	92	30	0	86	84	46	48
Government	6	27	21	14	17	47	42	6	7
Semi-Government	0	1	2	0	2	3	0	0	0
Government-Retired	2	16	19	3	21	30	20	0	3
Govt-Scheme-Pensioner	1	0	0	0	0	4	1	0	0
Private	8	33	55	15	41	107	52	8	7
Labour	7	2	22	7	2	13	23	0	2
Buisness	0	0	0	0	0	1	0	0	0
Unemployed	0	5	18	0	7	30	15	0	1

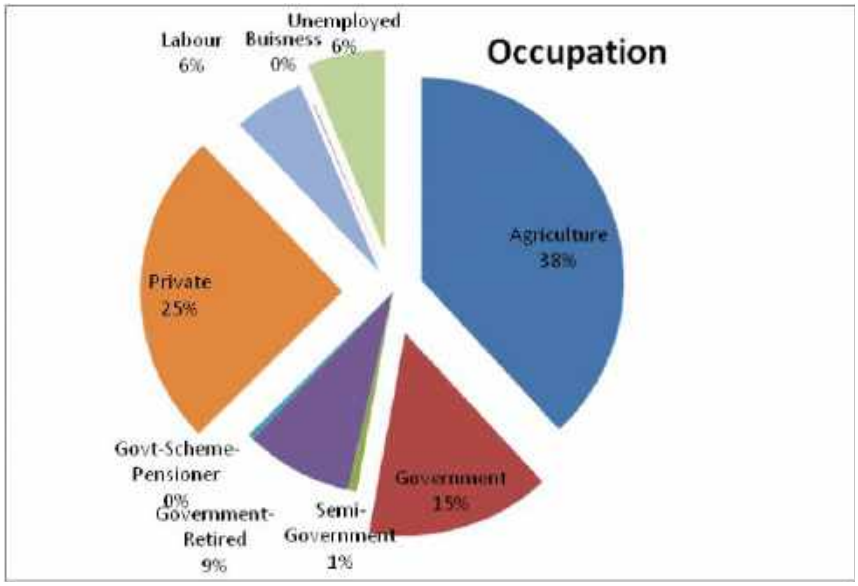

Fig. 10 : Composition of occupational structure

Common environmental issues

1. Forest fire is one of the major problems in the Kumaun hills, which leads to many problems such as soil loss, water shortage, landslide, loss of floral species etc. Generally forest fire takes place in pine forest during summer. As a result, under growth is very poor and responsible for rapid overflow of water leading soil erosion.

2. Soil erosion is a common phenomenon due to sandy loam and loamy sand texture of soil, litho, tectonic instability, torrential monsoon rainfall and faulty landuse. During heavy and frequent rainfall in the areas the loss of soil layer and nutrients is common problems faced by farmers. Uppermost soil is fertile layer that supports agriculture growth and production. Irregular topography boosted the soil erosion when heavy rain occurs and erode away the topmost fertile layer together.

3. Frequent land sliding can be seen in Mangoli, Jogura, Devidhura and Chopra villages. Study area crossed main boundary thrust zone demarcating Lesser Himalaya in the north and Outer (Siwalik) Himalaya in the south. Due to presence of thrust zone rocks are highly crushed and susceptible to gravity fall. During monsoon season heavy rainfall reduces the slope bearing capacity leading landslide.

4. Water scarcity in the villages is a matter of great concern is most of the streams are non-perennial. Due to forest fires and deforestation many perennial streams are losing its potential of water supply and some are dried up. In all villages, there are some perennial springs from which drinking water needs are fulfilled. In addition, there are seasonal and perennial streams nearby villages from which water may be collected in the tank and may be supplied to household.

5. There are bright prospects for diary and vegetables production in the region. Earlier whole supply of milk and vegetables use to be supplied by the farmers of the surrounding villages. Now, due to shortage of water people are not doing production at large scale. However, some villages for e.g., Bajoon, Mangoli, Khurpatal are significant in supply of vegetable and dairy products in the nearby towns. Farmers of the Jeolikot and Gethiya have almost abandoned the agriculture as input cost is more than output cost.

Study can be summarised as follows : All studied ten *Gram Panchayats* consist more than 45 villages including hamlets (*tok*) situated in Lesser Himalaya and Siwalik region of Nainital district. The terrain altitude ranges from 851 to 1899 metre which is having its bearing on temperature on the region. Along the rising altitude Sal, Mango, Pine, Quercus leucotriphora, Cedrus deodara are found. pH of the soil is acidic to alkaline, Mangoli has acidic soil and Alkaline in Chopra, Jeolikote, Gethia, Bhalyuti, Sariatal and remaining villages are having slightly acidic to neutral soil. The area is having rainfed agricultural production and is having very low productivity. The production of vegetables is transported to nearest urban centre. The transportation and communication is good to nearest urban centre such as Nainital, Kaladhungi, Haldwani, Ramnagar etc. Within villages, transport means is still donkeys and horses to transport goods upto nearest roads head. Transportation charges reduce the net benefit out of the earning from agricultural products. This is the one of the major reasons for migrating people to nearest urban centre abandoning their agricultural practices. This is one of the main reasons for intra-state and inter-state migration in Uttarakhand.

Conclusion

Rural environment characterisation is based on physical and economic data generated using topographical map, cadastral map, satellite data and household primary data. The data/information was stored in a digital database which is more safe and secure and known as Village Information System (VIS). It helps to visualize the current scenario of the landscape as well as socio economic condition of people GIS platform provide services to store both spatial and non-spatial information in one domain, it also makes easy to access and modify the information when necessary. Whole work is focused on the physical and socio-cultural environmental aspects. Overall study is very significant for village level planning and management of available resources and creation of infrastructure for the optimal land use and development of the area.

Acknowledgement

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Ecology and Economy of Home Gardens in a Village Environment of the Brahmaputra Valley, Assam

Nityananda Deka[1] and A.K.Bhagabati[2]

Abstract

The home gardens in the human habitats of the Brahmaputra floodplain constitute some unique production units maintained traditionally by the rural communities. With the shrinkage of the natural forest areas and consequent biodiversity loss, the importance of these gardens as repositories of local bioresources has substantially increased. This paper makes an attempt to study the status of and changes in the character of the home gardens and their ecological and economic roles in the context of a village located in the Brahmaputra floodplain, Assam. The study is based on primary data collected from the households, field visits and interviews with the family heads and mapping of the layout of the gardens and plant species available in them.

Keywords: *home garden, agroforestry, biodiversity, livelihoods, floodplain village*

Introduction

The home gardens, associated with the human habitats of the Brahmaputra valley, Assam are the most productive and eco-friendly agroforestry systems traditionally managed by the rural communities. They fulfill the domestic demand for agroforestry products all throughout the year and at the same time facilitate insitu conservation of local plants and animals. Locally called *bari-basti*, these gardens form an integral part of the subsistence farming system of the Assamese society. Developed very carefully within the local ecological settings, these gardens manifest the settlement history, socio-economic condition, traditional knowledge and belief systems, eco-friendly attitude and wisdom of the local communities.

The tradition of growing wild and cultured trees in such micro-agroecological set-up has resulted in a kind of highly diverse ethno-agroforestry landscapes with immense contribution to the valley's ecology and rural economy (Deka et al., 2011). The home gardens, which are usually developed in small plots in the backyard of residential houses, constitute some unique 'productive units' from where the villagers derive floral resources for day-to-day con-

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sumption (Bhagabati and Das, 1992; Amenu, 2017). With rich species diversity and variability in production cycle, the home gardens ensure year-round production and can reduce production risk caused by adverse climatic conditions and external market competition (Gliessman, 1990; Kumar and Nair, 2006; Galhena, 2012). This practice encourages mobilization of local resources and lessens the dependence on the costly external inputs. Resembling some small natural forests and mimicking their ecology, the home gardens constitute a highly complex system that represents a unique set of characteristics of sustainability of both natural and human systems in an area (Ramakrishnan, et al.,1994; Nair, 2006).

Presently, home garden agroforestry systems have received worldwide attention from environmentalists, ecologists, economists and geographers because of their immense potentiality for serving as multipurpose production systems enriching ecological diversity and supporting the traditional rural livelihoods (Gliessman, 1990; Christanty, 1990; Kumar and Nair, 2006; Tesfaye, 2005; Amenu, 2017). However, the

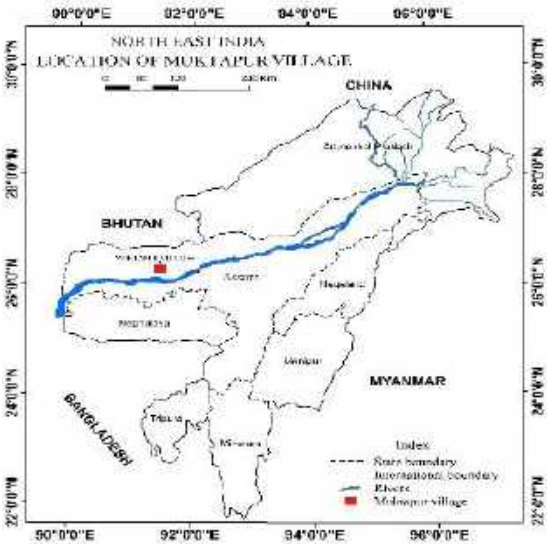

Fig. 1: Location of Muktapur village in N.E.India

home gardens distributed in the human habitats of the Brahmaputra valley, Assam have not been studied properly as yet. Interestingly, almost all the rural households belonging to the indigenous Assamese people have their own home gardens. From the beginning of the village culture in the valley, people are engaged in developing home gardens as a dependable production unit. The biological diversity of the village environment, which is retained more or less in the home gardens, is intrinsically linked with the livelihoods of the people and their production systems. However, with the introduction of modern agricultural practice and consequent socio-economic transformation, the biological and economic importance of the home gardens in the valley is significantly reduced.

Objectives

The main objectives of the study are as follows:

(i) to focus on the status and change of the home gardens in terms of their structure and composition in the study area, and

(ii) to explore the functions and utility of the home gardens in the local context.

Study area and methodology

The Brahmaputra valley in Assam by virtue of its varied topographic, edaphic and climatic conditions is richly endowed with diverse floral and faunal resources. With a total geographical area of 56,194 sq. km, accounting for 72 % of the State's total area, the valley forms a meso-agroecological zone. It is a constricted alluvial plain with a length of about of 700 km and an average width of 80 km. The mighty river Brahmaputra along with its 32 major north and south bank tributaries drain the valley and naturally keep it fertile.

The present study is dedicated to real salient features of the home gardens of a village called Muktapur, located in the north bank flood-

plain of the river Brahmaputra. Administratively, the village falls under Kamalpur Revenue Circle of Rangia sub-division, Kamrup district of Assam.

Muktapur is a typical Assamese village with a total population of 2080 distributed in as many as 408 households. Comprising of 11 hamlets *(chuba)* the village covers an area of 3.67 sq.km. The agroecosystem of the village is characterized by small-scale agriculture integrated traditionally with fish and livestock rearing. Almost all the households of the village have their home gardens of different sizes.

The present study is mainly based on primary sources of data and information collected through household survey, field visit and ground truthing, and interviews with the family heads. An inventory of plant species is done including a classification according to their nature and use. Based on the plant categories and the height of the plants some useful data is generated about full-grown home gardens, and canopy patterns.

Table 1: Number of home gardens according to size classes

	Size class (ha) of garden								
Parameter	< 0.04	0.04-0.08	0.08-0.13	0.13-0.16	0.16-0.20	0.20-0.24	0.24-0.28	> .28	Total
No. of home garden	117 (30.54)	111 (28.98)	57 (14.88)	52 (13.58)	14 (3.65)	5 (1.30)	14 (3.65)	13 (3.39)	383 (15.76)
garden	3.1 (8.62)	7.32 (20.35)	6.13 (17.04)	7.29 (20.26)	2.65 (7.36)	1.14 (3.17)	3.91 (10.87)	4.43 (12.31)	35.97 (11.62)

Source: Field survey, 2010-11; Note: Figures within parenthesis indicate the percentage of respective total.

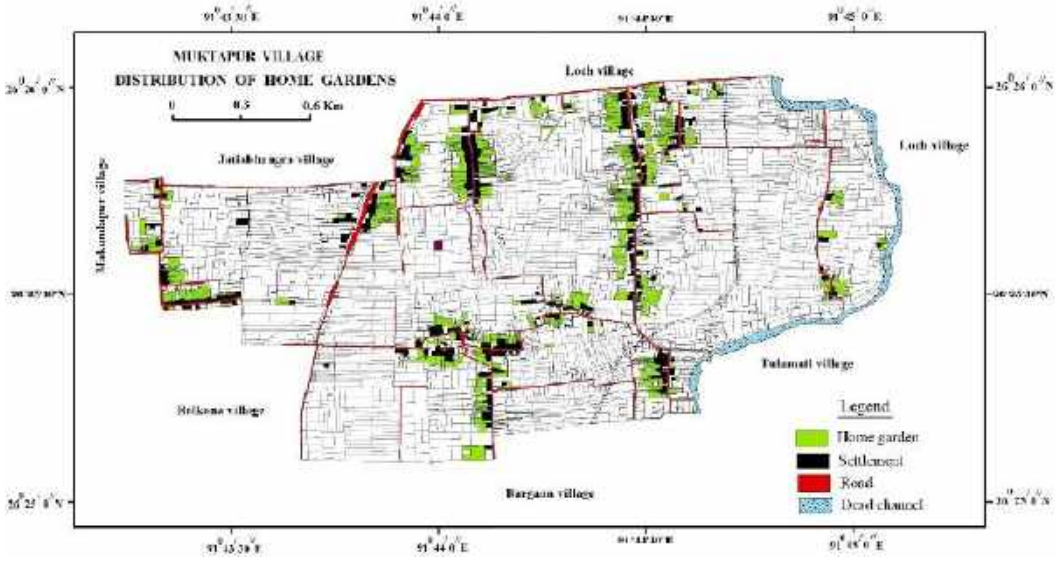

Fig. 2: Home gardens in the hamlets of Muktapur village

Relevant information concerning the size, production, species composition, utility, management practices of home gardens were collected through a structured survey schedule. The spatial distribution of home gardens is revealed on a village map through plot survey for each of the households (Fig 2). Moreover, in order to have an idea of the layout of the home gardens as well as the pattern of distribution of trees, detailed mapping is done for some home gardens selected for the purpose (Fig 5).

Present status of home gardens

Muktapur village is endowed with a large number of well-structured home gardens (Fig. 2). They cover a total area of 37.10 ha accounting for 12.03% of the total operational area of the village. Out of the 408 households of the village, 383 households (93.87 %) have ther home gardens. However, in most cases, the size of the home gardens is very small. Maximum number of home gardens (59.52 %) falls within the size classes of less than 0.08 hectare and 3.39 % are of size above 0.28 ha (Table 1).

The home gardens in the village a wide variety of planted and wild trees. The planted ones mainly comprise of the fruit-bearing and medicinal plants, while the naturally grown include the wood and fuel wood trees, herbs, shrubs and creepers. There were altogether 34,575 fruit-bearing trees and 2,414 wood trees in the home gardens of all the hamlets of the village (Table 2).

The wood and fuel wood trees in the home gardens account for 55.63 % of the total trees found in the village. The home gardens are endowed with a large number of nut-bearing and fruit-bearing trees such as coconut, betel nut, banana, mango, blackberry, jackfruit, olive, *kardoi*, *litchi*, poniol, *leteku*, etc.

Interestingly, out of the total fruit and nut-bearing trees available in the village, 90.74 % are found in the home gardens. The rest of the trees are scattered in the fallow and waste lands, road sides and common lands of the village.

Structure and composition

The home gardens are generally developed

Table 2: Distribution of fruit and wood trees in the home gardens

Hamlet (chuba)	Number of trees	
	Fruit tree	Wood tree
Auniati Chuba	2648	76
Daibagya Chuba	1435	153
Kalita Chuba	1707	129
Veko Chuba	1093	94
Brahman Chuba	2420	251
Kararіapara Chuba	2361	134
Alikash Chuba	2270	94
Satra Chuba	7531	886
Gayatola Chuba	8365	242
Bharali Chuba	3069	248
Maranoipar Chuba	1676	107
Total	34,575	2,414

Source: Based on field survey, 2010-11.

in slightly raised lands that usually spread from a distance of 10 - 50 metres from the backyard of the residential houses. As the homesteads *(gharbheti)* are generally built in a linear pattern along the village lanes and the home gardens are spread invariably from the backyard of the residential houses, that also form a linear green belt . Most home gardens in the Brahmaputra valley contain diverse plants of both seasonal and perennial types with different heights resembling a small natural forest. It is noteworthy that the vertically stratified gardens are potentially more productive because of their capability of utilizing sunlight, water and soil nutrients (Abdoellah,et al. 2001; Torquebiau and Penot, 2006). They also have the ability to protect the houses from high speed wind damage.

The structure of home gardens in the valley, however, varies spatially with the variation in ecological conditions and the socio-economic background of the ethnic groups. The composition of flora in the home gardens is basically the result of a combination of factors like farmer's decision, utility of the species, size of the garden, crown cover and ecological succession.

It is important to note that as the process of human habitation in the village under study has a record of about 500 years (Deka, 2012), many of the home gardens have eventually developed four to five levels of canopy cover.

The first layer is the ground story consisting of some grass species, herbs, small shrubs and herbaceous food crops not exceeding 0.31 metre in height. The second layer is composed of shrubs of 0.61- 0.91 metre height, while the third layer consists of trees of 3-4 metre in height (such as banana, papaya, *bogari*, *laobandha*, some citrus fruits, etc.). The fourth layer covers trees that rise upto 20 metres (such as coconut, betel nut, palms, jackfruit, thekera, etc.) and the uppermost layer comprises tall trees like moj, jori, bhoj, ahot, mango, jamun, etc., attaining a height of more than 20 metres.

Interestingly, the home gardens also have some horizontal zones with specific pattern of association of trees. Although a haphazard look in the horizontal distribution of trees is apparent, the plants can be distinguished spatially at species level (Fig.3). The fruit trees are usually grown in the front part of the home gardens close to residential houses primarily for the ease of protection and harvest. The betel nut trees along with the betel leaves are found to be distributed from the front part to the middle, while bamboos and canes occur towards the back end of the home gardens. The wood trees, however, are usually grown in the bordering areas of the gardens. Most of the herbs and shrubs grow naturally across the garden. Betel nut, betel leaf, banana, bamboo and mango are some of the most common plants found in almost all the home gardens of the valley as these have some special economic and cultural values among the residents of the valley.

Functions and utility

In many tropical and sub-tropical countries, home gardens continue to be an age-old land use practice which makes best possible use of nature's goods and services and contributes towards sustenance of the poor peasants (Wezel and Bender, 2003; Kumar and Nair, 2006; Shrestha, et al., 2004; Igwe et al., 2014; Amenu, 2017). Home gardening is a unique agroforestry system that performs some interesting economic, socio-cultural and ecological functions (Table 3).

The rich association of plant species in the home gardens of the Brahmaputra valley provides congenial habitats and refuge for many of the threatened minor animals, birds and insects and thus constitutes fertile grounds for micro level ethnobotanical studies. As human-nurtured micro habitats, home gardens extend key ecosystem services and also frovide connectivity to other agricultural and natural landscapes and

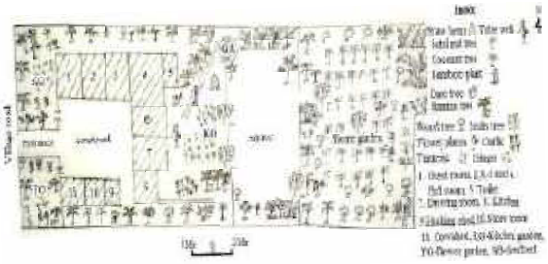

Fig 3: Layout of a typical village homestead including home garden

thus immensely contribute towards promoting in-situ conservation of plant genetic resources (Abdoellah, 1990; Conway, 1987; Kumar and Nair, 2006; Torquebiau and Penot, 2006; Leiva, et al., 2001; Pushpakumara, et al., 2010).

The home gardens within the human habitats of the Brahmaputra valley collectively support development of some green landscapes and also protect the residential houses from scorching heat and storm during summer. It is noteworthy that the natural forests of the valley are getting severely degraded through deforestation and illegal encroachment during the recent years. Many farmers residing close to the forests take the opportunity of raising some useful wild plants in their home gardens. Many medicinal plants, either cultivated or natural, found in the home gardens, are also used by the rural people who are too poor to afford costly medicine.

Moreover, the peasant economy of the Brahmaputra valley has been increasingly affected by severe crop damages caused by recurring floods, occasional drought, insect and animal attacks and also by the unprotected market price. In this situation, the home-gardens, by virtue of their year-long production cycle, act as backup against crop failure and thus contribute significantly towards sustaining rural livelihoods. In addition, the home gardens perform a unique educative role, particularly for the younger generation, by exposing directly to them a store house of local biodiversity, a mini sanctuary in other words, who would otherwise remain unaware of their rich bio-resources, their traditional use and future prospects for development.

Table 3: Selected home garden trees and their utility in Muktapur village

Local name	Botanical name	Number of trees in the village	Number of households possessing trees	Utility
Aam	*Mangifera indica*	927	278	Fruit, wood, religious
Kalajam	*Syzygium curmini*	193	117	Fruit, wood
Kothal	*Artocarpus sp.*	602	205	Fruit, wood
Bel	*Aegle marmelos*	9	7	Fruit, religious
Bogori	*Ziziphus mauritiana*	72	67	Fruit, firewood
Teteli	*Tamarindus indica*	69	61	Fruit, firewood
Leteku	*Baccaurea raniflora*	60	51	Fruit
Narikal	*Cocos nucifera*	828	219	Cash crop, religious and cultural
Tamol	*Areca catechu*	4,472	376	Cash crop, cultural
Pan	*Piper betle*	1,221	365	Cash crop, religious and cultural
Dalim	*Punica granatum L.*	35	47	Fruit, medicinal
Kal	—	19,217	383	Fruit, religious

Bakul	*Minusops elengi L.*	30	30	Religious, beautification
Kuji thekera	*Garcinia kydia Roxb*	37	33	Medicinal, wood
Jalphai	*Olea europia Linn*	22	19	Fruit, medicinal
Shilikha	*Terminalia cattapa L.*	24	20	Medicinal, religious
Kordoi	*Averrhoa carambola L.*	19	19	Fruit, medicinal
Madhuri aam	*Psidium guajava L*	237	219	Fruit, medicinal
Amlakhi	*Embilica officinalis*	67	65	Fruit, medicinal
Amara	*S. piñata (koem) kurz*	23	20	Fruit, medicinal, fire-wood
Ou	*Dillenia indica*	27	24	Medicinal, fruit
Ahat	*Ficus religiosa.*	12	8	Religious, shade
Jori	*Ficus hispida*	983	312	Firewood
Poma	*Cedrela toona*	456	284	Firewood, wood
Kadom	*Anthocephalus cadamba*	691	337	Firewood, wood
Simalu	*Bombax ceiba*	402	271	Wood, cotton
Moj	*Pithecellobium monadelphum*	980	330	Firewood
Arjun	*Terminalia arjuna*	18	0	Medicinal, religious, shade
Adimura	__	34	24	Religious, wood
Mahanim	*Azadirachta Indica*	337	289	Medicinal
Narasingha	*Murraya koenigii*	600	302	Medicinal
Posotia	*Vitex negudo*	182	174	Medicinal, tooth brashing
Gomari	*Gemlina arborea*	897	219	Wood, leaves as fodder
Chegun	*Tectona grandis*	1,982	279	Wood
Khaira	*Acacia catechu*	145	80	Wood
Dimoru	*Ficus hirta*	140	110	Fodder, firewood
Takou	*Livistonia jankinsonia*	24	21	Roofing and Japi preparing
Banh	*Bambusa balcooa*	21,576	349	Construction materials, making tools and utensils, firewood, fencing, etc
Bet	Calamus flagellum	15,567	180	Construction materials, making tools and utensils

Source: Based onField survey, 2010-11

In Muktapur village, the home garden resources are mainly used for home consumption. However, some farming families prefer to sell a proportion of the products for cash during the crisis and lean period (Table 4).

This agroforestry system also reflects the cultural choice of the people as many of the plants grown in these gardens are closely associated with the local culture. The indigenous agricultural knowledge and belief systems of different ethnic groups of the Brahmaputra valley are strongly interwoven with the nature of management of their home gardens. Interestingly, the rich home gardens symbolize the economic status of the concerned families. It is important to note that the home garden products such as

Table 4: Income from home gardens

Yearly earning from home gardens			
Income (Rs)	No. of HG	No. of beneficiary HH	Items sold
< 2000	124	71 (farmers) 36 (wage labourers) 6 (businessmen) 11 (service holders)	Banana, betel nut, mango, *jamun, lit chi*, betel leaf, fuel wood, coconut, vegetables
2000-5000	183	57 (farmers) 40 (wage labourers) 37 (businessmen) 49 (service holders)	Banana, citrus fruits, betel nut, betel leaf, coconut, fuel wood, vegetables
5000-10000	49	22 (farmers) 4 (wage labourers) 14 (businessmen) 9 (service holders)	Betel nut, betel leaf, coconut, banana, wood tree, fuel wood
>10000	27	7 (farmers) 0 (wage labourers) 14 (businessmen) 6 (service holders)	Timber, betel leaf, betel nut, coconut, fruits, fuel wood

Source: Field survey, 2010-11. Note: HG stands for home garden, HH is used for household

fruits, vegetables and some medicinal plants are shared mutually by the neighbouring families. Such spontaneous sharing indirectly helps in maintaining social integration, networking and building social capital in the rural societies (Kumar and Nair, 2006; Abdoellah, 1990; Galhena, 2012). It is seen in Muktapur village that many poor families, who do not have home gardens of their own, are allowed to collect at least some minor products freely from the home gardens of the fellow villagers. Thus, home gardening is found to act as an effective means in sustaining the unconditional co-operation among the families of the village community.

Management of home gardens

Being located within the homesteads, the home gardens usually receive required attention and care from the concerned households. These gardens need low cost management unlike some other farming systems, as the application of chemical fertilizer and pesticides in such gardens is extremely rare. It is worth mentioning here that the villagers generally apply cowdung and other organic wastes on their croplands in the winter season, but during the summer these inputs are used in the home gardens only. Again, for proper growth of shoots and stems mainly in the case of bamboos and betel leaf plants, the villagers carry fresh alluvium from the paddy fields to put around the roots of these plants. Thus, home garden products are largely organic in character.

Besides, the seeds and saplings to be planted in the gardens are mainly obtained from the nearby forest patches (*habi*) or the neighbouring households. In the case of contiguous home gardens, the owners usually demarcate their own gardens either by digging narrow drains or by fencing them with bamboo and jetropha plants. In order to allow proper penetration of sunlight for creating a favorable growth condition for other plants people often harvest the branches of the tall trees selectively. On the other

hand, for the protection of crops, like betel nut and coconut from the attack of squirrels people apply some traditional measures. Importantly, all the members of the family put their labour and all other efforts in maintaining a productive environment within their gardens.

Recent changes

There has been notable change in the size and characteristics of the home gardens in the villages of the Brahmaputra valley caused by the recent transformation in the ecological and socio-economic settings. With the so-called agricultural modernization and socio-economic changes experienced in the rural areas, the home gardens have also started getting transformed into some income-generating enterprises. It is noticed that many home gardens in the valley, which were once biologically very rich, have now been replaced either by small tea garden or wood tree plantations. The urban fringe-dwellers on the other hand are now more interested to use their home garden lands for construction of modern houses for the purpose of renting. Many people have also started planting some genetically modified plants in their gardens which ultimately lower their species diversity and productivity. In Muktapur village also, the introduction of certain economic plants in the home gardens has caused disappearance of many local plants leading to notable change in the traditional agroforestry systems (Table 5). Besides, the decline in plant diversity resulting from monocropping has caused gradual erosion of the rural ecosystem and instability in the traditional production system. Moreover, due to the rapid degradation and fragmentation of the wildlife habitats many wild animals have now started raiding the human habitats, especially the home gardens, in search of food.

It has been observed that recently in most of the villages of the Brahmaputra valley large groups of monkeys and squirrels cause serious damage to the home garden crops. The rapid spread of these animals may also be attributed to the disturbed trophic structure and food-chain abnormality in the rural ecosystems. It is also found that the unscientific application of chemical fertilizers and pesticides in the agricultural fields and tea gardens has badly affected the fish population of the adjoining wetlands. This has also adversely affected the amphibian diversity in the water bodies. With the decline in amphibian diversity the number of predatory birds and reptiles have also remarkably declined. It is a fact that some snakes and predatory birds are the main control factors of squirrels and monkey population. Thus the decline in these preda-

Table 5: Transformation of home gardens to other land use category in Muktapur

No. of home gardens Transformed	Area transformed (in ha)	Transformed to	Causes of transformation
10	0.60	Tree garden	Management problem, declining production due to animal attack, small landholding size, lower price for home garden products, etc.
4	0.20	Kitchen garden	
3	0.13	Housing	
2	0.12	Pond	

Source: Based on Field survey, 2010-11

tory species has encouraged the growth of animals, like squirrel and monkey which have already shown some negative impact on the traditional rural economy, particularly the system of home gardening.

It is disheartening to note that the villages of the Brahmaputra valley, which were once very rich in natural resources and highly productive for crops, fish and livestock, have now faced with a variety of new challenges. Eco-degradation, uneconomic size of landholding, smaller family size, rural depopulation, agricultural land abandonment, occupational shift, food habit change are some of the factors causing serious threat to the home gardening.

Conclusion

In the context of large scale deforestation, growing ecological imbalance and unsustainable socio-economic change in the Brahmaputra valley, scientific management and restoration of home gardens may be an effective step in reviving and revitalizing the valley's rural ecology and economy. As the agricultural practice in the valley is still subsistence in character and there has always been an element of uncertainty associated with the poor agricultural sector due mainly to erratic monsoon and crop damages caused by pests, insects and wild animals, scientifically managed home gardens may be a sustainable alternative for goods and services required by the peasant families. In order to promote social well-being, the multifunctional agroforestry systems need to be properly managed and strengthened by introducing useful plants and mobilizing the resources (Pandey, 2007). For sustainable rural livelihoods, the search for self-sustaining, low-input, diversified, and energy efficient agricultural system is now a major challenge for the researchers, farmers, and policy-makers worldwide (Altieri and Nicholls, 2000). Inspite of having lot of problems, the home gardens in the Brahmaputra valley in general and Muktapur village in particular, still play significant role in maintaining the rural economy sustainably.

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Perspectives on Urban Climate Change and Policy Measures in India

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Abstract

This paper is an attempt to outline the distinct features of urban micro climate from the climate of the countryside which we are generally familiar of. The study has also tried to distinguish the concept of urban climate change from that of global warming. The paper identifies the major causes of urban climate change as well as the remedial policy measures for a better climate change adaptation. The climates of large cities, particularly the megacities, considerably vary from the climate of villages in the outer fringe. Megacities experience 4^0 to 8^0C higher temperatures than the climate of the city region. The study finds that the urban climate is experiencing increasing weather extremity and uncertainty in proportion to urban hierarchy. The study reveals a further challenging nocturnal climatic condition in the major cities because of increasing thermal inversion. Growing urban heat island intensity in the already hotter tropical cities is more challenging than the temperate cities of higher climate change resilience. The urban climate is becoming considerably challenging in the Indian cities because our megacities are highly congested and crowded than the major cities of Brazil, China and Indonesia. Urban climate change threatens a poor quality of life to the middle class and the migrant labour in the developing countries like India, where despite a lower percentage of urbanization, there is much higher concentration and crowding in the few big cities.

Keywords*: urban climate change, urban heat island, microclimate, climate policy, climate change adaptation*

Introduction

Urban micro climate considerably differs from the surrounding macro climate of the countryside. The climates of megacities experience 4^0 to 8^0 C higher temperatures than the villages of outer fringe. Urban micro climate change refers to destabilised micro climate in the large metropolitan areas and megacities. While global warming has experienced an average 0.7^0C temperature rise in the last 100 years, the urban climate change has recorded a rise of 2^0 to 4^0C temperature in the major cities over a period of 50 years. Urban climate is becoming increasingly challenging in proportion to urban hierarchy. In a geographical parlance urban climatic extremity and uncertainty is closely related to city size, function, morphology and orientation. Today, we are living in an 'Urban Planet' wherein over 55 per cent of the world population is concentrated in the urban centres comprising less than 5 per cent of the land surface. The density

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and intensity of dynamic man-made environment is threatening the stability and sustainability of natural environment. The modern urban age of materialistic conquest is proving to be a destabilising Anthropocene to the economy, society and ecology. The problem of urban climate change appears more challenging in the Indian megacities. This is because India's major cities are far more congested and crowded than the big cities of Brazil, China and even Indonesia. India's major cities are more crowded because of the heaviest rural-urban migration. India's potentially migrant rural population exceeds the rural population of China. India in 2018 has over 900 million rural population while China correspondingly has less than 600 million rural population. Chinese economy is more capital intensive to prevent heavy rural-urban migration as against India's largely labour intensive unorganised sector. China's agricultural economy is also more sustainable to discourage rural exodus. The archipelago of Indonesia does not have a contiguous landmass. Hence, it prevents the uncontrolled migration and crowding in its major cities. Uncontrolled migration and the resultant urban poverty lead to low purchasing power, urban homelessness and increased vulnerability to urban climate change in India.

Concept of urban heat island, urban climate change and global warming

Most of the urban heat island studies have been traditionally confined to a single climatic variable of temperature. Generally, there has been a depiction of thermal environment in the city and its temperature growth. On the other hand, the concept of urban climate change considers all the variables of climate and changes therein. It encompasses an enquiry into urban temperatures, city atmospheric pressure, precipitation, humidity, wind velocity, calm weather conditions, cloud cover and evaporation changes. In one of the earliest enquiries on urban heat island, Oke (1973) discovered a causal relationship between the city size and urban heat island. Prior to it there were heat island studies for the global cities of London, New York, Paris, Tokyo and Moscow. Balling and Cerveny (1987) enquired the urban heat island in Phoenix, Arizona. Camilloni and Barros (1997) studied the thermal effects of urban heat island. Akbari (2005) in his study of urban heat island mitigation suggested the energy saving ways to control the temperature rise. Lee et. al. (2014) have noticed a more pronounced urban heat island in the humid cities on the sea.

Anonymous (1990) in a holistic enquiry of urban climate change included the variables other than temperature in the reports of Intergovernmental Panel on Climate Change. Qureshi and Khan (1994) estimated the climatic transition in Riyadh, Saudi Arabia. It measured the urban climate change not only in temperature, but also in rainfall trends, humidity, wind velocity, cloud cover and evaporation conditions. Deosthali (2000) examined the impact of urban growth on heat and moisture islands in the city of Pune. Naheed (2006) evaluated the climatic transition in the megacities of Delhi, Mumbai, Kolkata and Chennai. This crucial study made an important quantitative analysis of the urban climate. Infact, the terms urban heat island and urban climate change have, many a times, been used synonymously. The latter is all encompassing in its concept and usage. Ghazal (2015) in an outstanding analysis of urban climate change in the megacities of Ahmedabad, Hyderabad and Bangalore has depicted micro climatic changes in all the variables. This study has shown a cumulative effect of temperature rise (both daytime and nocturnal) along with humidity rise and wind velocity reduction. It has revealed the city climate all the more sultry in the already hotter tropics. It also brings out a causal relationship between the growing rainfall intensity and the imminent urban floods.

Geographers and climate scientists both have adopted the approach of using the long-term meteorological data and the short-term remote sensing data in depicting the urban heat island in the major cities. The major difference between the two approaches lies in the fact that the thermal remote sensing data depicts the sur-

face conditions of the urban heat island whereas; the meteorological data demonstrates the air temperature conditions over the cities. Streutker (2003) like many scholars used satellite remote sensing data for measuring the growth of urban heat island in Houston, Texas. Voogt and Oke (2003) utilized thermal remote sensing data for studying the urban heat island. Zhangyan (2006) employed LandSat TM data for showing the geographical distribution of urban heat island in Beijing. Changes in the air temperature characteristics have a crucial consequence on the sensible heat. This is because the resultant discomfort levels and heat stress are more a function of sensible heat rather than surface temperature. Remote Sensing surface data shows an instantaneous distribution of Urban Heat Island. It is based on one, two and three days of thermal infrared data. On the other hand, a galaxy of meteorological data is analysed to measure temporal dimension of air temperature. It helps a vivid depiction of urban climate change both in time and space.

As thermal remote sensing of the city surface is based only on a couple of observations, the author identifies it as a 'floating heat island'. From time to time, it might float between the commercial district, industrial district and residential district of a major city. Hence, a floating heat island may be less consequential to urban planning. For practical and planning purposes, the urban heat island and urban climate change studies are not tenable to small and medium size cities. This is because the climate change detection even in the medium size cities would be nominal and inconsequential. Hence, the author is of the view that such enquiries legitimately qualify for large size cities ranging from million plus to megacities in the developing countries. The micro climatic conditions in the metropolitan areas become increasingly challenging due to higher population and built-up densities as well as the concentration of commerce, industry, transportation and greenhouse gas emissions. The concept of global warming pertains to linear temperature increase. It is widespread in the rural-urban context. It has a regional dimension temperature rise. The degree of warming varies in the tropics, temperate and polar lands.

Causes of urban climate change

There are integrated causes of urban climate change in the urban landuse and landcover, demographic structure and greenhouse gas emissions. The author believes that one of the major causes of alarming urban climate change is the megacity-centric urbanization in India.

1. City size and built-up density was considered the first cause of urban heat island.
2. Population size and density was subsequently acknowledged as the second cause.
3. Industrial, commercial and transportational functions were identified as additional and effective causes of urban climate change.
4. Eventually, the growing greenhouse gas emissions and the resultant greenhouse effect is now considered the biggest cause of unprecedented radiative forcing and urban climate change. Greenhouse gas emission is the root cause of urban climate change as major cities are the source of 80 per cent emissions of carbon-dioxide, methane and CFCs. Suspended Particulate Matter (SPM) is another cause of urban climate change.
5. City morphology and orientation has been enquired as the latest cause of urban aerodynamics.
6. Loss of permeable surfaces and wetland depletion is another major cause of urban climate change because permeable surfaces and wetlands were the source of evaporative cooling. In the scarcity of vegetation and water, the radiative forcing is induced by the greenhouse gas emissions.

Mayhew (2006) noted 10-20 times higher concentration of aerosols in the city atmosphere

in comparison to the countryside. Higher concentration of aerosols in the city atmosphere acts as a radiative shield. These tiny suspended particles absorb radiative heat and prevent the cooling. Aerosols also act as condensation nuclei and induce upto 10 per cent higher rainfall in the large cities. All these conditions alter the urban temperature, rainfall, humidity, wind velocity as well as rain water absorption-runoff balance. The growing CO_2 and H_2O concentrations induce greenhouse effect and reduce evaporative cooling.

Characteristics of urban climate change

Urban climates of major cities are characterised with greenhouse induced thermal inversion. It acts as a lower atmospheric lid to reverse the environmental lapse rate. This dangerous situation tends to curtail the atmospheric mixing and slow down the air circulation. It prevents the vertical ventilation in the city. Thermal inversion tends to stabilise the air over a city to inflict heat stress because stable air will also prevent the radiative cooling of human body. Hence, thermal inversion might cause acute nocturnal distress to urban inhabitants. Nocturnal rural-urban temperatures considerably vary because rural areas cool quickly while the urban areas slowly cool down. Some scholars have reported 6^0 to 11^0C higher nocturnal urban temperatures in comparison to surrounding rural areas. This results into a pronounced nocturnal heat island. Ghazal (2015) revealed a much smaller diurnal range of temperature in the micro urban climates as compared to the rural surroundings. A decreasing diurnal range of temperature is the main cause of growing discomfort levels and heat stress. Urban heat island is more striking during the summers because the built-up surface absorbs more heat during the day and radiate more heat during the night. The intensely radiated heat is trapped by the urban air pollutants suspended in the lower atmosphere. A strong greenhouse effect maintains higher air temperature. Hence, mean minimum air temperature data depicts more convincing scenario of nocturnal heat island. However, the surface temperature method should preferably utilise daytime afternoon data because the surface is hottest in the afternoon.

It is surprising to note that the literature on urban climate suggests a low humidity, presumably due to lack of evaporative surfaces like vegetation and wetlands. The present author however, contends that the urban air is no less humid than the rural air. This may be because of very high amount of industrial, commercial and transportation exhaust. The urban hotel industry and the domestic sectors boil millions of litres of water. The boiling water adds to the water vapour which, in turn, adds to humidity. It means that both urban combustion and vaporization add to humidity. As a consequence, the urban air may in fact, be more humid than dry. Further, the longer urban summers may be more muggy than scorching. Finally urban areas may have higher absolute humidity than their rural counterparts.

Wind velocity over the heterogeneous urban surface is 20-30 per cent lower than in the surrounding rural areas. When air blows over the coarse, built-up urban terrain, the frictional drag of the surface decreases the wind velocity. Cities are also the areas of wind convergence, particularly during the longer summer season in the tropics. This may be because of the suction mechanism. As the city surface is hot, the air over it warms, expands and becomes lighter. On non-inversion days it tries to rise up. To replace the rising city air, the surrounding rural air gradually converges towards the city. Hence, a feeble urban air convection may be replaced by the gentle rural air advection. Heat island intensity may be notably high with low wind speed, calm weather conditions and clear skies with reduced advection. There is an evidence of a higher air temperature rise of 0.5^0 to 5^0C as compared to lower surface temperature rise of 0.5^0 to 2^0C in the temperate cities of northeastern U.S.A. This indicates that greenhouse gas emission is a more formidable factor of urban climate change than the nature of the built-up surface.

NASA's Goddard Institute for Space Studies reported the city temperature rise at a decadal rate of 0.12^0 to 0.45^0C from million to megacities over a period of 1961-2010. The projected temperature rise is 0.7^0 to 1.5^0C for 2010-2020. The projected temperature rise is 1.3^0C to 3.0^0C by 2050. A further temperature rise is projected as 1.7 C to 4.9 C by 2080. The city temperature rise by 2100, in the life-time of our children would be 2.3 C to 6.2 C. The mean annual precipitation of cities is estimated to change from -7 to + 10 per cent by 2020. It is projected to change from -9 to +15 per cent by 2050 and from -11 to + 21 per cent by 2080. By the end of this century, the precipitation is further likely to change from -14 to +28 per cent. The urban climate change with only two elements of climate would inflict an unbearable rise in the heat and humidity. The weather problem of sensible heat and humidity would further compound and complicate the sultry conditions in the wake of reducing wind velocity and growing calm weather conditions in the city atmosphere.

Unique problems of Indian megacities

Urban climate change is a threatening environmental challenge more so in the megacities of tropical developing countries, like India, where we face a formidable problem of spurious city growth with smothering congestion. One of the major causes of alarming climate change is rapid globalisation which is megacity-centric in India. Globalization in India has countered and curtailed the decentralisation policies and planning. It has reinvigorated the centralisation of economy and infrastructure. As a consequence to it there is massive rural-urban migration leading to sprawling slums and growing urban homelessness. Over 75 to 85 per cent urban population belongs to poor and middle class sections of the society who scarcely have an adaptation propensity to the future climatic inclemency of the major cities. The social pathology in the Indian megacities is highly fractured and vulnerable. The environmental disaster-defence mechanism is also very weak and inadequate.

Urban climate change in the tropical vis-à-vis temperate cities:

The characteristic feature of low latitude tropical climates is longer summers with shorter winters. Many of the coastal and peninsular cities in the tropics have annual summer with already uniformly higher temperatures. The subtropical cities of high continentality like Delhi and Chandigarh experience extremely high temperatures with prolonged summers. On the other hand, the characteristic features of high latitude, temperate climates are longer winters and shorter summers. The temperate cities of high continentality like Moscow and Urumqi are few in number and experience extremely low temperatures of biting cold and frost with prolonged winters. The tropical cities of already high temperatures with inherently hot and uncomfortable climate are at the critical limits of heat and humidity. Any further rise in their heat and humidity along with changes in other elements of climate would render them exceedingly unbearable to live in.

Tropical countries with only 30 to 35 per cent urban population have much larger megacities which are far more in number. Their megacity growth is uncontrolled and unmanageable. This top-heavy urbanisation is a clear evidence of growing centralised economy with widening regional imbalances and yawning social inequalities. While the temperate countries with 75 to 80 per cent urban population do not have much larger megacities except Tokyo. Despite very high proportion of urban population they have small number of megacities. Their megacity growth is restrained, hence manageable. The temperate and tropical megacity ratio is 1 : 4. In 2018, India has 9 megacities. By 2031, India may have 15 megacities with Delhi and Mumbai the world's largest. The future climates of large tropical cities would be more unbearable for a qualitative living than the climates of temperate cities. It seems unpleasant to visualise that by 2050, many rich people of large tropical cities might seek a refuge in the manageable temperate cities. Under such alarming condi-

tions, there is an emergent and urgent need to deeply enquire the trends and patterns of urban climate change and remedial measures for a meteorologically sustainable urban planning.

The Earth Institute's 2018 Environmental Performance Index (EPI) made an Environmental Health Assessment of 180 countries. It is based on 24 performance indicators to examine the environmental health of cities. India with spurious growth and sprawling urbanization is ranked 177th. It looks highly alarming at its face. The report identified low carbon emission economies of higher incomes as "Green Countries" and projected them as "Paragons of Environmental Virtue". Here, the researcher deems it crucial to clarify an invisible truth that many of the green countries heavily depend upon the imports from the so-called heavily polluting "Grey Countries" of weak environmental laws. Hence, the researcher identifies an environmental fact that green countries may be the "Proxy Polluters" while grey countries are voluntarily "Surrogate Polluters". To do away with the prevalent paradoxes and to seek an exit from this labyrinth, the economy and the environment ought to be complimentary considerations for a sustainable urban development.

Impact of urban climate change

The urban climate change would take its first toll on the health, longevity and well being of the urban poor and middle class, who in fact sustain the city industry, commerce and trade. As most of India's urban poor live in the informal settlements by unorganised, exploitative sector they are the foremost vulnerable to environmental hazards. The burden of urban climate change on the poor and middle class of the informal sector, particularly women, children and minority social groups would be much higher than the well-off people. As a result of it, morbidity would considerably exceed mortality. The labour efficiency and per capita labour productivity would decline. The national interests would sag down vis-à-vis international sustainability. Urban poor masses would have miserable living conditions because urban climate change adaptation would be far more challenging to this 65-70 per cent megacity population which lives on the margin of society. Only 10-15 per cent urbanites would afford sustainable air conditioning.

It is crucial to measure and understand the urban climate change because as per the IPCC estimates of 2014 nearly half of the world population would be exposed to urban heat stress by the year 2030. It is estimated that over 75 per cent of the global economy is urban and most of it is concentrated in the major cities so vulnerable to urban climate change. Urban climates have distinctly higher nocturnal heat stress because it also undermines the comfort levels and leisure. In the daytime people mostly get engaged at the work place but nights are mostly leisure time to relax and revive for the day's work. Sleepless nights due to growing discomfort levels would severely affect the poor people. The rich man's air conditioning heat exhaust would make the urban micro climate of the poor man's neighbourhood least sustainable.

Urban climate change mitigation and adaptation measures

The foremost requirement of climate change mitigation is a persistent phasing out of the conventional fuel energy in favour of non-conventional solar, tidal and wind energy. As most of the major cities are located in the coastal areas, the daily alternating land and sea breezes hold considerable potential of harnessing the wind energy. Over 7,500 km long coastline also holds a promise of generating the tidal energy in India. The sunny tropics have a ubiquitous scope of developing Solar Farms. 21st Century India needs to transform her traditional Agricultural Farms into Modern Photo-voltaic Farms. The need is indispensible because conventional energy emissions have squarely raised the intensity of urban climate change. Prime Minister Narendra Modi in his right earnest has taken a great policy initiative to launch a massive project of harnessing solar energy to make India con-

siderably self-sufficient in climate amelioration with the usage of non-conventional energy.

Urban greenery can effectively reduce both the surface and air temperatures. Increased greenery and reflective white surface coverings reduced the Paris temperatures by 2^0-3^0C. The biggest problem of India's urban climate change is megacity-centric urbanization. India with an imminently dangerous urban environment can mitigate the problem by effectively promoting bottom-up and top-down approaches to rapid urbanization. It is important to realise that many self proclaimed 'Green Countries' of the developed world heavily depend on the imports of water intensive consumer goods from the developing countries. And in return they are paradoxically labelled as 'polluting countries'. But the camouflaged truth is that the newly industrialised countries may be the 'proxy polluters' or 'surrogate polluters' to sustain the living standards of 'real polluters'. Nearly two decades ago a summit of the developed countries indicated a shift of so called laundry industries to the developing countries. In view of the ensuring trends of rapid industrialization in the developing countries one can predict that the future world may be broadly divided into 'agro-industrial world' of developing countries and 'techno-commercial world' of the developed countries.

Policy implications on urban climate change

The study is focussed on policy question for promoting the non-conventional, alternative solar and wind energy not only in the industrial and commercial sectors but also down to the household level in the domestic sector as a tangible remedial measure to the phenomenon of climate change. The serious threats of urban climatic uncertainties call for a sincere policy formulation and its implementation towards decentralization and diffusion of economy. In the wake of continued economic growth and diversification, rural-urban migration is unlikely to be slowed down. Hence, a 'Migrant Sustainability Policy' should invoke the 'Law of Social Salary' against the 'Ad-hoc Daily Wages Norms' in all the industrial-commercial undertaking of the Unorganised Sector. For example, all business establishments employing 25 or more labour should follow a policy provision of 'Mid-Day Meals' or 'Moral Meals' for their workers. This would be a more legitimate policy in favour of primary producers of the society than the largely Eye-Wash Mid-Day Meal Schemes in the schools. Moral Meals Policy would help improve the nutritional levels and performance efficiency of the migrant labour by saving their time for more work and higher per capita productivity.

Policy and practice dilemma on climate change mitigation

In 2008, India introduced its first National Action Plan on Climate Change (NAPCC) with the objective of climate change control by reducing the Greenhouse Gas Emissions. As a commitment to latest Paris Summit Agreement (2015) India announced the climate control policy to phase out the emission of fossil fuel energy like coal, petroleum and natural gas in favour of increasing non-fossil energy capacity with clean solar and wind energy. It might prove as a Paradigm Shift in India's Energy Security. In 2016, India's National Electricity Plan announced that India would generate 56.5 per cent of her energy by solar and wind sources within 10 years. In June 2016, the Ministry of Energy proposed to stop the construction of 4 Ultra Mega Power Plants of energy generation by coal. According to the Netherlands Environmental Assessment Agency, India in 2016 recorded an alarming 4.7 per cent rise in greenhouse gas emissions. India's NITI Aayog in 2017 has recommended an increase in the domestic production of coal, petroleum and natural gas as an imperative to India's energy security policy for 2017-2020.

India's Environment Minister Shri Harsh Vardhan in early 2018 promised to cut 50 per cent air pollution of 100 cities within next 5 years. While in 2018 National Budget, the Union Finance Minister Shri Arun Jaitley made no mention of climate investment. Hence, there is an

apparent lack of policy coordination on climate change issues. The imminent dangers of climate change have invoked a greater concern at the international policy making and decision taking than at the national policy level. As a result of it, the international consensus on climate change policy and its implementation is facing serious hurdles between the developed economies and the major developing countries. In fact, there is a mutually inclusive trust deficit leading to clash of interests among the community of nations. The more powerful invariably coin the baseless, yet echoing, terms like clash of civilizations.

Conclusion

A distinctly high problem of urban climate change in India is the result of rapid urbanization in the last three decades. This could be largely attributed to rapid globalization and the resultant centralisation of the infrastructure and economy since the adoption of liberalization policies from 1991. India's globalization is megacity-centric and so is the Indian Urbanization. This has rendered Indian urbanization more skewed than any other major economy in the world. India has nine megacities in Mumbai, Delhi, Kolkata, Chennai, Hyderabad, Bangalore, Ahmedabad, Pune and Surat with the total urban population of over 100 million persons. China's total urban population is nearly double of India's urban population. China's economy is nearly 5 times of our economy. Despite this, China has six global cities Tianjin, Shenzhen, Shanghai, Hong Kong and Beijing. This indicates that China's urbanization is less skewed. The urban climate change may be less alarming in China as compared to India. We need to make effective policy measures against centralised economy to control the massive growth of our large cities. There is also a policy need for a restrained globalization in our country.

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Failing Cityscape: Urbanization and Urban Climate

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Abstract

India is getting fast urbanized. With the rapid increase in urban population and consequent consumption the pollution scenario is moving in a direction that is detrimental to healthy living. Studies related to micro climate in general and urban climate in particular has become new research focus over last few decades. Cities are key site where climate change is being addressed. In this article we are trying to cover the changing pattern of urban environ over time with special case study of Delhi. Who is the most vulnerable to the climate change and at what effect? Excessive use of modern technology and improper management by municipality in current scenario has led the change in climate drastically. As a result floods are seen in some areas even low rainfall while smog in and around the cities, often termed as 'extreme weather event'. Further, normal natural phenomenon, like mist or fog become toxic and makes lives in the cities unliveable. Privatisation of transportation, constructions etc. also aggravate the environmental degradation. Private company either neglect or wilfully ignore to consider the Environment Impact Assessment (EIA) in comparison of government bodies. The theme has an extremely vast application; we will just discuss the effects of human on the climate or urban climate to be specific.

Keywords: *urbanisation, urban climate, urban heat island, extreme weather event, climate change*

Introduction

Human interactions, especially urban and industrial activities have completely transformed the planet in terms of climate, vegetation, topography just to avail or cater to their continuous increasing needs. This unhindered thirst of development imbibes a dark side of human existence leading to possible failures for the cityscape itself. Henderson (2003) calls it a significant effect on climate with a 'drastic jump towards the future humans'. This drastic jump towards future human is discussed now as a new era, 'Anthropocene' or 'Capitalocene' (Davies, 2016; Angus, 2016; Avallone and Leonardi, 2018; Moore, 2016). Moving beyond 'Holocene' is a conceptual proposition and scholars have questioned the announcement of new epoch 'Anthropocene' (Malm and Hornborg, 2014). We are neither endorsing nor refuting this particular proposition; rather bring to debate if the homosapeins are only ecosapiens or they also can contribute to the planet's survival beyond self-interest. This change has occurred at such a level that it is palpable in everyday life of each human being. 'Industrialization, Globalization and Urbanization' are some such words which might perpetuate a sense of development

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as they are perceived but as a drawback they are drawing us closer to the same destination from where we have started (Chenery, 1968). These types of processes are making the planet unliveable once again.

The theory on the 'climate of cities' or 'urban climate' was first published by the Ake Sundborg in 1950, a Swedish geographer and geomorphologist. The paper which he published cited the "existence of a warm core coinciding with the most densely build up and populated portion of the city", and demonstrate that the "core is best developed under nocturnal conditions with clear skies and calm winds" (Kungl, 2008:30). However his explicit mention of effects on isotherm patterns of topography within the urban areas differs from that in neighbouring rural areas as a result of urban development (Kungl, 2008). Urbanization greatly changes the form of the landscape and also produces changes in an area's air, precipitation, temperature, humidity etc, (Hoppe, 1986:2). Cities which emerged and grew in the aftermath of Industrial Revolution became cassier to faster and irreversible changes in terms of ambient air quality and landuse, owing to energy based city life and multiple avenues of non-essential consumptions. Gregory (1985) linked this with continuous growth of urban population, saying moreover urban climate as a phenomena took shape from the industrial revolution or the mid 18th century which was followed by robust urbanisation at 54 per cent and projected rate by 2050, 70 to 75 per cent.

Impact of urbanization on climate

More than 50 per cent of the World population now lives in towns and cities. This proportion is expected to rise to 66 per cent by 2050; some estimates put the percentage as 70 to 75 per cent (Batty, 2012; Gregory, 1985; United Nations, 2014). The rate of growth of urban population is relatively higher in the less developed countries (LDC), compared to more developed countries (MDC). This also means higher level of consumption in current MDC is getting transmitted as aspiration as well as a real opportunity across cities of LDC. Such continuously growing hyper consumption propels changes in climatic condition such as temperature, humidity, amount of precipitation etc in urban areas especially in large metro-political cities. These changes are fuelled due to construction and re-fabrication of artificial structure and surface like tall building blocks, paved streets, higher number of chimney and motor vehicle etc (Batty, 2012). The continuous growing consumption by the urban dwellers can be said responsible for the category like 'the Antrhopocene' by the Nobel Laureate Paul Crutzen (2002) in an article titled 'the geology of mankind' in Nature. Cities are rightly considered as cites of hybrid phenomena interlacing biophysical resources, cultural processes and global power structure through trajectory of hierarchical technologies. Hybridity of cities has been discussed across disciplines including sociology and ecology (Bhabha, 1994). O'Neil and Kahn (2000) set the tone for Paul Crutzen (2002), when they proposed homosapeins 'homo economus' with a potential to be a 'keystone' species. Keystone species in words of O'Neil and Kahn (2000:333) controls the environment and thereby determine the other species that can survive in its presence. The extent of affluence generated through high-tech modernity is unquestionably large and has altered the global environ. However, the impact of such high-tech modernity generated affluence can not possibly be universalized, because it is predicated on an international division of labour (Malm and Hornborg, 2014). Such division not only is responsible for price and wage differences but also consumption behaviours and demand for 'goods' and 'services'. The obvious and measurable impacts of changing environ includes, higher temperature regimes, flash floods along with dete-

riorating ambient air quality in different cities. Based on IPCC statistics, David Satterhwaite (2008) in his study highlighted episodes of floods and heat-waves as major impacts with which cities across the globe have to fight. Gaitani et. al. (2011) in their study of Athens showed that there is possibility of having higher temperature between 1 and 6^0C compared to the surrounding rural areas. Champan et al. (2017: 1921), wrote that 'urban growth was found to have a large impact on local temperature, in some cases by up to 50 C in NE USA'. Tahir and Muhammad (2014) in their work established extreme weather conditions, and showed while the highest temperature rose by about 1.4 degree, the lowest temperature decreased by 2 degree. The quantum of actual contribution of urbanization process in the changing climate remain a matter of further study and research, one can not deny the clear association between change in temperature regimes and increasing urbanization across the world.

Cities since long have been considered as environmental entities. Chicago School used the term 'urban ecology' for over 9 decades in 1925. The conception primarily focussed on arrangement of settlement did talk about interaction between different sets of people and economic activities, primarily industrial production. With deteriorating urban climate in European cities and fatal episodes of 'smog' and 'cholera' in London, study and maintenance of city environ became pertinent. The idea of ambient air quality, having institution to monitor such air and water quality began from the global north and the south emulated it in due course of time. These studies and initiatives surely ensue longstanding interest in the impacts of urbanization on precipitation and temperature both locally and regionally. Available evidences suggest that urbanization and precipitation are positively correlated, though contradictory realities have also been reported and therefore a consensus on the relationship between precipitation and urbanization is not been yet reached. Burian and Shepherd (2005) in their studies established the relationship between the increase in downwind rainfall and urbanization. Landsberg (1956) and Changnon (1968) have also in their separate study discussed the extent to which urbanization may induce and strengthen precipitation. The most rapid rate of increase in rainfall is reported from Sau Polo (+29mm/decade), while the steepest decrease has occurred in Harare (-21mm/decade) over the last century (Kungl, 2008). The change in rainfall pattern coupled with unscientific and unmonitored landuse alteration results in flash flood and the cities. The recent episodes of floods in the Indian cities of Chennai, Bangalore, Cochin indicate towards the grave nature of the impact. Government of India (2017:3) in its report has acknowledged, that 'there has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Guwahati and Delhi in 2010. The most recent devastating ones were Srinagar in 2014 and Chennai in 2015'. Owing to inappropriate landuse and unmonitored transformation of surface along with failure of administration and Municipal Corporation of Gurgaon, there was monster traffic jam in Gurgaon in July 2016, commonly known as Gurujam, with a rainfall of 54 mm in a day. People faced 4-5 hour to just travel 2 km (Delhi Report 2, 2016). There are several such examples of similar situations and the July 2016is only an example. Crisis in one city affect the other cities in many more ways because of globalisation all the cities are interconnected. Failure of one component will lead cascading effect and consequent failure of the entire system. There are multiple reasons for

urban flooding including changed weather conditions, as noted in the study of Kungl (2008); increased peak flow, reduced infiltration, faulty storm water drainage and so on (Rafiq et. al. 2016). Reduced infiltration is primarily due to higher proportion of concrete surface, which also contribute to rise in temperature and consequent creation of urban heat island (UHI).

Urban heat island

The urban heat island (UHI) is considered as the most obvious example of how landuse change has impacted the local and regional climate in and around any city. UHI is defined as urban areas being warmer than surrounding rural areas (Chapman et al, 2017). It is reported in a study by Chapman et al (2017), that in north eastern USA the local temperature is up by about 5^0C and Gaithani et al (2014), about Athens about 6^0C, Batty (2012) argued that the 'annual mean air temperature of a city with one million or more people can be 1 to 3°C warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 12°C'. With the decreasing city size impact and intensity of the heat island decline, however, smaller cities and towns also produce heat islands. Studies (Champman, 2017; Gaithani, 2014; Tahir, 2014) suggest that wind speed has the potential to decrease the intensity of the heat island effect in urban areas; however study on Mumbai and Delhi by Grover and Singh (2015) found Delhi condition more intense than that of Mumbai. The primary reason for such a situation can be contributed to higher proportion of concrete surface in Mumbai compared to Delhi. More densely organized cities have more congested, chaotic and closely spaced neighbourhoods, which hinder adequate wind movement and reduce ventilation in urban canyons. There are two types of UHI in metropolitan areas, namely: 'surface urban heat island' and 'atmospheric urban heat island'. Surface urban heat island is a direct impact of insolation and is triggered due to different nature of surface, like roads, pavement, etc. in towns and cities compared to the rural areas. Akbari and Menon (2007) in their study estimated the rise up to 27-50^0C on a hot summer day due to higher absorption of incoming radiation by the exposed surfaces. Atmospheric urban heat island is further subdivided into two, 'canopy level' and 'boundary level'. The causes or factors responsible for the creation of the urban heat island are similar to the reasons that have been given above for the change in urban climate in general. These includes insolation which leads to the absorption of heat energy by the urban structures, loss of vegetation which decreases the moisture content in the air, less albedo which further increases the temperature. Apart from these, urban geometry, which is responsible for variation in wind velocity due to dimension and spacing of buildings, is considered important (Akbari and Menon, 2007). In highly urbanized and developed areas, surfaces and structures are often marked by obstruction, at least partially by objects, such as neighbouring buildings. They become large thermal masses because the rate of release of their heat become slower because of these obstructions and neighbour emission even above the surface (Pomerantz, 2000). Especially at night, the air above urban centers is typically warmer than air over rural areas. Night time atmospheric heat islands can have serious health implications for urban residents during summer months. Health of urban citizens is not only under threat due to UHI, but more directly due to deteriorating air quality, an important part of urban micro climate. The change in temperature also determine the energy requirement in the city as Chapman et al (2017: 1922) noted that the 'changes to temperature from climate change will affect the amount of heating and cooling used by urban residents and the associated anthropogenic heat release, which would either increase or decrease the UHI de-

pending on whether the reduction in cooling or increase in heating requirements was larger' (Oleson, 2012).

Ambient air quality

Air quality of urban areas is for long been under consideration since the infamous episode of London smog in nineteenth century. Anthropogenic air pollutants are found to be concentrated in urban atmosphere across the globe since industrial revolution. Increasing vehicular traffic, continuous growing industries, and domestic heating are prime sources of these emission that contribute to polluting air. Rapidly increasing population, unplanned urbanization, and industrialization are the main contributors to urban air pollution primarily in developing countries. Twenty first century is the century of urbanization in the less developed countries. The rate of growth of urban population in developing country is far higher than in the developed countries. This also means that air and water quality is fast deteriorating in these countries. The ambient air quality data show that oxide of Nitrogen has continuously increased across metro-cities of India, though sulphur dioxide has shown a decline over the period time. Ambient air quality in Chennai and Kolkata shows worst deterioration in terms of NO2 concentration level over last 2 decades.

Table 1 Ambient air quality of sulphur dioxide (SO2) and nitrogen oxide (NO2) level

	Cities/yearSulphur dioxide (SO2)						Oxides of Nitrogen (NO2)					
	1996	2000	2004	2008	2012	2015	1996	2000	2004	2008	2012	2015
Ahmedabad	25.0	8.4	15.7	12.3	12.0	13.0	14.8	28.6	24.3	20.0	24.0	21.0
Bangalore	20.7	20.7	8.5	15.2	14.0	6.0	28.0	40.2	51.8	40.8	28.0	20.0
Chennai	8.1	12.5	12.2	6.6	5.0	5.0	39.7	39.9	46.1	56.7	59.0	65.0
Hyderabad	16.8	12.4	5.6	5.5	4.0	4.0	25.0	25.2	30.3	26.2	28.0	23.0
Kolkata	21.3	17.4	9.3	7.7	12.0	7.0	29.3	34.8	59.7	64.0	70.0	56.0
Mumbai	18.0	12.1	6.7	8.7	5.0	4.0	35.3	25.5	18.3	39.3	20.0	25.0

Source: Central Pollution Control Board (CPCB), New Delhi

However, the major problem for the cities after 90s has been growing particulate matters in the city. Ahmadabad has shown tremendous improvement with continuous decline in the PM10 concentration. Hyderabad and Bangalore are two cities which have reported continuous deterioration in the air quality in terms of PM 10 level; these cities have also grown faster than other metropolitan cities in the country over last two decades. These statistics, though does not

Table 2 Ambient air quality of particulate matter (PM10) level (Âµg/m3)

City	1996	2000	2004	2008	2012	2015
Ahmedabad	-	237.0	152.0	88.0	83.0	89.0
Bangalore	-	89.7	69.0	100.0	121.0	119.0
Chennai	-	65.0	60.0	63.0	57.0	59.0
Hyderabad	-	155.0	149.0	214.0	237.0	220.0
Kolkata	-	98.0	71.0	85.0	79.0	93.0
Mumbai	-	145.0	134.0	103.0	135.0	105.0

Source: CPCB, New Delhi

reflect the extreme conditions on a particular day, which can be due to combination of factors, including metrological conditions and human factors.

According to the latest air quality database, 97 per cent of cities in low- and middle income countries with more than 1,00,000 inhabitants do not meet WHO air quality guidelines (WHO, 2018). However, in high-income countries, that percentage decreases to 49 per cent. Indian urban spaces have witnessed a boom in the automobile population over since 1991, when Indian economy was liberalized. The consequence in terms of air quality deterioration mostly remained in annual reports of CPCB and occasional reporting in print and electronic media at time when air quality becomes unsuitable to breathe. Immediate and panic reactions have become accepted responses, with little emphasis on long-term or medium-term measures to contain the particulate matters in the air.

Delhi: A case study

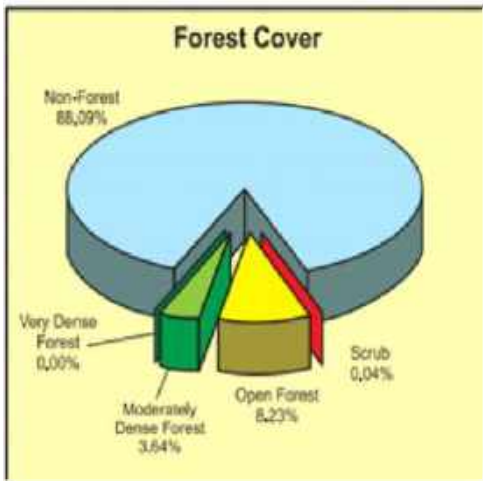
Indian cities are amongst the dirtiest cities across the world, to the extent that 14 cities are in India out of 15 most polluted cities listed in the latest realised list of World Health Organization in 2018 (TOI, 2018). Based on the data of 2016, Delhi is listed at number 6 out of all the dirty cities. Nothing can be a better example of an urban area than Delhi, the capital of India, where schools have to be shut down for days owing to severely high level of pollution in the air during early November. The Guardian (Nov 7, 2017) wrote, 'Delhi doctors declare pollution emergency as smog chokes city' comparing breathing in the city equivalent to smoking 50 cigarettes daily. Levels of PM 2.5 in Delhi reached 710 micrograms per cubic metre, more than 11 times the World Health Organisation's safe limit in the first week of November. Slow wind, cooler temperature, festivals, and burning of husk were attributed to the rise in the particulate matter to the dangerous level. With rapid urbanisation in India, the situation is bound to get worse, if proper measures are not taken to curb the pollution. WHO in its study estimated the corresponding health impacts on premature mortality and morbidity and noted that Delhi is among the top 10 cities with the worst air quality. With increasing emphasis on consumption and a large population, there is a continuous increase in number of automobiles in the city. These automobiles offer a continuous supply of green house gases into the atmosphere which apart from causing pollution also contribute to the increase in temperature of the city. Being an industrial hub, a large number of industries function in the national capital region (NCR). Head offices of various departments have been established here. Large number of offices means a greater need of air conditioning and refrigeration. Thus, CFCs is also produced in huge quantities. Continuous influx of people into the city lays an immense pressure on availability of residential complexes, resulting in continuous construction and increased level of generation of PM 2.5 and PM 10. The vegetation-cover of the city region as compared to the sea of concrete and asphalt is on decline. This causes low albedo and high absorption of solar energy, thus, accentuating the formation of urban heat island. Formation of urban heat island is noted in different studies (Grover and Singh, 2015), which also adds to the erratic precipitation in the form of rainfall. There is no definite time of rainfall and it occurs partially throughout the city. Increasing number of automobile in the city has gone to a critical level and driving towards the city and in the city is considered havoc, to the extent that the administration tried taking steps to regulate the number of vehicle on road. The climate in the vicinity of the city is comparatively cooler but it also poses a danger of becoming urban heat island due to the continuous expansion of the city. One of the major sources

of this pollution is emissions from vehicles in the cities. The estimated volume of road based traffic would rise to 12,546 billion passengers-km in 2030-31 from 3,079 billion passenger-km in 2000-01 the major share would be of private and para-transit modes (55.73%) (Chandiramani, 2016). To tackle the pollution in Delhi, the government took an initiative by implementing odd-even formula for four wheeler private vehicle for 15 days on trial basis starting from January 1st 2016. Under this, vehicles having odd number plate ride on odd days while even number plate car ride on even days applicable from 8 am to 8 pm except Sundays. This formula got mixed review and mixed response, as some experts criticised the formula while some reports said that during the 15 days trial the micro-climatic condition became worse than the usual. Even the Supreme Court said that the step taken by Delhi government is improper as they implement the odd-even formula without consideration of certain problems faced by people during that time. However, we cannot say with certainty that this scheme completely failed. As the failure of 'odd-even' can not be established with certainty; in order to implement it again government should take care of specific problems raised. Government could further organise the awareness campaign among people as well as school children, emotional advertisement appeal as it relates to the soft corner of human being, make essay way to excess the public transport and also increase the number of public transport. However, improving public transport, especially the 'last mile connectivity' has to be improved for better implementation and desired results. Implementation of regulation and pollution check is essential. For transport official's regular check the pollution norms and standard need to be set. Instruction given by higher authority has to percolate to the street-level implementation. In certain case it was reported that despite severe objections from the transport department, the automobile companies continue selling BHARAT STAGE III (BS III) vehicles violating the rules.

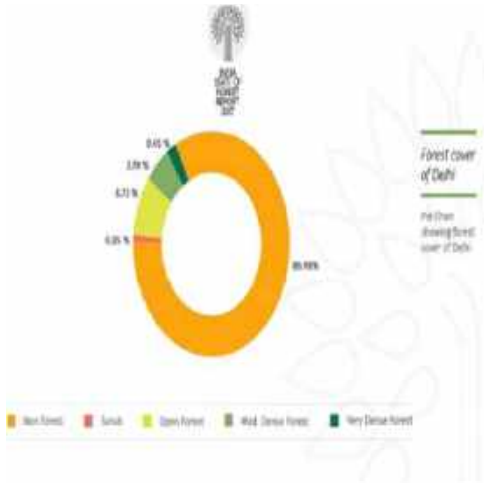
There are additional issues, which ought to be considered in order to mitigate the impact of climate change in metropolitan city like Delhi. It might be addressed if governments, administration, planners and citizens work together and are aware of the environmental degradation. The issues are follows:

Trees cover in Delhi went down from 123 sq. km. in 2009 to 111 sq. km. in 2015, before rising to 113 sq. km. in 2017 according to the forest survey of India's state of forest reports (Nandi, 2018). Vegetation has the potential to modify climate at large scale and also the micro-climate in any city-region, especially the impact of UHI (Grover and Singh, 2015). The government at one point of time was in the process to order felling off of the 17000 trees in South Delhi for redevelopment of colonies; it would further lower the available green-space in Delhi if such an order gets implemented. After the huge protest by environmentalists and civilian, government withdrew the orders.

For the last two consecutive years lifestyle of people in Delhi has become worse during the winter season because of smog in early winter. In 2016, the pollution level of Delhi increased by 16 times more than the safe limit, while in 2017 on November 7, the air quality was reported to be more than 10 times worse than the WHO permissible limit (Delhi Report 1, 2016; Guardian, 2017). Delhi's air quality has been deteriorating since early 1990s. The table below shows the increase in concentration of NO2 over last two decades. The concentration of particulate matter is on the rise and worsens in early winter, due to lowering temperature which constrains the ability of air to rise and pollutants fail to escape.



Forest cover in 2005



Forest cover in 2017

Source: Forest Survey of India (Forest Survey of India, 2005 and 2017)

Table 3: Ambient air quality of sulphur dioxide (SO2), nitrogen oxide (NO2) and particulate matter (PM10) level (Âµg/m3)

Delhi	1996	2000	2004	2008	2012	2015
(SO2)	17.3	15.2	9.9	6.6	5.0	5.0
(NO2)	39.7	39.9	46.1	56.7	59.0	65.0
PM10	-	155	149	214	237	220

Source: CPCB, New Delhi

Smog in the air has the potential to cause severe health hazards. WHO has identified, five specific diseases, namely, acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease (COPD), lung cancer, ischaemic heart disease (IHD), and stroke (WHO, 2018). Reduced visibility adds to higher road accidents on Delhi roads which otherwise also is vulnerable for drivers. In other words, Delhi lifestyle seems to come to a grinding halt for few days, as schools were closed, doctors issue advisory to people especially with asthmatic symptoms and cardiac cases. The government officials, agencies and citizens need to take steps towards mitigation of such problems.

Contemporary relevance of urban climate

It is established that specific heat capacity of building material is much higher than clay, which causes extreme heat in summer and extreme cold in winter (Chapman, et al., 2017; Pomerantz, 2000). This has multiplier effect, as people living in town use more air conditioning material without considering the consequences that further contributes to enhance air temperature. Alterations of surface area, improper urban planning, air pollution etc are causing this increasingly growing phenomena and it is accountable for human discomfort, human causalities and decline of climate. Owing to vehicular and other emission, urban areas also contain higher concentration of pollutants such as carbon monoxide, the oxide of sulphur and nitrogen, and particulate matters. The concentration of pollutants depends upon the emission source and often gets compounded by certain

practices of burning in surrounding regions, including brick-knil. If there is higher number of emission sources, it will lead to higher temperature, poor visibility and erratic precipitation in and around those cities. This is one of the reasons why Delhi is covered with smog in winter which laid the severe problem for Delhi people. In summer due to the hot climate the air rises up usually higher than that of winter and clears the air.

According to the World Economic Forum, Delhi, Varanasi and Patna are among the 4300 most polluted cities based on the amount of particulate matter under 2.5 micrograms found in every cubic meter of air. A recent study by the Indian institute of Tropical Meteorology (IITM) and the World Meteorological Organisation in Geneva, Switzerland, lists Delhi along with Kolkata, Jaipur, Ahmedabad, Mumbai, Nagpur, Bengaluru, Hyderabad as cities with significant temperature rise during 1971-2013. Delhi is among four cities in the list which showed a decreased in mean annual temperature from 1901-1970, before the trend got reversed (Madaan, 2016). This indicates increasing urbanisation has played a key role in rising temperature. Development or expansion of cities and towns results in the loss of vegetation cover. A study by Choudhary and Arya (2018) shows that cemented road, large building blogs are replacing vegetation which is ultimately incrising temperature in and around the cities (Bhargawa, 2017). The intensity of urban heat island depends upon the materials which have been used for the construction and its heat emission and absorption capacity.

It is heartening to note that cities are also increasingly becoming sites for climate response. Bulkeley (2013) argues that urban centres are vital part of the global response to climate change. City plays a multi-dimensional role in the creation and recreation of climate change narratives. Gaitani et al. (2011) in their study of the city of Athens showed the impact of intervention in the form of introduction of different material in the city. In the study it was established that use of 'cool pavement' can decrease pavement temperature by 10 degree and solar reflectance by 0.25 (Gaitani et al, 2011:54-55). The measure like increase in green space has also had the potential to moderate the city's micro-climate (Schiano-phan et al. 2015; Zhou et al., 2018). Cities in these ways are not only sites of climate negotiations, but also site of positive interventions to mitigate the negative externalities of industrialization based urbanization process.

Conclusion

The discussion here and earlier in literature indicate towards multiple views about certainty and extent of the exact contribution that cities make to green house gases (GHG) emissions and about relative vulnerabilities to the effects of climate change. Urban climate effects in particular the 'urban heat island effect', erratic precipitation pattern, changing ambient air quality due to high population density and economic activities are responsible for worldwide greenhouse gas emission. The proportion of contribution of cities in GHG ranges between 40 per cent 80 per cent (Shepherd, 2005).

Urban populations in developing countries are both vulnerable and are increasingly contributing to climatic threats and consequent negative health effects. The quest for decent livelihood is forcing people to migrate toward the cities. It is the government responsibility through institutions to provide the safe environment, clean air, safe drinking water facilities, transport facilities etc. for their citizen. In order to mitigate or reduce the Urban Heat Island, institutional initiative to incorporate technology and materials that has lower heat emission would be desirable. Along with institutional initiatives, it is also the responsibility of citizens to protect the environment at individual's level.

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Urbanization and Land use/Land Cover Change in Varanasi City

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Abstract

Urban areas contribute a significant share to nation's gross domestic product (GDP). In India, the urban population is currently 31.16 per cent of the total population and it contributes over 60 per cent of India's GDP. It is projected that urban India will contribute nearly 75 per cent of the national GDP in the next 15 years. Cities are also referred to as the engines of economic growth. There is an increasing need for the cities to get smarter to handle this large-scale urbanization and finding new ways to manage risk, increase efficiency, and improve quality of life. The present study of land cover of Varanasi City from 2001 to 2016 (15 years) shows rapid change in the landscape as there is high growth in the built up area only within fifteen years. The study is based on the detection of change in the urban land cover of Varanasi City using temporal data of Landsat TM 7 and Landsat ETM images of 2001 and 2016. Detection of change by using images of two decades is very much effective as it is projects the variation in the landscape over time. Evaluation of the urban landscape change from 2001 to 2016 can provide important information on decision making processes as it can indicate the increase in urban area or reduction in vegetated area, with significant impact on the environment. Built-up areas have occupied the sparse and densely vegetated lands while fallow land has reduced marginally and water body is showing almost stagnant condition over time.

Keywords: *urban development, sustainability, land use/land cover change, change detection, varanasi city*

Introduction

India is one of the countries with the treasure of great cultural heritage but also one of the inadequate users of these assets for poverty reduction and inclusive development especially in urban areas (Silverman, 2011). Indian cities are passing through early urbanization stage. Emphasis has been given on urban renewal as an integral part of urban development and planning has started gaining acceptance with the national and the state governments now putting in place more funding. It is essential to link cultural treasure with city development planning

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and local economy development together with inclusive development (Yigitcanlar and Velibeyoglu, 2008). There is a rising consensus in the scenario of urban India that encourages building of appropriate policies at national, state and local levels, financial mechanisms and capacity for efficient management are urgently required to improve the stewardship of historical and heritage assets in order to improve livelihoods and empower urban poor communities (Chambers and Conway, 1992). A major move in focus is required to fill existing identified knowledge gap in a critical moment of the urbanization process in India. Rehabilitating historical assets, conserving their cultural wealth and upgrading their infrastructure are the integrated approach to urban local economic development whereby historic cities can be leveraged as (a) community service hubs for internal users (local communities living in the historic cores and surrounding neighbourhoods); and (b) sustainable tourist destinations (people travelling from other cities, other regions, countries).

Study area

Varanasi is one of the metropolitan cities of India (Das and Parikh, 2004) lies in the state of Uttar Pradesh. It is the fourth largest city of the state well known for its mystic Ghats and rich architectural heritage. The city is situated between two mighty rivers viz. "Varuna" and "Assi" and therefore known as Varanasi (Kumar et al., 2012). The city is also called Banaras or Kashi (Singh, 1997). The city is believed to be more than 3000 years old and considered as one of the oldest living cities of the world. Holy River Ganga passes through the cast of the city (Kumar et al., 2012). There are 85 ghats on the river Ganga, frequently visited by large number of pilgrims everyday for taking holy dips in river Ganga. The city has good connectivity with air, road and railway links due to its favorable topography.

This historic city has a typical character where more than 100 narrow lanes having houses and commercial establishments on both sides leading to 85 ghats (Nayak, Raha and Das, 1995). These lanes stretch to 0.5 to 0.8 km, long and connected with the main roads of the city. The other parts of the city enjoy relatively wider roads and better infrastructure. The newer developments are taking place beyond Varuna River called Varuna Par as well as on the other side of River Assi. Varanasi has number of celebrated temples besides holy river Ganga which attract a large number of devotees from within and outside the country.

The city is also known for its silk spinning and weaving industries as well as for metal manufacturing industry. Banarasi sarees are renowned globally for their gold and silver brocade or zari, fine silk and opulent embroidery (Basole, 2015; Singh and Naik, 2009). Besides, the city exports betel leave handicrafts, rugs and durries to various foreign countries. The indigenous population of the city is also famous for their great skills in producing brass ware, copper ware as well as gold jewellery. Varanasi town lies between the 25°15' to 25°22' North latitude and 82°57' to 83°01' East longitude. The river Ganga only here flows south to north having the world famous Ghats (Hamner et al., 2006) on the left bank of the river

Objective of the study

The main objective of present research paper is to analyse to understand urban development processes.

Demographic trends and urban profile

Varanasi Municipal Corporation (VMC) sprawl over 82.1 sq. kms providing shelter to over 1.2 million as per 2011 Census and covering 34.7 per cent of district population. The corporation is divided into 5 administrative zones and 90 wards for decentralised governance and efficient service delivery. The increase of population in Varanasi urban agglomerate area being

near about 2 million in 1931 and reaching over 14 million in 2011 (Figure 2). Although the increase in population has remained constant, the growth rate has fluctuated in several decades. One prominent feature to be noted is that after 1991, the growth rate has declined considerably indicating the fact that urban renewal is the need of the hour.

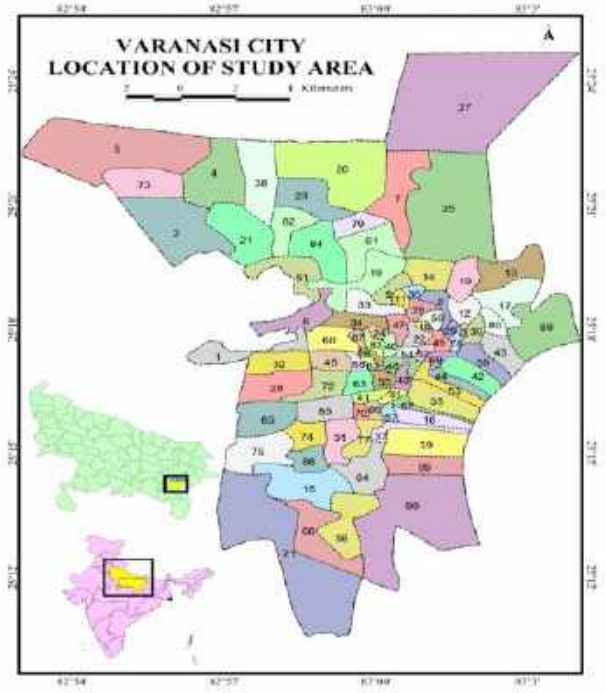

Fig. 1
Source: Prepared by authors

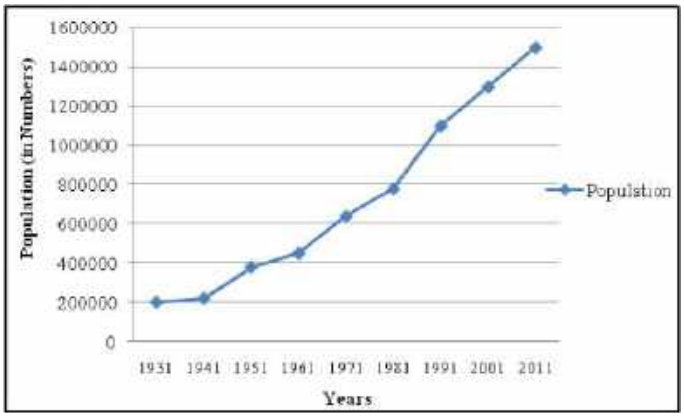

Fig. 2
Source: Census of India, 2011

Present land use scenario

Efficient land management is a tough task for administrative authorities to tackle for city's development (Carter, 2002). Also in the context of haphazard urban expansion valuable agricultural lands are transforming into urban lands (Xiao et al., 2006 and Fazal, 2000). Urban land is a scarce resource and needs to be judiciously utilised according to the dynamic needs of the urban environment (Seto et al., 2011). In order to prepare blue print of future land uses, a study of the existing land use is necessary (Figure 3).

The development area of Varanasi Municipal Corporation has been broadly divided into two zones: Zone A and Zone B (Singh, 1977). Haphazard urban offshoot are growing in the area to the left of River Ganga (comprising of areas like BHU, Varanasi Municipal area) and Zone B along the right bank of river Ganga (including areas like Ramnagar and Mughal Sarai) (Joshi, Kumar and Agrawal, 2009). Emphasis has been given on zone A in the Master Plan 2011. The total area of city under planning jurisdiction was 14,494.40 ha. in the year 1991 (Rana and Singh, 2000). The residential area constitutes with maximum of 38 per cent area (i.e. 5457.24 ha) followed by agricultural and allied activities, accounted with share of around 20 per cent (i.e. 2832.06 ha), further followed by space for parks and playgrounds as recreational activities, which constitute 19 per cent (i.e. 2705.76 ha). The detailed land utilization pattern for the Varanasi town as per the master plan report of year 1991 is discussed (Table 1).

Master plan 2011

Varanasi Development Authority (VDA) has come with the Master Plan 2011 for the futuristic development of the city, states that total area of the city will increase from 14494.40 ha to 17927.22 ha. This increase in total area of city with 23.68 per cent has been recorded in the Master Plan 2011.

The land use pattern of the city for year 2011 revealed that considerable change in residential land use, registered a growth of more than 14 per cent as compared with master plan of 1991 which in the existing Master Plan accounted with almost 52 per cent of the total land use. This increase would be due to rising demand of residential sector for meeting the needs of migrating as well as local growing population. Industrial area holds the share of 3.66 per cent in total land use, which has been recorded

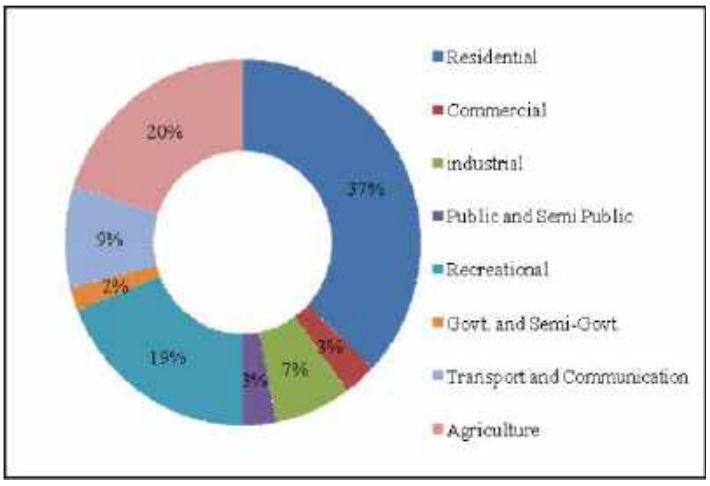

Fig. 3
Source: Master Plan, 2011

Table 1: Land use pattern, Master Plan, 1991

Land use	Area (Ha)	Percentage
Residential	5457.24	37.65
Commercial	475.10	3.28
Industrial	981.37	6.77
Public and Semi Public	450.42	3.11
Recreational	2705.76	18.67
Govt. and Semi-Govt.	292.18	2.02
Transport and Communication	1300.27	8.97
Agriculture	2832.06	19.54
Total Area	14494.40	100.00

Source: Master Plan, 1991

with drastic fall of almost 46 per cent. Industrial and commercial land use together comprise of marginal share of over 7 per cent of the total land use (Table 2)

Table 2: Land Use Pattern Existing Master Plan, 2011

Land Use	Area in Ha	Percentage
Residential	9254.61	51.61
Commercial	618.23	3.45
Industrial	656.19	3.66
Public and Semi Public	1309.07	7.30
Recreational	984.47	5.49
Services	103.97	0.58
Govt. and Semi-Govt.	1433.15	7.99
Tourism and Heritage	423.73	2.37
Transport and Communication	1460.35	8.15
Agriculture	1683.45	9.39
Total	17927.22	100.00

Source: Master Plan 2011, Varanasi

The share of total area under the hold of tourism and allied activities is significantly low (less than 3 per cent), compared to similar placed cities are 6 per cent. It can be observed from the above tables that there is a sharp reduction in the agricultural land use, which clearly indicates that rural agricultural land on the fringe and suburbs are gradually being used up for the construction of new colonies (Figure 4).

The major setbacks of Master Plan 1991, which have been tried to mitigate in the Master plan 2011 are under utilization of area prescribed for industrial land use, issues of unauthorized constructions, developments which came up due to the construction of the bye-pass and under utilization of areas under green/recreational use (Figure 5).

The detailed analysis of Master Plan

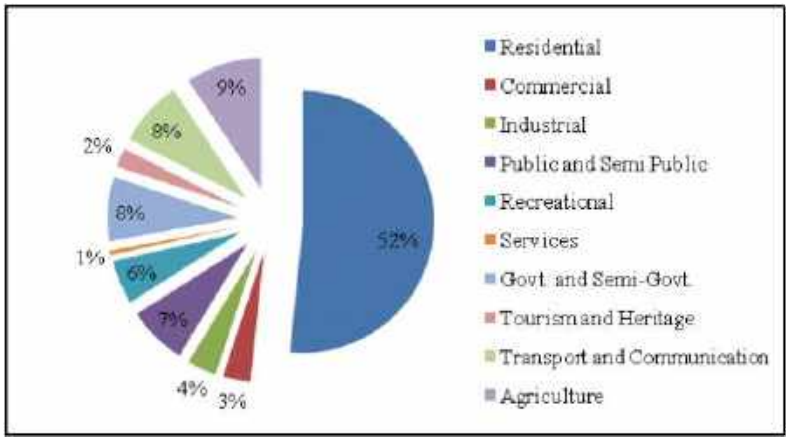

Fig. 4

Source: Master Plan-2011, Varanasi

Varanasi 1991 provides the picture of identified gaps between proposed and achieved targets over the period of two decades, the land uses could not be developed to the expected levels. Major identified gaps can be observed in residential, recreational, PSP and industrial uses where the development was less than the prescribed levels. MPV-2011 focuses on the development of residential, industrial and recreational areas.

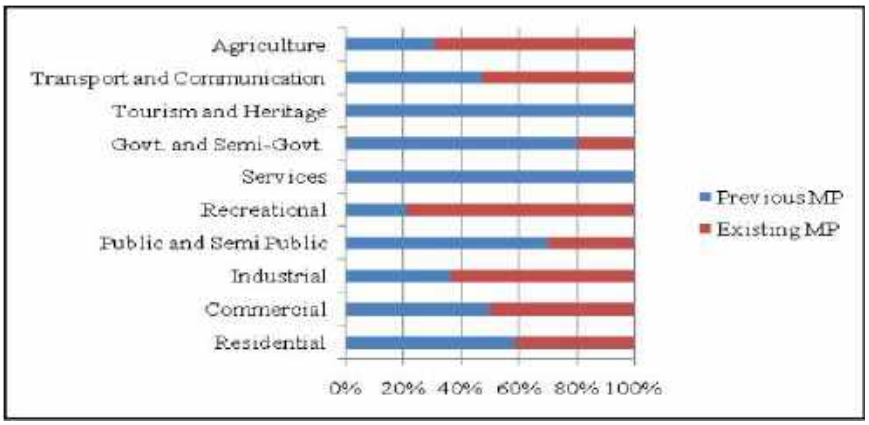

Fig. 5

Source: Master Plan-2011, Varanasi

The emerging key issue relating to physical planning and growth management in Varanasi is that physical development and growth is unsustainable. The attention should be given on the implementation of Master Plan correctly and reserved lands have to be used for specified purpose. Master Plan should be implemented with periodic monitoring at appropriate intervals. The planning department lacks with proper assessment of the land requirement for the planned development.

Land use/land cover changes: a spatio temporal analysis

Land cover of Indian cities is changing rapidly due to continuous rapid population growth

and urbanization. Peripheral or suburban area of city is growing at a faster rate. Sparse vegetation, wetland, forest and water body are transforming into built-up area, to satisfy the demand rising of infrastructure and industry for the highly growing population. Remote sensing is a crucial tool for planners in studying land cover changes. Satellite imageries provide the opportunity to administrators assisting in rapid acquisition and time series data of land cover, useful to identify the spatio-temporal land cover changes and getting brief picture of its exorbitant impact on the environment. Continuous changes in worldwide urban processes, especially the urban expansion posing direct and indirect significant impacts on natural and human systems at all geographic scales (Miller and Small, 2003). Socio-economic problems posing adverse impacts of crowding, insufficient infrastructure and housing together with urban climate and ecology related problems in urban set up needs the constant monitoring.

Availability of high resolution satellite data simplifies the task of detailed spatial analysis, identification and monitoring of environmental issues in urban regions at desirable spatio-temporal scales (Miller and Small, 2003). Urban environment presents the snapshot of one of the most important areas for remote sensing analysis due to the high spatial and spectral diversity of surface features (Maktav et al., 2005). The detailed analysis of spatio-temporal characteristics of land cover changes is also necessary to understand the pattern of urbanization. Any significant variation with respect to urban expansion or vegetation and agricultural land may have profound impact on the people of the region. Furthermore, such in-depth analysis can provide sufficient information for decision-making. A large number of researchers have studied land cover changes particularly in the urban areas. The present study is based on the detection of change in the urban land cover of Varanasi City using temporal data of Landsat TM 7 and Landsat ETM. Images of 2001 and 2016 have been considered to analyse the change in that area. Detection of change by using images of two decades is very much effective as it is projecting the variation in the landscape over time. Evaluation of the landscape change from 2001 to 2016 can provide important information on decision making processes as it can indicate the increase in urban area or reduction in vegetated area, with significant impact on the environment. Change in a particular land cover has been critically analysed and mapped in this study.

Data base

In the present study two satellite imageries have been downloaded from the USGS website (http://glovis.usgs.gov) over the 15 years of time period (2001-2016). The details of the satellite imageries, acquisition date and resolution have been given in table 3. Both the data sets are projected in UTM projection with zone number 43 and WGS 84 datum. Satellite image of 2001 has been considered as the base data and image of 2016 is co-registered using first order polynomial model with that data base (Table 3).

Methodology

Land cover classification

Tools and techniques of image analysis are

Table 3: Details of Satellite Images Used in the Study

Sensor type	Acquisition date	Spatial resolution
Landsat TM 7	13 April 2001	28.7 m
Landsat ETM 8	03 April 2016	28.7 m

Source: http://glovis.usgs.gov

rapidly evolving, with the growing requirement of discrete thematic land surface information from satellite imagery using classification based techniques (Prenzel and Treitz, 2005). In the present study, 28.7 meter resolution TM data is used for the estimation of land cover in the urban area. But high resolution data could be more useful to identify the complex land cover of Varanasi City. However, Landsat imagery is useful for first level of classification of such urban land cover. Major land cover types are considered and following classes have been chosen like-Built-up, water body, dense vegetation, sparse vegetation, cultivated land and fallow land.

Identification of the urban pattern of land cover changes over time is extremely complex. Availability of Satellite data with good spectral and radiometric resolution is crucial for accurate land use and land cover classification. Over the period of time digital classification has received particular attention in the last few decades due to excessive growth in computing power. Jain and Dubes (1988) presented a description of number of clustering techniques for digital classification. Automated classification methods are usually based on multi-spectral classification techniques (per-pixel classifiers). These methods assign a pixel to a class after determination of its statistical similarities, with respect to a set of classes in terms of reflectance (Gong et al., 1992). The flow chart of these methods is given in figure 6.

Change detection

Land cover change is a continuous phenomenon in expanding cities. Change detection can be done in couple of ways, including image differencing, thematic land cover change and contextual change analysis. The present study highlights thematic land use and land cover analysis considering three decades and radiometric normalization is ignored. Change matrix has been produced to display the changes that have occurred due to urban expansion and subsequent growth. A flow diagram for the methodology is given in Figure 6 with the sequential explanation of the entire processing to identify land use - land cover changes.

Land use land cover change analysis

The satellite imageries of the year 2001 and 2016 given in figure 7 and 8 provide the highlights of spatio-temporal changes in land use and land cover occurred in the city within a period of fifteen years. Present study of Varanasi City land cover from 2001 to 2016 shows rapid change in the landscape as there is high growth in the built up area only within fifteen years. Built-up areas have occupied the sparse and densely vegetated lands while fallow land has reduced marginally and water body is showing almost stagnant condition over time. Urban built-up area has extended outwards from the central eastern part to the rest of the region and has grabbed most of the areas in northern, western and southern part. Eastern part is rather saturated from the beginning as it marks the limit or boundary of the Varanasi City area and if this trend of growth continues then most of the vegetated areas will be occupied by built up in

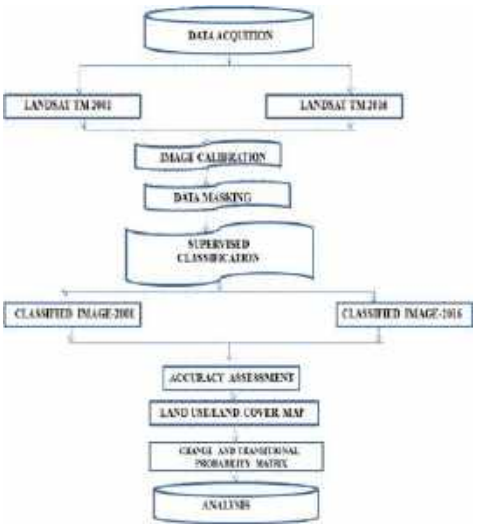

Fig. 6

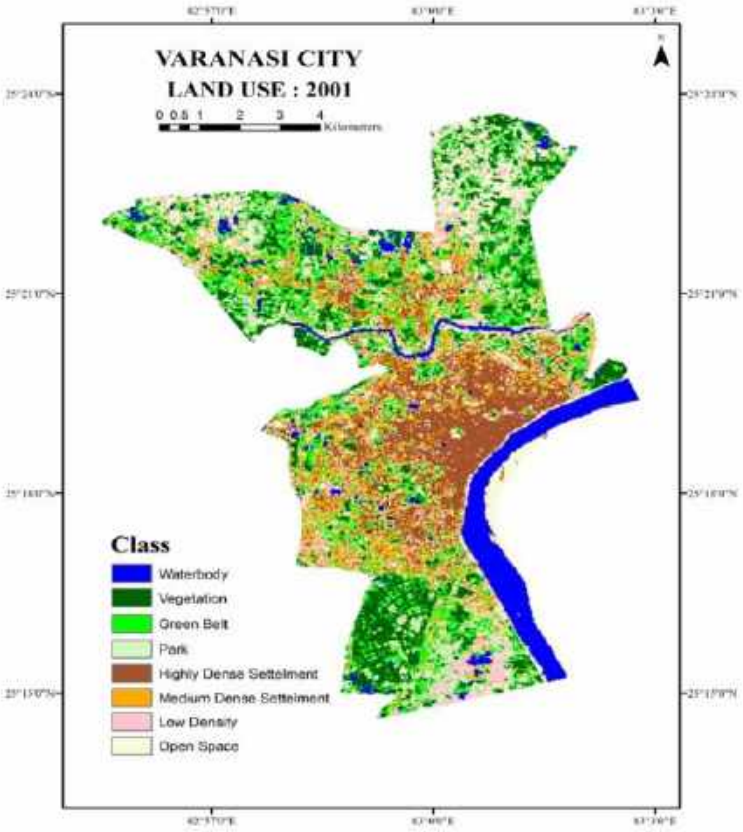

Fig. 7
Source: Prepared by authors

near future which may create a threat to environment (Figure 9).

The major vegetation loss due to urbanization is seen in the western, northern and southern boundary of Varanasi City during 2001-16. Major portion of Varanasi City is dominated by the land use class built up area as found from the 2016 image analysis, and also gradual decrease in vegetation and fallow lands in the surrounding area of the city observed. The land cover statistics of year 2001 and 2016 is given in the table 4, which shows the sequence of change of individual land cover type over the period of 15 years.

The highlight of the glimpse of the story of land use and land cover changes in Varanasi city, depicts the massive shift in land utilization categories just within a time span of fifteen years (Table 4 and Figure 10).

The area under green belt has registered significant fall of 847.04 ha. due to the rapid increase of area under highly and medium dense settlements which have increased dramatically from 1223.07 ha. and 1285.41 ha. in the year 2001 to 2547.54 ha. and 2632.21 ha. The peak rise in settlements area is also responsible for sharp decline of area under open space, park, vegetation and water body. The share of area under park has registered a decline of 881.68, followed by green belts with 847.04 ha. further followed by area under vegetation, water bodies and open spaces with rapid decline of 786.14, 355.42 and 91.95 ha.

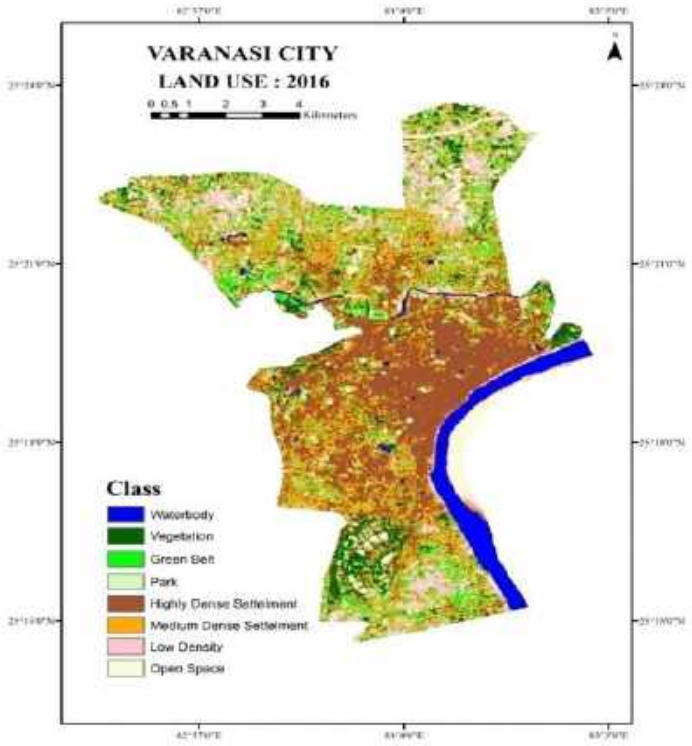

Fig. 8
Source: Prepared by authors

Table 4: Changes in land use/cover in Varanasi City

Class	Area (ha)		
	2001	2016	Change
Green Belt	1549.53	702.49	-847.04
Highly Dense Settlement	1223.07	2547.54	1324.47
Medium Dense Settlement	1285.41	2632.21	1346.8
Low Density	1159.7	1450.66	290.96
Open Space	452.39	360.44	-91.95
Park	972.65	90.97	-881.68
Vegetation	1243.85	457.71	-786.14
Water Body	824.28	468.86	-355.42
Total	8710.88	8710.88	

Source: Calculated from Landsat Images of 2001 and 2016

Conclusion

Varanasi city provides the massive shift in land utilization categories just within a time span of fifteen years. The area under green belt has registered significant fall of 847.04 ha. due to the rapid increase of area under highly and medium dense settlements which have increased dramatically from 1223.07 ha. and 1285.41 ha. in the year 2001 to 2547.54 ha. and 2632.21 ha. The peak rise in settlements area is also responsible for sharp decline of area under open space, park, vegetation and water body. The share of area under park has registered a decline of 881.68, followed by green belts with 847.04 ha. further followed by area under vegetation, water bodies and open spaces with rapid decline of 786.14, 355.42 and 91.95 ha. The study of land cover of Varanasi City from 2001 to 2016 shows rapid change in the landscape as there is high growth in the built up area only within fifteen years. Built-up areas have occupied the sparse and densely vegetated lands while fallow land has reduced marginally and water body is showing almost stagnant condition over time. Urban built-up area has extended outwards from the central eastern part to the rest of the region and has grabbed most of the areas in northern, western and southern part.

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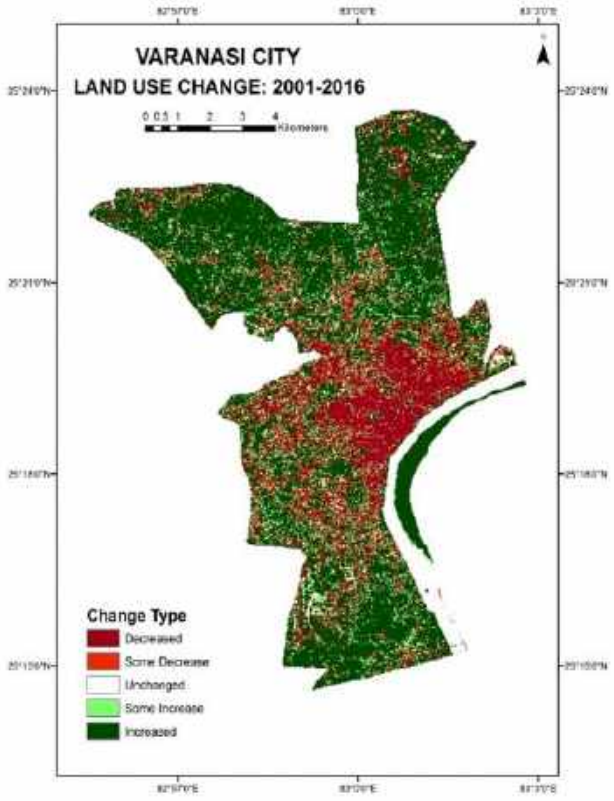

Fig. 9
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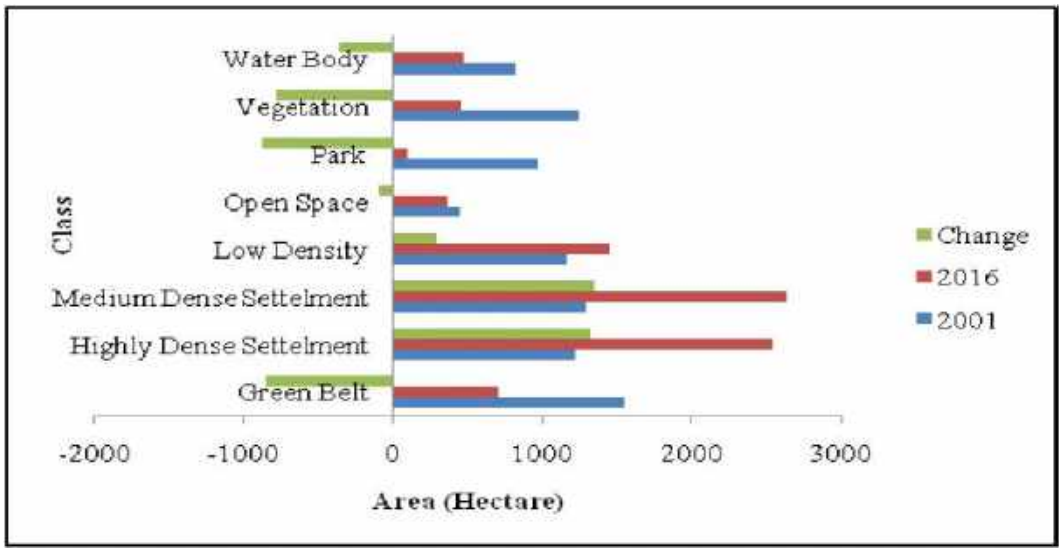

Fig. 10

Source: Calculated from Landsat Images of 2001 and 2016

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Urban Sprawl and Its Impact on land Use and Socio-Economic Condition: A Case Study of Barddhaman District, West Bengal

Arindam Dasgupta[1] and Suman Paul[2]

Abstract

Urban sprawl is a worldwide phenomenon. It is not only a haphazard physical explosion of urban population but also manifests a disorderly and discontinuous development of urban places. Urban sprawl may also be termed as process which takes place slowly or rapidly to occupy the adjacent land of a city or a town and brings about socio-cultural changes in the land use pattern, demographic features (population growth, literacy rate, occupational structure etc.) and transforms the economic livelihood of the people of the concerned area. In the present study villages within 10 km. circular buffer of Burdwan Municipality have been chosen which are located in Barddhaman - I & II blocks of Barddhaman district, West Bengal. The objectives of the study are two folds- First to identify the direction and type of urban sprawl which has taken place in BarddhamanI and BarddhamanII block during 1971 - 2001 and second, try to assess the nature of influence of this process on the social and economic condition of the study area by selecting three villages within 10 km. circular buffer of Burdwan Municipality. To identify the direction and type of urban sprawl, toposheets, LISS III Images of different time span of the study area have been considered along with different secondary data sources. Village level Census data have been analyzed for four consecutive census years i.e. 1971, 1981, 1991 and 2001 in order to find out the nature of influence of urban sprawl on the socio-economic aspects of the study area. The analysis of satellite imageries of different time span has indicated that the urban sprawl has been spreading fast in the surrounding region of Burdwan Municipality located in both Barddhaman-I and Barddhaman block-II and specially toward eastern direction where urban sprawl has taken shape of ribbon development along the NH -2 . Another type of sprawl i.e., leapfrog development have been found in the north-eastern part of the both the blocks and low density sprawl have been identified in the surrounding region of Burdwan Municipality. The temporal study (2001-2011) of land use of the three selected villages has revealed interesting nature of changes and household survey have portrayed socio-economic characteristics related to sprawl.

Keywords: *circular buffer, ribbon development, leapfrog development, temporal study, land use*

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Introduction

Unplanned spatial growth of a town or city occurs due to increase in population can be termed as urban sprawl. Hence, any area, which is under the jurisdiction of a municipal corporation, cantonment, or any notified town, exceeds its administrative boundary and grows outward without any check, is considered to be a sprawl. It has been observed that urban sprawl is a worldwide phenomenon. In developed countries about 3,000 sq. km. area of agricultural land has been swallowed by urban growth every year. Japan has lost about 7.3 per cent of its agricultural land for construction of buildings and roads. European countries like Norway and the Netherlands have lost 1.6 percent and 4.3 per cent of their agricultural land respectively due to haphazard urban growth (O.E.C.D.1979). Similarly, U.S.A. and Canada have lost 4,800 sq. km. of prime cropland under roads, building and reservoirs and other non-farm uses (Tiwari & Saxsena, 2012). In India 180,000 sq km of land (5.5 per cent of the total geographical area) is under various types of urban land use. A number of authors have defined urban sprawl in their way. Such as Deshpande (1992) has recognized the process of urban sprawl like the "floating water" which occupies every place available for its spread. Research works on various aspects of urban sprawl have been carried out by some social scientists that have helped to understand the nature and mechanism of sprawl. Mujtaba (1994) has described the process of urban sprawl in Hyderabad city using remote sensing approach to identify type and directions of urban sprawl. He observed that the rate, at which a particular area grows i.e. sprawls, is not the same. There are several factors, which govern the rate and are also responsible for the growth to continue in a particular direction. The 'traffic node' is assumed to be the most important factor for the beginning of a settlement. The impetus generated due to installation of any industry is next important factor in growth of a city. Commercial activity - the third important factor in identifying the type and direction of growth of urban areas, and the physical factors of the region like rivers, plains, hills etc are equally important factors for determining the direction of sprawl.

Types of sprawl

In general, three types of sprawl can be identified (Barnes, et.al. 2001)

A. Low Density Sprawl: This is a consumptive use of land for urban purposes along margins of existing metropolitan areas. This type of sprawl is supported by a piecemeal extension of basic urban infrastructure such as water, electricity, sewage, and sanitation systems and roads.

B. Ribbon Sprawl: It is a development that follows major transportation corridors outward from the urban cores. Lands adjacent to the corridors are developed but those without direct access remain in rural use/cover. Over time these near by raw lands may be converted into urban areas as land values increase and infrastructure is extended perpendicularly from major road lines.

C. Leap Frog Development: This is a discontinuous pattern of urbanization with patches of development that are widely separated from each other and from the boundaries. (After Barnes et.al, 2001)

Study area

It has been found from the report of BDA on Burdwan Planning Area that Burdwan Municipality is one of the top most densely populated area (12,416 persons/ sq.km in 2001)among the municipalities outside Kolkata Municipal Area (KMA) in West Bengal.(KMDAReport,2005). It is worth noting that the proportion of urban population in relation to rural population is steadily increasing (in 1971 rural-urban population ratio was 77:23 and it has changed to 65:35 in 1991) in the whole district. The present study

focuses the two blocks i.e. Barddhaman I and II which include Burdwan Municipality. The area of Barddhaman block-I is 250.41sq.km. and density of population is 718 person/sq.km. whereas the area of Barddhaman block-II is 189.57 sq. km. and density is 733 person/ sq.km.(2001).These two blocks have registered a decline in population growth during 1991-2001 in comparison to previous decades. For example, Barddhaman I block has registered 107% population growth during 1981-1991 and it showed only 23.93% in the next decade (KMDA Report, 2005). Interestingly both of the blocks have shown an increasing trend in population density (KMDA Report, 2005). This indicates the process of urban growth has occurred considerably in these two blocks and it will be worthwhile to study the result of such process. The present study has been taken up in two phases. In the first phase, Barddhaman I and II Blocks have been chosen to study the overall pattern of urban sprawl. In the second phase, three villages i.e. Chandul and Sadhanpur from Block-I and Nandur of Block-II within 10 km buffer area of Burdwan Municipality (fig. no.- 1) have been considered to examine the effect of urban growth on their land use pattern and socio-economic profile. The study area located between 87^0 47' E to 87^0 57' E Longitudes and 23^0 11' N to 23^0 19' N Latitudes.

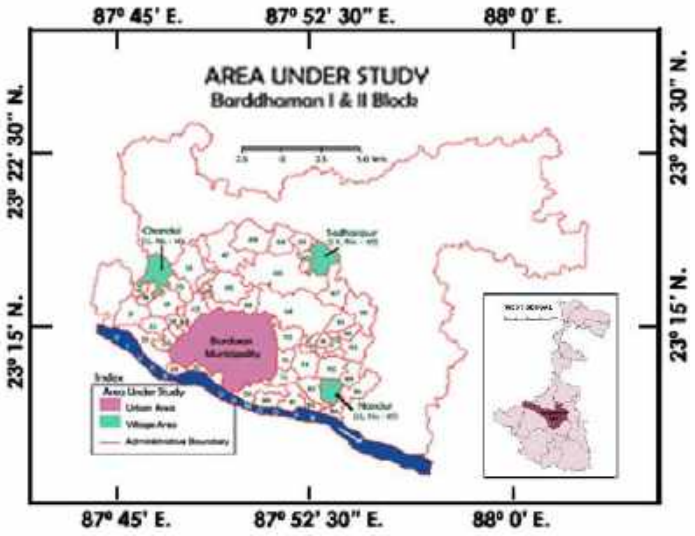

Fig. 1

Objectives

The major objectives of the study are:

- To identify the direction and type of urban sprawl which has taken place in Barddhaman I and II Blocks during 1971 - 2001
- To study the changing pattern of population growth, household density and occupational pattern of the villages within 10 km buffer of Burdwan Municipality during 1971-2001
- To find out the nature of change in land use pattern of the selected three villages within the 10 km. buffer of Burdwan municipality due to rapid growth of built-up area during 2001-2011 and
- Finally, to investigate the influence of

sprawl on the socio-economic profile of the selected villages based on detailed household survey.

Methodology and data base

In order to study the spatial pattern and extent of sprawl during 1971 - 2001 in the study area, SOI sheets (73 M/15 and 73 M/16) with the scale of 1:50000 of 1964 have been considered as base year. Landsat TM (P/R: 139/44) for 1991 and Landsat ETM+ (P/R: 139/44) for 2001 satellite images have been taken into account to analyse the spatio-temporal change in built-up area of Barddhaman I and II Blocks with the help of softwares like Geomatica 10.1; TNT Mips. The method of Maximum Likelihood Classifier (MCL) was used to classify the different land uses in the study area. After that, only built-up areas were extracted from classified images of different time span in order to give a fair idea about nature of change.

Selection of the villages in the study area

Three villages out of fifty four (54) villages of the two blocks which fall within 10 km. buffer of Burdwan Municipality have been selected on the basis of the variables (population density, average family size, household density and percentage of non-primary workers to total workers) chosen from Primary Census Abstract, Barddhaman District, West Bengal Series, 1971-2001. The reason behind the selection is that these villages have shown an increasing trend in all the above mentioned variables during the study period. In order to study the changing socio-economic profile of these villages, 25 households have been randomly chosen from each village and door to door survey was conducted with questionnaire. Secondary sources such as District Gazetteer, Barddhaman and reports concerning socio-economic survey of Burdwan Planning Area (2002-03) have been considered for getting an idea of old and new urban developments in the study area

Findings and analysis

Analysis of Pattern of Sprawl (1971 - 2001)

Burdwan Municipality was established in 1865 but the process of urbanization started before 1650 and gradually the municipality has

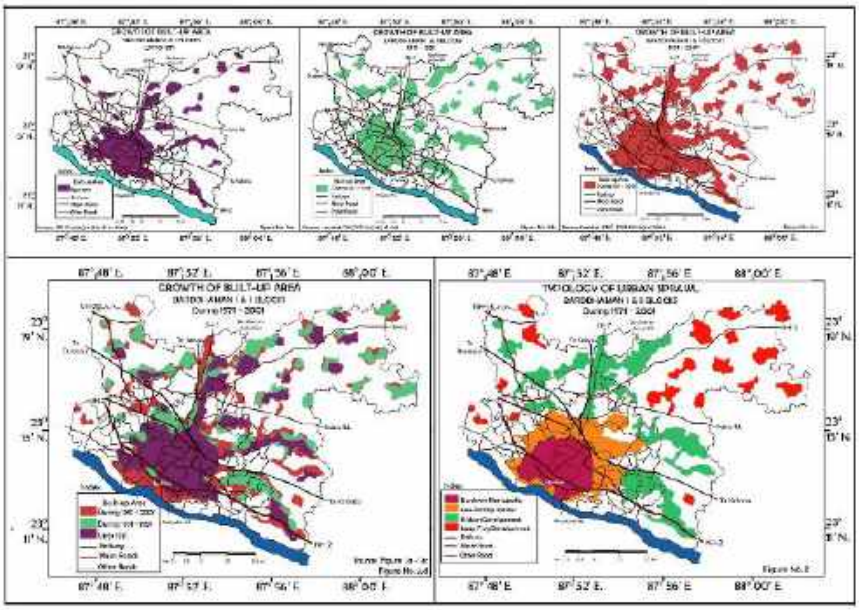

Fig. 2 : Area during 1991-2001

been transformed into a big urban centre as Burdwan is the district headquarters also. The pressure of population has been steadily increasing in this urban centre as it has started providing various types of facilities. In the present study, the urban sprawl which has taken place within the 10 km. circular buffer of Burdwan Municipality under Burdwan - I and II Blocks has been studied in three phases. The different pattern of sprawl during 1971-2001 has been shown in fig. No.-2

- Phase I - Development of Built-up Area up to 1971
- Phase II - Development of Built-up Area during 1971-1991
- Phase III - Development of Built-up

Development of urban built-up area up to 1971

In this phase the only evidence available is Survey of India Toposheets (Toposheet No. 73 M/15 and 73 M/16) which has suggested that extension of urban built-up area occurred in the adjacent areas of Burdwan Municipality i.e. Barddhaman - I and II Blocks. The growth of built-up areas has been observed on all sides of the outer boundary of Barddhaman Municipal-

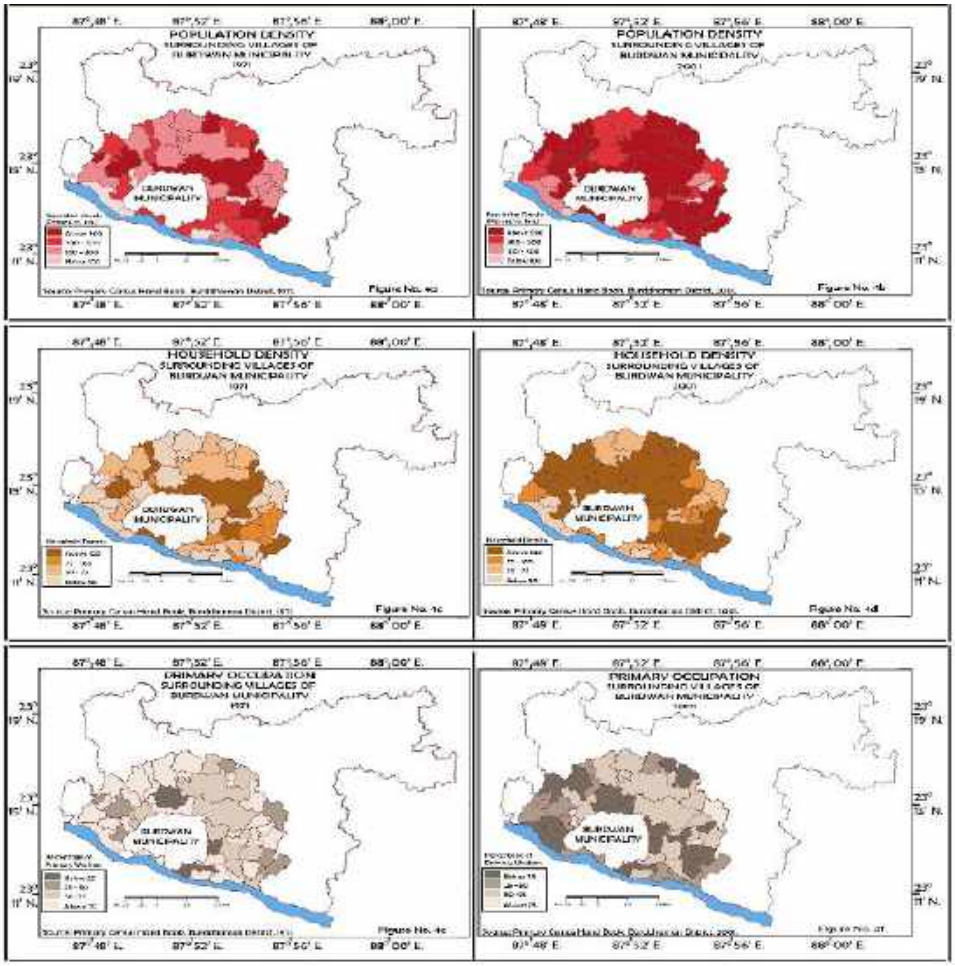

Fig. 3b

ity and it has been further extended along Burdwan-Katwa roadway (SH7) towards northern direction. As this development occurred depending on this transport corridor outward from the core of the Burdwan Municipality, this can be termed as ribbon development. Some built-up areas were also developed on the eastern side of the outer boundary of Barddhaman town along NH-2. It has been found that built-up areas have grown in a leap frog manner on the north-eastern portion of the Barddhaman-I and II Block on both side of the SH-2 (connecting Burdwan and Krishnanagar) (Fig. 3a)

Development of urban built-up area during 1971-1991

It has been found that within twenty years new built-up areas have come up in the eastern, north-eastern and north-western part of the two

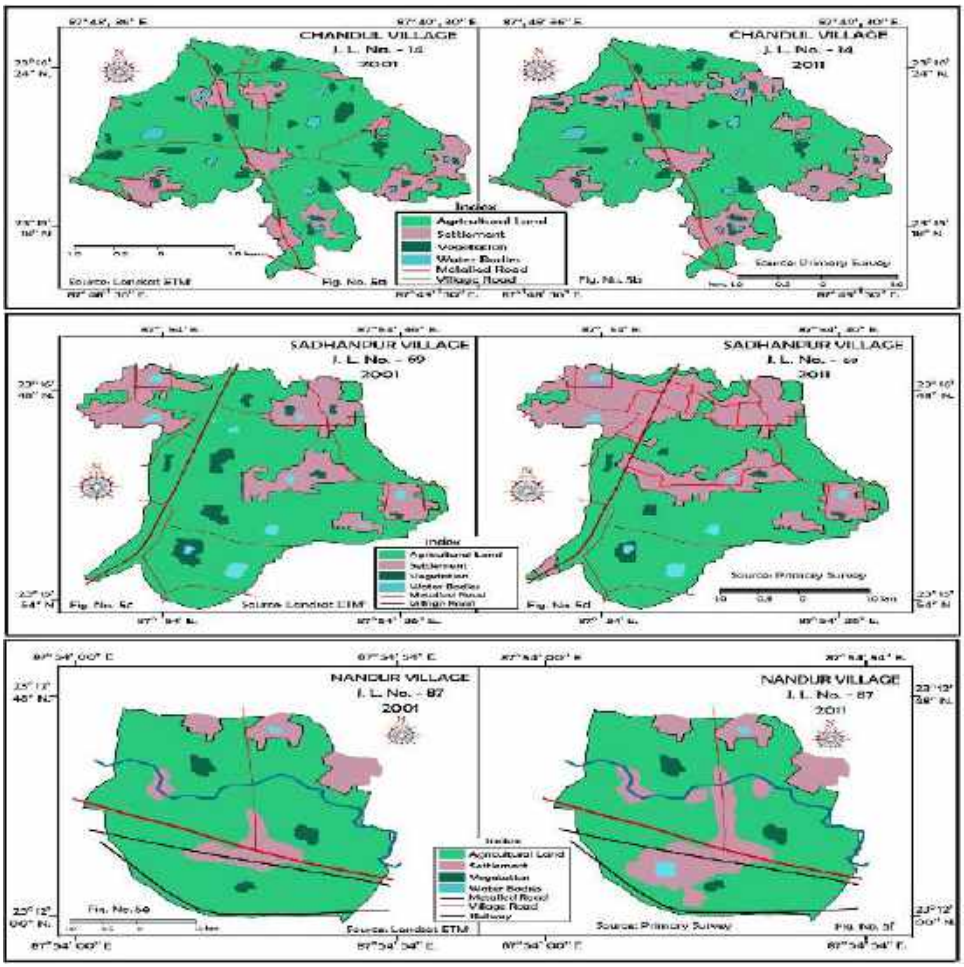

Fig. 3b

blocks under study. The villages located on the eastern side of the outer boundary of Burdwan town (such as Nandur, Gangur, Parra, Sadhanpur and Alisa) experienced rapid expansion of built-up areas on the village land. In the northern direction, ribbon sprawl has further strengthen its presence along Burdwan Katwa Roadway The spread of urban areas was due to growth of communication, development of industries, service sectors, increasing opportunities of job sec-

tors etc. The built up area along NH-2 has been further extended towards Burdwan Municipality whereas built up areas in the north-eastern portion of Burdwan - II Block along Burdwan-Krishnagar roadway SH2 have grown larger. Moreover, new built-up areas have emerged on the north-western part of Burdwan - I Block

Development of urban built-up area during 1991-2001

The unplanned growth of urban built up area occupied more and more village land after 1991 as demand was high for land in order to construct new projects as promoted by Barddhaman Development Authority on PPP (Public Private Partnership) basis. The eastern portion of Barddhaman Municipality falling under Barddhaman Block-II has experienced tremendous growth in built up area along NH2, Bye Pass and Eastern Railway line and also southern portion of Bye pass. These built up areas have taken the advantage of prominuty to both railway line and road and other facilities. The growth of the built up area in thirty years have taken a definite shape and they are portrayed in Fig. 3c and 3d

A number of Mini Townships have also been planned and implemented. These townships are being developed on the land which is basically a village land. The owners of the land have sold of land to the government/ or other private forms based on good offer price. One such township is named Ulhas which has been developed 5 km. away from the municipality. It is a joint project by Burdwan Zilla Parishad and Bengal Ambuja group Srachi Burdwan Developers have started constructing a mini town ship named 'Renaissance' spread over 256 acres of land which is located in the outskirts of Barddhaman town at village Goda. These are efforts on part of Govt. of West Bengal to facilitate the growth of Barddhaman town ship. In this process considerable amount of village land has been transformed into built up area.

Population characteristics and sprawl

The growth rate of the population in the municipality was 49.82 per cent during the period 1971-2001. It is interesting to note that most of the surrounding villages (within 10km circular buffer) show higher growth rates ranging from 150 to 1200 per cent. Relatively high growth rates are observed in Nari(618), Ichhlabad (469), Goda (324), Nandur (310), Chandul (289), all in the periphery of the municipality and along the major transport routes.

The population density of Burdwan Municipality has increased from 6322 person/sq. km. in 1971 to 12,396 person/sq.km. in 2001 i.e. the density has doubled in three decades. Similarly, there has been a rapid increase in the density of population in the peripheral villages and those connected by transport routes. A dramatic increase in population density can be observed in villages like in case of Nari where the population density increased from 294 persons/sq. km in 1971 to 2116 persons/sq. km in 2001 and for Chandul from 309 persons/sq. km in 1971 to 1503 persons/sq. km in 2001. Another village Sadhanpur has registered an increase in population density from 446 persons/sq. km in 1971 to 1867 persons/sq. km in 2001. In case of Nandur the increase in population density is 489 persons/sq. km in 1971 to 1016 persons/sq. km in 2001. It has been further analyzed from the density data that the average density of population in the surrounding villages was between 360 and 1800 person sq.km. in 1971 which at present has increased to 1400-6001 person/sq.km.(fig. no. 4a and 4b).

The increase in the number of occupied residential houses is also an indication of sprawl. In most of the surrounding villages the increase in the number of households has been four to five times. The highest increase can be observed in Goda and Bahir Sabarmangla villages (eight to nine times) whereas Nandur has registered three times, Sadhanpur four times and Chandul near

about two times (fig. no. - 4c and 4d).

The occupational structure also shows a great change. In all the surrounding villages where urban spread is taking place the percentage of workers engaged in non-agricultural activities ranged from 60 to 94%whereas in 1971 this was between 20 and 40%. In the municipality, the share of workers engaged in non-agricultural sector increased from 88.93% to 98.40% between 1971 to 2001. So there is necessity to carry out in depth household level study in three selected villages in order to understand the nature of influence of sprawl on land use and other socio-economic aspects. (fig.no.-4e and 4f)

Land use pattern of the selected villages

Chandul village which occupies 2.39 sq. km. area with population of 3592 (2001), is located in the extreme western part of the 10 km. buffer region of Burdwan Municipality where national highway NH-2 passes through and various artery roads join this highway. It suggests that Chandul village is well connected with various parts of the district. In 2001 the built up areas in this village developed mainly along the road or at the junction of the roads which further spread in the adjacent areas and assumed a greater size(Fig. no.- 5a and 5b). It seems that this sort of connectivity has played an important role for the development of new built-up areas in this village.

Sadhanpur village is located in the northern part of the 10 km. buffer of Burdwan municipality and it has an area of 2.02 sq. km. with population of 3771 (2001). Most of the built-up area has developed on the northern portion of the village and this growth has been facilitated by a main road which passes through the western part of the village from north to south direction. The northern part of this road join with SH-2 (road connecting Barddhaman to Krishnanagar) and southern part of this road connects with SH-7 (road connecting Burdwan to Katwa) which have given great impetus for future development in this village (Fig.no.-5c and 5d).

Nandur village is located in the east of Burdwan Municipality within 10 km. buffer. This village has an area of 1.37 sq. km. and the population of this village is 1392 (2001). The growth of built-up area shows a ribbon type development along village road which is extended from south to north direction. This road joins another major road which passes through the village from south-east to north-west direction. Maximum growth of built-up area has occurred at this junction and it has further spread to the south of the Eastern railway (main line). Small patches of built-up area have also been observed along a canal which crosses the village from east to west direction (Fig. no. 5e and 5f).

Table 1: Land use pattern during 2001-2011 in three selected village

Percentage of land use to total area of village	2001			2011		
	Chandul	Sadhanpur	Nandur	Chandul	Sadhanpur	Nandur
Built-up	22.7	27.4	22.7	48.6	45.3	43.3
Agriculture	65.8	66.1	69.3	43.2	49.7	51.8
Vegetation	7.2	4.2	5.8	5.4	3.6	3.6
Water Bodies	4.3	2.3	2.2	2.8	1.4	1.3

Source: Computed by authors, based on land use survey.

Changing land use pattern of the selected villages

In this phase of study, the Landsat ETM+ image of 2001 has been merged with the respective mouza maps of the selected villages in order to update the land use pattern which existed in 2001. Later the Google Image of the selected villages has been considered to understand the nature of change that has taken place in the 10 years netion 2001-2011. This change has been verified with proper field study and interaction with local people. The land use classes affected by the haphazard growth of built-up area are agricultural land, water bodies and land under vegetation cover.

Table 1 illustrates the overall land use pattern of the selected villages in 2001 and 2011. The table also suggest that there is a considerable increase in built-up area in villages in 2011 as compared to 2001. On the other hand it is also clear that the share of land under agriculture, vegetation and water bodies have shown a decline in 2011 as compared to 2001(Fig.no.-6a).

Table 2: Nature of change in land use pattern during 2001-2011 in sample villages

	Percentage of land use to Total Area of Village	2001 - 2011		
		Chandul	Sadhanpur	Nandur
Category	Built-up	25.9	17.9	20.6
	Agriculture	-22.6	-16.4	-17.5
	Vegetation	-1.8	-0.6	-2.2
	Water Bodies	-1.5	-0.9	-0.9

Table 2 clearly shows that, the expansion of the built-up area has been taken place mainly at the cost of agricultural land. However, small percentage of area of water bodies and vegetation cover have also been affected due to growth of built-up area. If the areal extent of the built-up area is considered, it has been found that 25.9% of land in Chandul village has been occupied by the new construction where as 22.6% of agricultural land as well as 1.8% of land under vegetation and 1.5% area under water bod-

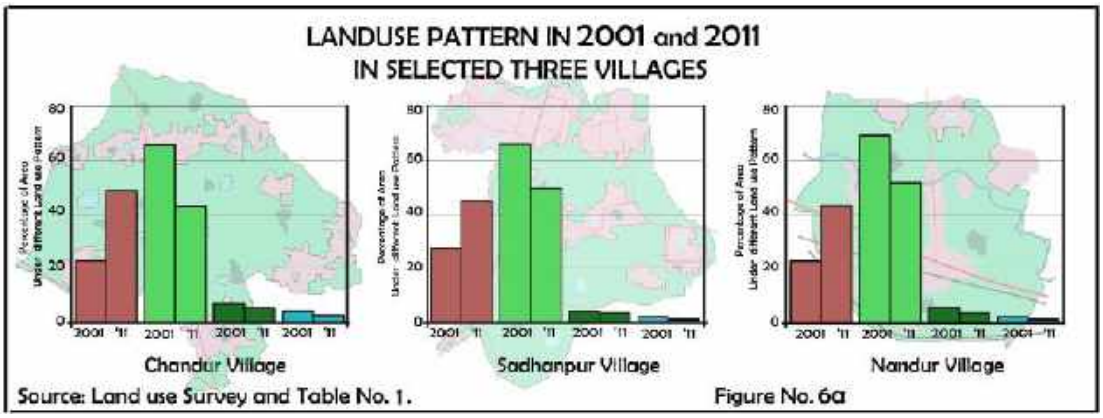

Fig. 4

ies have recorded a decline. On ther hand Sadhanpur village has recorded 17.9% growth in built-up area and consequently the agricultural land and land under vegetation and water bodies have shown a decrease of 16.4%, 0.6% and 0.9% respectively. In case of Nandur village, 17.5% of agricultural land contributed in the growth of new built-up areas where as the share of land under vegetation and water bodies are much lesser (Fig.no.-6b).

Impact of sprawl on socio-economic condition in the study area

Whenever sprawl takes place in an area, certain socio-economic characteristics have become evident and they are called as indicator of sprawl. Some of those socio-economic parameters have been chosen in order to understand the influence of sprawl in the selected villages

Duration of stay at present residence

This is a parameter which has been studied to identify since when the residents have occupied the land. The duration of stay has been classified into three categories namely <10 years, 10-20 years and >20 years. Table 3 shows that in all the selected villages more than 43% of the household have occupied the land in less than 10 years duration. Similarly the duration of stay

Table 3 : Duration of stay at present residence

Name of the village	Duration of stay at present residence		
	< 10 Yrs.	10 - 20 Yrs.	> 20 Yrs.
Chandul	44.61	36.76	18.63
Sadhanpur	43.89	32.67	23.44
Nandur	46.56	32.66	20.78

Source: Primary Household Survey, 2010

Table 4 : Period of purchase of land

Name of the village	Share of land purchased (%)		
	Before 1991	Before 1991	Before 1991
Chandul	20.34	20.34	20.34
Sadhanpur	18.78	18.78	18.78
Nandur	19.64	19.64	19.64

Source: Primary Household Survey, 2010

Table 5: House Structure

Name of the village	House Structure of surveyed households		
Single-storied	Single Stories	Double-storied	Multi-storied
Chandul	37.2	53.6	9.2
Sadhanpur	27.4	65.7	6.9
Nandur	27.8	66.7	5.5

Source: Primary Household Survey, 2010

in the last 10-20 years is moderate in all the three localities. The percentage of surveyed households that have started to occupy the present residence more than 20 years ago is low in all the three villages. These facts points to the fact that most of the residential development has taken place in recent years, mainly after 1990s.

The respondents were interviewed to ascertain when they have purchased the land. This information will help to understand the period in which the occupancy of land and sprawl process has started in this region. It is clear from the table 4 that more than 40 % of the household have purchased the land after 2001.

House structure of the selected villages

It has been found from the survey that 65% of the surveyed households in Sadhanpur village are staying in pucca house whereas 70% of the surveyed households in Chandul and 72% of the surveyed households in Nandur live in pucca houses. This shows that urban influence in all the villages is gradually increasing. Table 5 shows on an average, 50% of the surveyed households in all the three selected villages live in two-storied houses. This indicates that two storied houses are very common feature in this area

Household income

Household income is an important factor to analyze the economic status of the people settling in the region. Table 6 shows that more than 40% of surveyed households in all the three selected villages have monthly income between Rs.10000-15000. However, highest percentage (11.3%) of surveyed households with monthly income more than 15,000 is found in Chandul village. This may be because this area benefits from maximum accessibility and has been taken over by the comparatively well off population

Reason for selecting the place of residence

The respondents were asked to state the

Table 6: Household Income

Name of the villages	Percentage of household income in thousand rupees			
	< 5	5 - 10	10 - 15	>15
Chandul	9.8	30.2	48.7	11.3
Sadhanpur	11.2	36.8	44.7	7.3
Nandur	4.2	44.6	42.7	8.5

Source: Primary Household Survey, 2010

Table 7: Reasons for selecting the place for residence

Reasons for selecting	Name of the villages		
Place for Residence	Chandul	Sadhanpur	Nandur
Education Facility	8.6	9.8	9.6^0
Proximity to Station	21.2	12.6	11.71
Near to Road 16.1	26.6	18.6^0	
Low Land Price14.8	21.7	23.8^0	
Easy to access to Working Place	36.8	27.8	33.59
Others	2.5	1.5	2.7^0

Source: Primary Household Survey, 2010

reason for selecting the village to live in. In case of Chandul village, easy access to working place and proximity to station are the main reasons for selection shown in table-7. On the other hand, easy access to working place, nearness to the road and cheaper land price have attracted the people to select Sadhanpur. Proximity to station, low land price, and easy access to working place area are the factors which have played an important role in choosing Nandur village for place of residence.

Neighbourhood relations

The respondents were asked to judge their relation with neighbours. This aspect was taken into consideration in order to see how the new population has interacted with the locals. It can be found from table-8 that more than 50% of the surveyed households in Chandul village have no interaction with the locals whereas more than 45 % of the surveyed households in other two villages have no interaction with the locals. On the other hand, 18-20% of the surveyed households in all the three villages have good interac-

Table 8: Neighbourhood relation

Name of the village	Neighbourhood relation (% of surveyed households)		
	No interaction	Moderate	Good
Chandul	55.9	23.7	20.4
Sadhanpur	46.3	32.2	21.5
Nandur	44.3	36.9	18.8

Source: Primary Household Survey, 2010

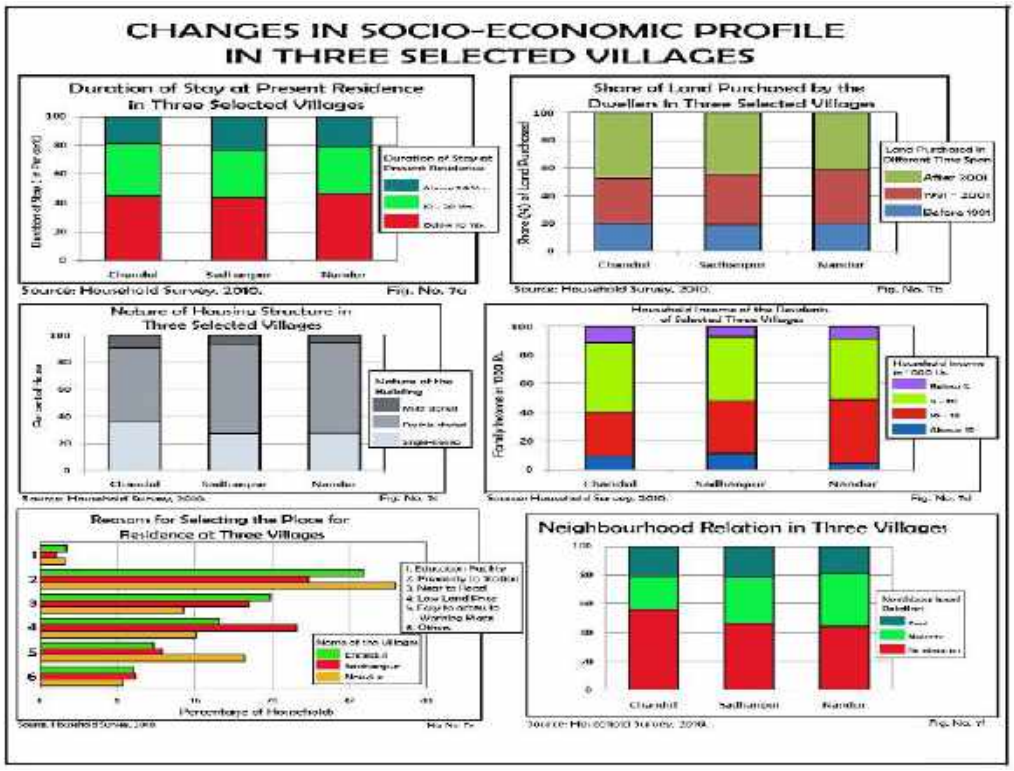

Fig. 5

tion with the local population. This shows that lack of integration is found in respect of socialization when urban sprawl gradually occurs.

Conclusion

The study reveals that urban sprawl is taking place fast in the surrounding villages located within 10km. buffer of Burdwan Municipality under Barddhaman Block-I and Block-II. The sprawl is mainly observed along the major transport corridors.

It is also expected that growth of unplanned built up area will further spread in the adjoining areas and may be transformed in to an urban agglomeration in near future.

The village level study indicates that this spread of built up area has brought about changes in land use pattern.

Agricultural land, water bodies and vegetation cover are rapidly vanishing and new urban structure are emerging and cultural landscape is also going through a transition phase.

It will be interesting to study in future about the space problems and availability of basic amenities in these areas and how these are going to affect the quality of life of these people.

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Societal Perception of Waste Water Management and Condition of Holy River Ganga in Varanasi City

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Abstract

This paper presents the current status of waste water management and related sanitation scenario in Varanasi city. The results are based on the personal survey conducted through questionnaire. It has been observed that the total sewage generated in the city is estimated to be 350 MLD, of which 102 MLD is treated at sewage treatment plants and the remaining discharged into the River Ganga and Varuna through open drains. The present condition of the river is alarming. In Varanasi alone, the Rever Ganga is being polluted everyday with over 250 MLD of untreated sewage.

The sewer lines in the city are more than 80 years old and are prone to choking and leakages. Lack of suitable facilities (equipment and infrastructure) and under estimation of sewage waste generation rates, inadequate management and technical skills are the man problems before the administrators. Beside, there is real electrical power supply problem.As a result, the intermittent operation of sewage pumping stations and sewage treatment plants is ineffective in protecting water quality of the river Ganga and in provisioning safe drinking water and sanitation in Varanasi. People's perception towards waste water management is found to be at variance, depending on their educational level, income and other constraints.

Keywords: *waste water management, sewage, Ganga, sanitation*

Introduction

Varanasi is one of the oldest living cities in the world. Social issue at stake is how to keep this holiest city clean and healthy.Drainage and waste water management system are closely inter-related aspects of sanitation. Proper drainage and waste management are essential for keeping the environment clean and healthy. Drainage refers to a channel for carrying waste water away from the premises of buildings or houses. It not only takes away the waste water but also storm water.

The situation of coverage of drainage network both sewage and open in Varanasi city, is rather poor. The low lying areas in the city including Ravindrapuri, Kamachha, Godaulia, Teliabagh, Lanka, Khojwa, Nagwa, Sigra, Mehmoorganj, Sunderpur and trans-Varuna area, including Bhojubir, Bharlai (Shivpur) and

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Pandeypur, are the worst affected, thereby revealing the virtually non-existent drainage system. The slow evacuation of water, taking more than 24 hours to recede could be attributed to lack of proper drainage system in the city.Increase in urban population (around 1.5 million as per 2001 census) has resulted into a wild growth of houses in cramped spaces, inviting people to attach their drains to sewer pipelines directly at the cost of general hygiene and cleanliness (TOI, 22 August 2008). Sewerage network hardly covers 35 per cent of the total area of the city (Rapid Assessment Report, 2006). The existing sewerage system has been designed exclusively to carry domestic sewage only, but owing to its traditionally laying in the core city area, storm water also enters the trunk sewer directly or through manholes and branch sewers. This leads to reduced efficiency of waste water disposal particularly in the rainy season. Underground sewerage network was provided in the town during 1898-1917. Under this project, three sewer systems were provided, namely the main sewer, Orderly Bazar sewer and Ghat intercepting sewer. Total length of the sewer covered under this project was 16.52 km. The main sewer from Assi crossing to Konia-Rajghat, Orderly Bazar sewer and Ghat sewer from Meer Ghat to Trilochan Ghat were constructed (Fig.1). These were designed to carry domestic waste water only and storm water was allowed to flow through the existing open drains. The main sewer still serves the city as the trunk sewer which runs parallel to the bank of the river Ganga, passes through heavily built up area to Church crossing and onwards along NaiSadak to Benia, Kabirchaura, Maidagin and Rajghat, after which it discharges into the river Ganga at about 0.5 km downstream of Malaviya Bridge. During the year 1967-68, a diversion sewer was laid down from the last manhole of the trunk sewer on G.T. Road to Konia and a pumping station was installed to utilize sewage for sewage farming.

Objective of the study

1. To examine coverage of drainage network both sewage and open in Varanasi city.
2. To evaluate people's perception towards waste water disposal system.

Database and methods

The present research work is based mainly on empirical data collected from secondary and primary sources. Secondary data have been collected from various sources such as Varanasi Municipal Corporation; Jal Sansthan, Bhelupur; *Varanasi etc*. In order to know the people's perception towards form of waste water disposal system and related health problems, the data have been collected by interviewing 1008 persons living in different localities of the city, and belonging to different cross-sections of the society through a standardized questionnaire survey

Drainage and sewerage system

The existing sewer network caters primarily to the old city, comprising mainly of the Ghat area. Presently, only 35 per cent of the total area is provided with the underground sewer network with a total length of 400 km of pipeline. The entire trans-Varuna and nearly half of the cis-Varuna area is unsewered. The total sewage generated in the city is estimated as 350 MLD, of which 102 MLD is treated at sewage treatment plants and the remaining 248 MLD is discharged into the River Ganga and Varuna through open drains (TOI, 22 March, 2009). The River Ganga is today facing extreme pollution pressures and associated threats to its biodiversity and environmental sustainability. It has been reported "managing Varanasi's sewage and industrial effluents is a major problem for PM (Narendra Modi), who wants Clean

Ganga mission to focus on urban sewage and industrial effluents to check pollution at source. Not a single treatment plant has been set up in the city in the last two decades even as per 2011 Census, the city recorded a decadal growth of 17.32% in its population adding to its municipal sewage manifold (TOI, 8 Jan, 2015). An ever-growing population, inadequately planned urbanization, and rapid industrialization have adversely affected water quality in the river (The world Bank, 31 May, 2011). To clean this holy river, a major effort was initiated by the Government of India in the form of Ganga Action Plan (GAP) way back in the year 1986. Under this plan, three sewage treatment plants (STPs) viz. Dinapur STP (1986), Bhagwanpur STP (1988) and Diesel Locomotive Works STP (1989) were commissioned with combined treatment capacity of 101.8 million liters per day (MLD) for the treatment of waste water. These STPs are specifically designed to treat waste water discharged from domestic sector and to provide only primary and secondary treatment to wastewater functioning on activated sludge process technology. There is no provision for the advance treatment of wastewater. But, at Varanasi more than seven thousand cottage, small and medium scale industries are located in and around the city. Majority of these industries are devoid of effluent treatment facility and ultimately discharge their effluents laden with toxic metals directly into the city sewage, which eventually drains into the holy river Ganga that serves the huge population of northern India. This inappropriate disposal of untreated or partially treated waste water ultimately aggravates the problems associated with the pollution of river Ganga (Mishra, 2015).

During the course of survey, most of the sewerage are found choked by silt. Garbage cleaning and maintenance of sewer line is not proper. As a result, the carrying capacity of sewer system is drastically reduced due to silting. The clogging of these drains due to polythene and waste dumps leads to the formation of stagnant pools of water, that results in foul smell. The Nalas and rivers of the city are in a critical state due to the quantum of untreated sewage and waste water entering them every day. The situation becomes worst during the rainy season when major parts of the city covering low-lying areas are water-logged. A total number of 88 colonies in 14 wards of the city witnessed water-logging. As per records of CMO office, these wards include :Sikraul, Shivpur, Nadesar, Sarnath, Adampur, Jaitpura, Kotwali, Chowk, Dashashwamedh, Chetganj, Sigra, Bhelupur, Khojwa and Nagwa (TOI, 29 August 2008; i next, 23 August 2009).

Management of sewerage system

Table 1 shows existing Nalas and sewer lines of the city along with their type and point of discharge. For management of city sewerage system, the whole city has been divided into four sewerage districts (Fig.1), namely the central city, sub-central city, trans-Varuna and BHU sewerage districts. The central city sewerage system is the oldest one, having half to one km breadth from the river and about 5 km in length from Assi to Rajghat, while sub-central city covers area between Varuna river and Assi, falling west of the central city. The trans-Varuna sewerage district is on the other side of the city where there is no regular sewerage system. This area has been developed in a very short span of time from Shivpur to Pandeypur. BHU sewerage system covers mainly BHU campus which is fully sewered.

Table 1. Main existing nalas and sewers

Point of discharge	Sl. No.	Name of drain/nala	Measured flow (MLD)		Type	Remarks
			1986	2000		
Ganga River	1	Nakkidrain	-	0.00	Open channel	Running almost dry
	2	Samneghatdrain	-	0.00	Circular pipe	Running almost dry
	3	Assinala	22.0	44.5	Open Channel	-
	4	Shivala drain	1.00	5.5	Circular pipe	Intercepted in to main sewer
	5	Harish Chandra ghatDrain	1.50	2.50	Rectangular	Intercepted in to main sewer
	6	Mansarovar drain	2.50	2.50	Circular pipe	Intercepted in to main sewer under GAP-1
	7	Dr. R.P. Ghatnala (Ghoranala)	20.00	25.00	Rectangular	Intercepted in to main sewer
	8	Jalesan drain	2.75	3.75	Rectangular	Intercepted in to main sewer
	9	Sankathaghat	-	0.30	Rectangular	Intercepted in to main sewer
	10	TrilochanghatDrain	2.00	3.50	Rectangular	Inter cepted in to main sewer
	11	Telianala	1.00	3.00	-	Intercepted in to main sewer under GAP-1
	12	Bhainsasurnala	-	0.40	-	-
	13	Rajghat Railway nala	-	0.03	Circular pipe	-
	14	Rajghat Outfall	100.00	130.00	Circular pipe	Intercepted in to main sewer under GAP-1
Varuna river (Right bank)	15	Phuwarianala	3.20	7.60	Open Channel	
	16	Sadar Bazar nala	0.90	2.00		
	17	Drain of hotels	0.20	0.20		
	18	Raja Bazar nala	0.10	0.10		
	19	Teliabaghnala	10.80	18.00		
	20	Nala near NakhiGhat	0.10	0.10		
	21	Konia bypass	-	50.00		
Varuna river (Left bank)	22	Central Jail nala	2.80	6.50		
	23	Orderly Bazar nala	2.20	7.00		
	24	Chamrautianala	1.30	3.00		
	25	Nala of Khajuri Colony	1.20	1.50		
	26	Banaras nala No.5	0.80	1.00		
	27	Hukulgangnala	1.90	2.50		
	28	Nala of NaiBasti	0.30	3.00		
	29	Narokharnala	-	7.5		

Source : The study on Water Quality Management Plan for Ganga river in the Republic of India. Final Report, Vol. 3, JICA, July 2005.

For disposal of waste and storm water, the Municipal Corporation of Varanasi has also made provision of storm water drainage system. The rivers Ganga, Varuna and Assi are the three natural streams which finally receive the storm water flowing during rainy season in the city. Storm water ultimately joins the river Ganga through several natural channels/drains. About five to six main open channel drains were built during the Mughal rule. These channels join the river Ganga between upstream and Varuna flowed into Ganga. These drains have also been known as Shahi/Nawabi drains. All these are brick drains with different shapes and sizes. The largest one is Ghoranala. Table 1 shows the details of open drains, joining Assi, Varuna and ultimately to river Ganga.

Health and safety risks associated with waste water management

There are some big nalas in the city which are very dangerous both to human and animal lives. The largest nala is Rajghat outfall which discharges 130 MLD of waste water every day. Teliabaghnala contributes to 18 MLD of waste water which joins the river Varuna at the right bank. The major part of the central and sub-central city is also provided with open-drains along the road side which join either sewerage system or open drains. The in-depth survey of the city reveals that in many parts of the city, these open drains have been encroached or interrupted due to which the flow of water is heavily constricted. These drains are also choked with filth and polythene, causing water

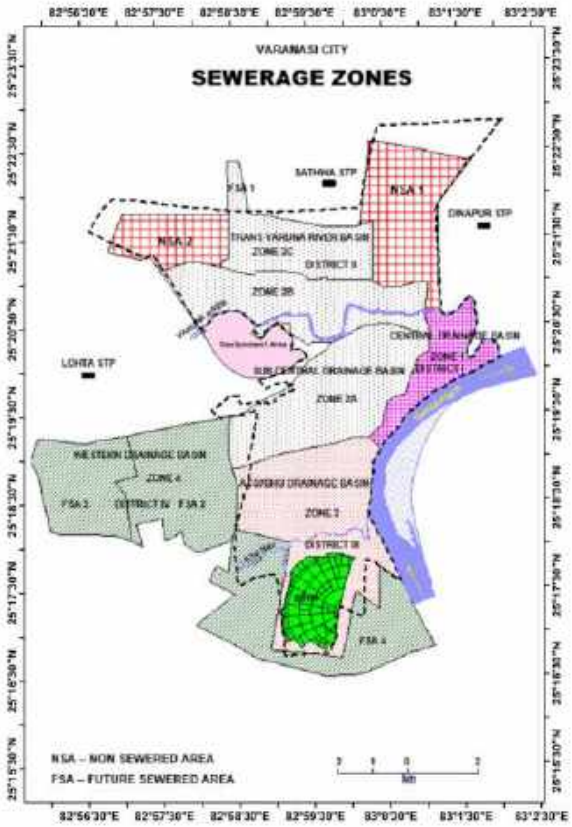

Figure 1

logging very frequently. The situation takes the worst turn during heavy rains when substantial parts of the city are water-logged, causing insanitary condition.

Though sewer lines were cleaned in some areas, such as Durgakund, Bhelupur and Sigra, the dumping of removed sewage on the roads aggravated the situation, leaving piles of waste lying on the busy Cantonment-Lanka route. According to official reports, efforts are made to clean the old sewer pipelines in these areas with the help of hydraulics machines that suck the sewage at high pressure to remove any blockage in the pipeline. However, the slow progress in the maintenance of sewer pipelines has left some new areas open to leakages and overflowing sewage (Dwivedi, 2012). There was a proposal to purchase leakage detection equipment under the JNNURM that could identity the leakage in pipelines with greater accuracy. However, an assurance on the issue reads: "Efforts to widen the gap between water supply and sewer pipelines are also on to prevent leakages".

Perception towards waste water disposal system

In order to provide proper waste water disposal system, it is desirable to know people's response towards the availability of waste water disposal system in their locality. To know the form of waste water disposal system, question has also been asked to the respondents during household survey in all the 14 sanitary wards. Of the total 1008 households, 74.2 per cent households have mentioned that there is provision of underground sewerage system for the discharge of waste water. It is interesting to note that all the houses of Khojwa, Jaitpura and Nadesar sanitary wards are provided with sewer pipe lines. In Dashashwmedh, Sigra, Kotwali, Adampur sanitary wards, more than 95 per cent of the households have sewerage facilities for waste water discharge (Table 2). It is also noted that a significant number of households in sanitary wards such as Sikraul, Shivpur, Sarnath are without sewage waste water disposal system. In these wards less than 25 per cent of the households are connected to sewer pipe lines. The survey reveals that on an average 16 per cent of the surveyed households have provision of open drains for waste water disposal. The maximum number (72.2%) of the households in Shivpur ward have reported that there is a provision of open drains in their locality followed by Sikraul (62.5%). Further in Dashashwmedh, Sigra, Kotwali, Adampur sanitary wards less than 3 per cent of the households are reported to have open drainage system for waste water discharge. The maximum percentage (80.6%) of households in Sarnath sanitary ward have reported that there is no provision of either sewerage system or open drainage system for waste water discharge. It is perhaps due to mixed urban and rural settlement in Sarnath ward. In a few of the wards lying in the outer zone of the city, there is provision of septic tank for disposal of waste water. Sikraul registered the highest (15.3%) percentage of households having septic tanks whereas in Shivpur (1.4%) the minimum number of households are discharging their waste water to septic tanks. It is apparent from the analysis that the central and sub-central parts of the city are mostly sewered and have also provision of open drains for waste water disposal from houses whereas sanitary wards lying in the outer zone of the city are partially sewered and have provision of open drainage system for waste water disposal. However, for toilets septic tanks are constructed.

To have an idea regarding the state of maintenance of drainage system, responses from the households are tabulated (Table 3). Out of the total respondents, 73.61 per cent have reported that drainage system is cleaned irregularly. The maximum number (100%) of respondents of Sarnath followed by Chetganj (88.9), Nagwa (81%) and Adampur (80.0%) have reported that

Table 2. Form of waste water disposal (Responses in percentage)

Sl. No.	Sanitary wards	Sewerage	Open drainage	No facility	Own septic tank/under-ground tank
1.	Bhelupur	66.7	31.9	1.4	
2.	Khojwa	100.0			
3.	Nagwa	47.2	29.2	23.6	
4.	Dashashwmedh	98.6	1.4		
5.	Chetganj	86.1	12.5	1.4	
6.	Sigra	98.6	1.4		
7.	Kotwali	97.2	2.8		
8.	Chowk	100.0			
9.	Adampur	97.2	2.8		
10.	Jaitpura	100.0			
11.	Sikraul	9.7	62.5	12.5	15.3
12.	Nadesar	100.0			
13.	Shivpur	25.0	72.2	1.4	1.4
14.	Sarnath	12.5	6.9	80.6	
	Average of all the wards	74.2	16.0	8.6	1.2

Source : Based on Personal Survey.

Table 3. Answer to the question 'If open, what is the frequency of cleaning drainage?' (inpercentage)

Sl.No.	Sanitary ward	Regular	Irregular
1.	Bhelupur	21.7	78.3
2.	Nagwa and khojwa	19	81.0
3.	Dashashwmedh	30.0	70.0
4.	Chetganj	11.1	88.9
5.	Sigra	35.0	65.0
6.	Kotwali and chowk	50.0	50.0
7.	Adampur and Jaitpura	20.0	80.0
8.	Sikraul and Nadesar	44.4	55.6
9.	Shivpur	32.7	67.3
10.	Sarnath	–	100.0
	Average of all the wards	26.39	73.61

Source : Based on Personal Survey.

cleaning of drainage is most irregular. The responses evinced that most of the households in all the sanitary wards are not satisfactory with regard to cleaning work of Municipal Corporation of Varanasi which lead to choking of drains frequently and causing overflow. It also results in stagnant pool of waste water along the roadside and low-lying areas, creating foul odour which creates a fragile condition for the spread of diseases.

Problems related to sewerage system and suggestions

The present generation of domestic waste water in Varanasi is 350 MLD, which will increase to 430 MLD in 2021. Keeping in view the increasing population in the city, the installed capacity of sewage treatment is only 102 MLD through three Sewerage Treatment Plants (STPs): Dinapur, Bhagwanpur and Diesel Locomotive Works (DLW) STP. Capacities of these STPs are 80 MLD, 10 MLD and 12 MLD respectively. One STP of 37 MLD capacity is under plan to be installed at Ramna.

Some of the problems identified regarding sewerage system are as follows:

(i) The existing sewerage system is inadequate with 70 per cent area of the city uncovered with sewer system, leading to discharge of untreated sewage in open drains, polluting the River Ganga and Varuna.

(ii) Capacity of STPs is inadequate to treat the existing sewage, leading to disposal of untreated sewer into the River Ganga and Varuna, thus polluting the river water.

(iii) Combined system of disposal, putting more pressure on the system and STPs, especially during the rainy season.

(iv) Present sewer infrastructure, including sewer network (branch/main/trunk sewers) and pumping stations is very old and immediate renovation/rehabilitation is required.

(v) Frequent clogging of sewerage system is caused due to combined sewer and storm water drainage and waste dumps, particularly during monsoons.

(vi) Considering the huge quantum of waste water being discharged into the rivers, namely the River Ganga, Varuna and Assi, there is an urgent need to intercept the flow of waste water into these water bodies to prevent further pollution.

The main problems, which need to be addressed, for storm water drainage, are:

(i) Lack of lined drainage in the city, leading to contamination of ground water.

(ii) Frequent clogging of drains due to dumping of waste in the drains which lead to insanitary conditions

(iii) Siltation reduces the carrying capacity of drains leading to water logging, particularly during monsoons.

(iv) Need for an organised storm water network to reduce the load on sewer network, choked open drains due to waste.

The direct discharge of sewage into the river is the main factor responsible for increasing pollution load to the river Ganga. In Varanasi, over 250 MLD sewage goes directly into the river through various sources along the ghats. Over 350 MLD sewage is generated in the city while installed capacity of sewage treatment plants is 102 MLD only (TOI, 22 March 2009). In an initiative taken by Sankat Mochan Foundation (SMF), all the sources have been identified with Global Positioning System (GPS) and superimposed by National Remote Sensing Agency, Hyderabad on their satellite image. As per observation, there are 33 sources of sewage discharge into the river at Varanasi.

The city is to get two more STPs of 140 MLD and 120 MLD capacities. The 140 MLD STP may be constructed with the fund provided by the Japan International Cooperation Agency (JICA), while the 120 MLD STP will be built under Jawaharlal Nehru National Urban Renewal Mission (JNNURM)(TOI, 27 August 2014).

The Union ministry of environment and forests has sanctioned two major projects: A fund of Rs. 0.85 million for the preparation of de-

tailed project report (DPR) and build 37 MLD sewage treatment plant (STP) using Advanced Integrated Wastewater Oxidation Pond System (AIWPS) technology at Ramna in Varanasi. This technology has been successfully used at many places in California and elsewhere. The AIWPS is a series of four ponds (TOI, 22 March, 2009; 5 August 2009).

Preparation of DPR of the interceptor of about 100 MLD sewage handling capacity for Varanasi Ghats on the bank of Ganga and adjoining areas. SMF along with its associate GO2 Water, Inc. have been entrusted with the job. Time is running out without commencement of any concrete work in Varanasi to clean Ganga. In 2011 the World Bank loaned the GOI one billion USD to clean the Ganga. The World Bank and GOI's deadline is 2020 for National Mission for Clean Ganga. SMF is currently under negotiations with the GoI and working diligently to see this plan put in action for Ganga and the people.

For Namami Gange, an integrated Ganga conservation mission, a fund of Rs 2,037 crore has been allocated in the Union budget 2014-15. The mission is being launched because a substantial amount of money has been spent in the conservation and improvement of the Ganga but it has not yielded desired results. This is because of lack of concerted effort by all stakeholders (TOI, 27 August 2014).

Rs. 1916.2 million has been sanctioned under JNNURM to implement the storm water drainage plan in the city . Under this plan, 28 km nala will be repaired and about 24 new nala will be constructed (Hindustan, 12 September, 2009). Repairing of old nallas include Sundamapur to Bajardiha, Teliana to Sarainandan, Lallpura Muslim school to Sigra Police station, Badshahbag colony to Fatman road, Kazisadullapura to Varuna river, Chhohra crossing to Kamalgadha slaughter house, Sanskrit University to Chaukaghat and Chandra crossing to Narokhar nala etc. New nalas will be constructed at Shivpur, Usarpurva, Takia Road, Mahavir Mandir, Har Narain Vihar, Piplani Katra, Shivala, Pisachmochan, Jagatganj, Bajardiha, Nagwa, Andhrapul, Jawahar Nagar, Naria, Karaudi, Andharapul, Hari Nagar, Paramhansh nagar, Aurangabad and city railway station. All these drains will be joined to main sewer which will be ultimately treated at proposed STP located at Ramna and Shivpur.

Concluding remarks

The river Ganga is the lifeline of the city. The lives of the people living here and the economy is largely intertwined with the river. A significant volume of untreated sewage and poorly treated industrial effluents is discharged in the Ganga. The Central government and the concerned state governments are working together on the Mission Clean Ganga to conserve this vital resource. Clean ganga is a national mission. Societal perception/awareness is key to achieving waste water management in Varanasi. Encouragement for people's participation in cleaning river Ganga and to maintain its purity will act as a catalyst in making the plan a grand success for sustainable development of river Ganga.This is linked with good sanitation and environment. Policy makers working hand in hand with people can make it happen Clean Ganga and healthy environment.

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Perception of Urban Residents towards Drinking Water Quality and Supply: A Case of Varanasi City

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Abstract

Ensuring a safe and continual water supply is of utmost importance as the health and well-being of individuals and society very much depend on it. Adequate supply of water of requisite quality for drinking, bathing, cooking etc is closely linked with personal hygiene and public health. The water requirement for different activities varies with life style, culture, diet and wealth. Therefore, it must be distributed judiciously among the consumers for varied uses. Economic growth of a city largely depends on a water supply system capable of supplying sufficient quantity of potable water to all residents. Rapid growth of population, particularly in urban areas has exerted tremendous pressure on water supply. On the one hand, demand for water has been continuously rising in urban areas due to change in life style; on the other hand ground water potential is declining due to overexploitation and expansion of concrete structures over the years. As a result, city authorities find difficulty to provide adequate quantity of good water to their residents. Keeping the aforesaid in view, the present paper attempts to analyse empirically the responses and reactions of residents in respect to drinking water quality and supply in Varanasi- a million + city of India. For this study, 700 persons from various cross-sections of society and space were selected and interviewed with the help of a questionnaire. The results of such survey can be of much help to municipal authorities in decision making to ensure sufficient safe water to all urban residents including the very poor.

Keywords: *water quality, water supply, public health, awareness, perception*

Introduction

The gravity of environmental problems can be better assessed on the basis of their perception by the individuals and community (Singh and Singh, 2010). In recent years, there has been an increasing concern for the quality of life as well as our environment.

Response and sensitivity (degree of like or dislike for something) both vary from person to person as well as place to place with rising level of environmental pollution in cities and towns. The people's concern towards increasing level of pollution and its ill effects change as it is not perceived alike by everyone (Kayastha and Kumra, 1986). Different people depending on background characteristics respond to the same stimuli in different ways. Perception of inhabitants at city level, therefore, can be of immense

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help to municipal authorities to solve the problems of cities.

Of the several issues, provision of clean drinking water is of utmost importance as the health and well-being of individuals and society very much depend on it. It is estimated that 80 percent of all illness in developing countries can be traced to contaminated water (Rajagopalan, 2005). It should, therefore, find equal emphasis in city planning as the number of doctors and hospitals. Due to rapid growth of population and economic activities, provision of safe and clean water as well as sanitation has become more difficult to achieve, especially in cities and towns of developing countries including India. Without understanding perception and attitude of people towards state of water quality and supply and their satisfaction, planning for health and well-being will remain a mere academic exercise. The biggest challenge before the policy and decision makers is to translate the improved awareness into action. As a result, there exist a wide gap in perception of the people and administration. Therefore, a study of perception of the people to drinking water quality and supply becomes very important as it affects the livability of thousands of urban residents housed in a small space.

Concept of perception

Attitude is a hypothetical construct that represents an individual's degree of like or dislike for something while the individual organization of stimuli relating to an extreme event or pollution or human adjustment is defined as perception. Recently, perception study has become the basic tool for formulating and implementing viable remedial measures and management process for the welfare of society (Kayastha and Kumra, 1986). Such studies will help in laying down the policies for environmental management. Oxford Dictionary defines perception as 'the process of taking cognizance of a sensible or quasi sensible object' while psychology defines it as 'the process of becoming immediately aware of something'. According to Brookfield (1969) perception in environmental context refers to 'the perception of the whole environment or of specific selected elements within it or even of space in the abstract'. Perception of environment depends on individual's past experiences and present set of attitude. Dunlap (1980) observed that age, level of education and income are predictive of environmental perception.

Perception studies at city level

Initially, geographers have shown more concern in perception studies of natural hazards wherein the main focus was to evaluate the perception and behavior of people to natural hazards, and their probability of occurrence and estimate of threat. For example, Kayastha and Yadav (1980) studied perception of people about the flood hazard in Eastern Uttar Pradesh. Recently, perception studies at local level (city or neighborhoods) have become a subject matter of research by geographers due to its growing size, high density and multiplicity of functions. The human adjustment to power crisis (frequency and spell of load shedding) in Calcutta city has been studied by Nag (1980). Kumra (1981) has made an attempt to study the perception of environmental pollution in Kanpur city through interview of 500 persons representing various sections of society and space. Desai (1982) in her study examined the resident's perception on environmental quality in Ahmedabad city. Singh et.al.(1988) analysed people's perception towards air, water and noise pollution and their management in urban environment of Varanasi. Prasad (1991) has studied the perception of solid waste pollution in Delhi metropolitan city. Selvan (1995) examined the perception and satisfaction level of housing environment, solid waste disposal, sewage system and water supply in Madras city. Laxmi Narayan (1996) studied the people's perception regarding the problem of air pollution and its effects

on human health in Varanasi city. Dube and Kumar (1997) tried to assess the environmental problems caused due to solid waste and its impact on human health in Varanasi city. Siddiqui (2003) tried to study people's responses towards sanitary facility and their effects on human health in Kanpur city. In a study on solid waste Singh and Singh (2010) have examined the association of individual's education with the levels of perceptions. In another study Pandey and Singh (2012 and 2014) have analysed the issues related to water quality and supply in Varanasi city on the basis of responses/ feelings of urban residents.

It may be noted here that geographers try to understand people's attitudes and behaviors towards environment in spatial connotation. Here, authors have attempted to assess the perception of urban residents towards water quality and supply in Varanasi- the cultural capital of India. The present investigation is exclusively based on primary data collected through a structured questionnaire. For this purpose, 700 persons representing various cross-sections of society and space were intensively interviewed and the information thus obtained was tabulated and analyzed in sequel.

Objectives

The objectives of the present study may be precisely put as follows:

(1) To assess the state of water quality and supply as perceived by urban residents.

(2) To examine the satisfaction level of respondents towards water quality and supply.

Data base and methodology

This study is mainly based on primary data. The primary data concerning the perception of people regarding water supply, water quality, levels of satisfaction and paying of water tax were collected with the help of a structured questionnaire administered to a statistically selected sample of 700 households. For this purpose, a detailed survey was conducted during 2008-09. Random purposive sampling technique has been adopted to select the sample (50 households) from each sanitary zone. From each household only one person aged 15 and above has been interviewed. The questionnaire enquires from each of the respondent about his/her background characteristics, sources of water supply, quality of water supply, amount of water supply, mode of water storage and purification in the house, satisfaction level, paying for water etc. The information obtained has been categorized and analyzed using simple percentage as well as standard statistical techniques through SPSS (12.0) and Microsoft office Excel 2007. Besides, pictorial presentation of analysed data has been exhibited in the form of diagram and map using the Corel draw 12.0 version and Microsoft office 2007.

Study area

Varanasi (formerly known as Banaras) is one of the oldest living cities of the world and most favored destination of tourists and pilgrims. It is worldwide famous as cultural capital of the country. It has grown over an approximately 10 km stretch on crescent shaped left bank of the holy river Ganga from Samane *Ghat* to Rajghat (Fig.2). There are 84 *ghats* (stairways to the river bank). The river Ganga is the life line of the city. The total area of Varanasi city is about 79.79 km2. The city has experienced rapid population growth between 1951 (241,923 persons) and 2011(11, 98,491 persons). The average population density was recorded as 150 persons/ ha whereas average household size is found to be 6.3 persons (2011). For the convenience of civic administration, the city is divided into 90 wards, 16 water supply zones and 14 sanitary wards. The city is well connected with different parts of the country through rail, road and air services. The residents of the city receive water

supply from the river Ganga and deep bore tube wells.

Results and discussion

Background characteristics of the survey respondents

Background characteristics of the respondents help in gaining the knowledge of a thing or event. In accordance their responses and reactions about physical and social environment may vary. It is in this context background characteristics of surveyed respondents have been presented here of the total respondents, 61.43 per cent are males and 38.57 per cent are females. Maximum number of respondents (48.7%) belong to 30-49 years of age group followed by 40-49 years age group (24.3 %).

Educational attainment helps in bringing a change in the mental attitude towards the quality of environment. It also enhances the ability of individuals to express his/her degree of preference to various environmental components. About 82.71 per cent respondents are literate and only 17.29 per cent are illiterate. Among literates, 21.57 per cent respondents are educated up to primary school whereas 34.14 per cent are educated up to graduation and above. Among graduates 75.31 per cent are males and the remaining 24.69 per cent are females. The standard of living, life style and maintenance of personal hygiene and cleanliness largely depend upon the income level of the household. Of the total respondents, 17.29 per cent respondents are poor as their income is below Rs.1000 while the income of 18.14 per cent ranges between Rs.1000 to 2000. Another 17.29 percent earn between Rs.2000 to 5000. About 18.57 per cent of the respondents have monthly income between Rs. 5000 to 10000 Only 7.43 per cent interviewees earn more than Rs. 10000. Closely associated with this is the occupational composition of a population of the total respondents, 27.57 per cent are daily wage earners, 20.14 per cent are engaged in business, 16.86 per cent in services, and 2.00 per cent are engaged in various industrial units. About 7.0 per cent are self employed while 26.43 per cent respondents (students and housewives) did not participate in any economic activity.

It is notable here that of the several variables, education and income are the most significant as they make the people more awakened and responsive to various issues.

Perception of urban residents towards water supply

Our cities have grown in size and function. As a result, the demand of water has increased manifold. Due to over exploitation of sources of water over the years, water tables have not only dropped but also their quality on account of pollution has degraded. In the past few decades, public concern over the availability and quality of drinking water has grown considerably. Their concerns have arisen as a result of increased awareness about environmental pollution and episodes of water-borne disease outbreaks. Sources of drinking water reflect the health condition of people. It is rightly said that health of a population can be best judged by the water they drink.

In Varanasi, a large number of households still lack piped water supply in their homes. To know the state of water supply in Varanasi, people's responses this effect have been assessed. For more precise analysis, responses were also tabulated according to the income level as drinking water facility for the sole use of household depends up on the economic condition. Of the total respondents, nearly two-third (66.86 per cent) reported that they have access to piped water supply provided by *Jal Sansthan* followed by 16.0 per cent from hand pumps installed either within premise or outside the premise of house. More than one-third (39.57 per cent) respondents reported that they received

piped water at home.

It is ironical that even after six and half decades of trying a substantial proportion of population (33.14%) in Varanasi still do not have access to piped water supply (even community taps) at all.

It is notable that households belonging to Rs. 5000 and above income group have the highest coverage (61.00 per cent) with piped water connections while the lowest (6.61 per cent) is recorded in below Rs.1000 income group. It is evinced from Table 1 that 63.79 per cent households belonging to lower income group (below Rs.2000) draw water either from stand posts (community taps) or common hand pumps installed by *Jal Nigam*. During the survey, it has been also observed that maximum number of households whose income is more than Rs. 10,000 have their own deep bore wells for exclusive use followed by 16.92 per cent households belonging to Rs.5000-10,000 income group. However, only 1.57 per cent households belonging to Rs.1000-2000 income group have their own bore well. It is satisfying to note that none of the households lying in above Rs. 5000 income group use well water. However, a shocking 6.4 per cent households with income below Rs. 5000 still draw water from unsafe sources such as wells, river etc. This puts at risk people. It needs urgent attention of municipal authorities.

Table 1: Incomewise responses towards sources of water supply

Income group (Rs.)	Government stand Post	Road side hand pump	Piped water connection at Home	Own hand pump	Borewell Tubewell	Other sources
Below 1000	59 (48.8)	39 (32.2)	8 (6.6)	2 (1.7)	-	5 (4.1)
1000-2000	56 (44.1)	24 (18.9)	30 (23.6)	3 (2.4)	2 (1.6)	5 (3.9)
2000-5000	25 (20.7)	24 (19.8)	39 (32.2)	4 (3.3)	17 (14.0)	3 (2.5)
Above 5000	11 (6.0)	-	111 (61.0)	15 (8.2)	45 (24.7)	-
Income Not Stated	40 (26.8)	1 (0.7)	89 (59.7)	-	11 (7.4)	8 (5.4)
Total	191 (27.3)	88 (12.6)	277 (39.6)	24 (3.4)	75 (10.7)	21 (3.0)

Note: Figures in parentheses are the percentage value.
Source: Based on Field Survey, 2008-2009

The forgoing analysis reveals that households belonging to lower income group depend entirely on stand posts (community taps) provided by *Jal Sansthan* of city for water supply. They cannot afford to have their own (bore well) system water supply in their premises whereas households belonging to relatively higher income group have installed either hand pump or bore well inside the house to meet out their daily water need during the period of scarcity/crisis, especially in summer season.

Based on the observations (values) of Table 1, Chi-square test ($p < 0.05$ at 8 degree of freedom) showed that there is positive association between income level and sources of water supply, i.e., lower the income, more the use of public sources of water supply and vice versa. It reveals that drinking water sources at home depends upon income level of the household.

Duration of water supply

Independent estimates show that in most cities water supply to homes does not average more than four hours a day. It necessitates to examine the duration of water supply available

to inhabitants in the study area. The enquiry reveals that the duration of water supply to homes is not adequate. There exists quite variation in duration of water supply across the city from season to season and place to place. Table 2 shows the responses regarding duration of water supply in different sanitary wards of the city. In summer, 39.10 per cent households get water supply for 2-4 hours a day. The maximum number of such households lie in Nadesar (58.82%) followed by Khojwan (50.0%) whereas minimum in Shivpur (15.0%) and Sarnath (20.0%). As many as 36.75 per cent households avail this facility for less than 2 hours duration. The maximum percentage of such households (above 60 %) are found in Sarnath (80.0 %) followed by Nagawa (75.0 %), Adampur (61.9 per cent) and Jaitpura (60.9 %). Only 24.15 per cent households avail this facility for over 4 hours duration. The maximum numbers of such households (75.0 %) are found in Shivpur ward. In rainy season, 35.33 per cent households get water supply for 2-4 hours. The maximum number of such households lie in Sikraul (51.85%) followed by Dashaswamedh (48.72%) whereas minimum in Shivpur (18.75%) and Jaitpura (24.39%). Nearly one-third surveyed households receive water supply for over 4 hours duration in this season. The maximum numbers of such households (78.13%) are found in Shivpur ward while minimum (14.29%) in Nagawa ward. However, 31.26 per cent households experienced water shortage in rainy season. The maximum number of households that receive water supply for less than 2 hours are found in Jaitpura (56.10%), Nagawa (53.57%) and Adampur (47.62 %). In winter season, duration of water supply is better than

Table 2: Seasonwise duration of piped water supply

S. No.	Ward	Summer season			Rainy season			Winter season		
		<2 hrs	2-4 hrs	>4 hrs	<2 hrs	2-4 hrs	>4 hrs	<2 hrs	2-4 hrs	>4 hrs
1.	Adampur	61.90	33.33	4.76	47.62	30.95	21.43	33.3	40.5	26.2
2.	Jaitpura	60.98	31.71	7.32	56.10	24.39	19.51	46.3	34.1	19.5
3.	Nagawa	75.00	25.0	-	53.57	32.14	14.29	39.3	35.7	25.0
4.	Bhelupur	22.58	48.39	29.03	22.58	35.48	41.94	22.6	29.0	48.4
5.	Khojwan	30.00	50.0	20.0	36.67	46.67	16.67	33.3	30.0	36.7
6.	Sikraul	51.85	44.44	3.70	18.52	51.85	29.63	51.9	18.5	29.6
7.	Sarnath	80.00	20.0	-	40.00	40.00	20.00	46.7	40.0	13.3
8.	Shivpur	9.38	15.63	75.0	3.13	18.75	78.13	3.1	28.1	68.8
9.	Nadesar	5.88	58.82	35.29	26.47	38.24	35.29	26.5	47.1	26.5
10.	Dashaswamedh	32.50	42.50	25.0	28.21	48.72	23.08	25.0	27.5	47.5
11.	Sigra	25.00	28.13	46.88	28.13	31.25	40.63	50.0	25.0	25.0
12.	Chetganj	31.58	47.37	21.05	28.95	39.47	31.58	21.1	50.0	28.9
13.	Kotwali	28.95	42.11	28.95	26.32	31.58	42.11	39.5	28.9	31.6
14.	Chauk	22.50	47.50	30.00	20.00	32.50	47.50	22.5	32.5	45.0
	Total	36.75	39.10	24.15	31.26	35.33	33.40	32.1	33.5	34.4

Source: Based on Field Survey, 2008-2009

the summer and rainy seasons. Out of total surveyed households, 34.4 per cent receive water supply for more than 4 hour a day. The maximum number of such householdsl lie in Shivpur (68.8%) followed by Dashaswamedh (47.1%) whereas minimum in Sarnath (13.3%). Around 31.8 per cent households receive piped water for less than 2 hours duration. The maximum number of such households are found in Sikraul (51.0 %) followed by Sigra (50.0%) and Sarnath (46.7%) wards. Due to shorter duration of tap water supply, the households store the water in plastic/ steel bucket, water filter, earthen pot, over head tank/ ground tank etc depending upon the economic condition. Under the prevailing situation round- the clock water supply seems a daunting task. Inadequate water supply and that too for a short duration contributes to unhygienic and insanitary conditions in several parts of the city.

Response about water supply sufficiency

Adequate supply of water is important for human beings as it affects the personal hygiene and health. Hence, a question, 'Is water supply sufficient to your family's need?' was asked from the respondents. Of all the persons interviewed, 55.86 per cent reported that they get sufficient water for the domestic uses while 41.71 percent respondents do not receive sufficient drinking water. However, 2.43 per cent respondents answered 'can't say'. The largest number of respondents of Bhelupur ward (80 %) mentioned that they receive adequate amount of water whereas only 36 per cent respondents of Sarnath ward receive required amount of water for use. However, 64.0 per cent respondents of Sarnath ward reported that they are not getting sufficient water to meet out their domestic requirements. They feel shortage of water for drinking, cooking, bathing and washing.

Perception towards water quality

To assess the perception of people towards status of water quality, the respondents were asked, 'Do you find any change in water quality?'. Of the total respondents, about 44.3 per cent respondents perceived the deterioration in water quality. 72 per cent respondents of Adampur ward stated that the quality of supplied water is not satisfactory (Fig.1). They often found contamination (w.r.t. colour, test and smell) in water. Similar response (complaint) has been received from the majority of respondents of Jaitpura (60 %), Nagawa (58.0 %) and Khojwan (54.0%) wards whereas only nine persons (18%) of Shivpur ward reported about poor quality of water supply followed by Chetganj (28%). However, 39.0 per cent respondents did not perceive any change in water quality.

At ward level, maximum (64.0 %) respondents of Shivpur opined this view followed by Bhelupur (56.0 %). It is interesting to note that Dashaswamedh ward is quite close to *Jal Sansthan*, but 52.0 per cent respondents of this ward have reported that they found contamination in supplied water. However, 16.6 per cent interviewees did not respond to this question.

Responses have also been compiled on the basis of educational level of respondents (Table 3). Of the total respondents, 44.4 percent respondents perceived change in water quality. Among them, maximum percentage of respondents (75.3) who have completed 12 years of education noticed the change in water quality whereas those respondents who have a schooling of primary level have poor perception to water quality. It was observed that with an increase in the educational attainment, the problem was better perceived. It was on account of high awareness among educated people as well their concern to water quality and its effect on health.

The analysis of the responses to the query 'How did you perceive change in water quality?' reveals that 44.4 per cent respondents perceived the change in water quality by colour,

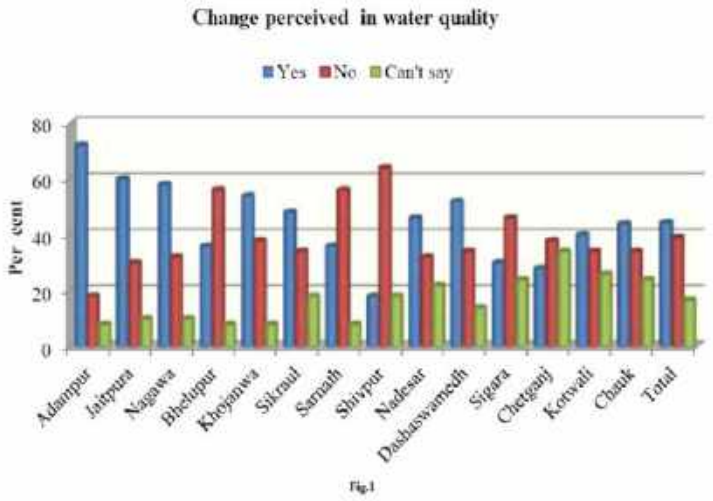

Fig.1

Table 3: Educationalwise response about change in water quality

Educational Level	Yes	No	Can't say
Illiterate	21 (17.4)	52 (43.0)	48 (39.7)
Primary	27 (29.7)	37 (40.7)	27 (29.7)
J.H.S	43 (71.7)	7 (11.7)	10 (16.7)
High school	56 (56.0)	26 (26.0)	18 (18.0)
Intermediate	67 (75.3)	15 (16.9)	7 (7.9)
Graduation & Above	97 (40.6)	136 (56.9)	6 (2.5)
Total	311 (44.4)	273 (39.0)	116 (16.6)

Note: Figures in parentheses are the percentage value

Source: Based on Field Survey, 2008-2009

smell and taste. Among them, 16.43 percent respondents noticed through change in colour of water whereas 13.43 per cent through smell and 6.71 per cent by taste. Another 7.86 per cent respondents stated that they perceived change in quality of water taking cognizance of all the three.

Out of total respondents who perceived change in colour of water, maximum (14.8 %) respondents belong to Adampur ward followed by the respondents of Dashaswamedh (11.3 %), Sikraul (9.6%) and Nagwa (9.6%) whereas lowest percentage of such respondents(3.5 %) was found in Chetganj, Nadesar, Sigra and Shivpur wards. Further, 13.43 per cent respondents perceived the poor quality of water through taste. The maximum percentage of such respondents were found in Adampura (12.8%) followed by Jaitpura (9.6%). Nearly 7 per cent respondents perceived the problem through bad odour. Around 7.86 per cent respondents perceived deterioration in quality of water by change in colour, smell and taste of water. Maximum respondents of Nadesar ward (16.4%) observed change in colour, smell and taste of supplied water in their locality followed by Khojwan (14.5%), Jaitpura (9.1%) and Nagawa (9.1%) wards.

Adampur, Jaitpura, Nagawa, Khojwan, Dashaswamedh, Sigra and Kotwali wards situated in central and sub-central parts of the city. The respondents of areas during the field visits stated that they are not getting satisfactory quality of water. It may be because of leakage in drinking water pipelines. The water was observed yellowish in colour, saline in taste and sometimes worms are also seen coming out from the taps. It evinces that a good number of city's populations use contaminated water.

To analyze the relationship between people's concern towards quality of water and educational level, responses were compiled and tabulated according to educational level of the respondents (Table 4).

Table 4: Educationalwise responses about change in water quality perceived

Educational level	Colour	Smell	Taste	All the three	No response
Illiterate	5 (4.3)	6 (6.4)	4 (8.5)	6 (10.9)	100 (25.7)
Primary	6 (5.2)	8 (8.5)	6 (12.8)	7 (12.7)	64 (16.5)
J.H.S	12 (10.4)	15 (16.0)	8 (17.0)	8 (14.5)	17 (4.4)
High school	19 (16.5)	18 (19.1)	8 (17.0)	11 (20.0)	44 (11.3)
Intermediate	27 (23.5)	20 (21.3)	9 (19.1)	11 (20.0)	22 (5.7)
Graduation & Above	46 (40.0)	27 (28.7)	12 (25.5)	12 (21.8)	42 (36.5)
Total	115 (100)	94 (100)	47 (100)	55 (100)	389 (100)

Note: Figures in parentheses are the percentage value
Source: Based on Field Survey, 2008-2009

The results reveal that about 44.43 per cent respondents observed poor quality of piped water w.r.t. colour, smell and taste. It is interesting to note that of the total respondents (115) who noticed change in colour, highest number of respondents (40%) belong to higher educational group *i.e.* graduation and above. The lowest percentage (4.3%) was observed in case of below primary level of respondents. Further, 94 persons reported change in smell of water. Among them, again the largest number of respondents (28.7%) has educational attainment of graduation and above level whereas the lowest number of respondents (6.4%) belongs to those who have schooling of less than 5 years. Those who opined that they found change in all the three parameters *i.e.* colour, smell and taste, the largest number (21.8 %) have completed 14 or more years of schooling while only 10.9 per cent respondents have a schooling of 5 or less years. The analysis revealed that with an increase in educational level, the issue of water quality was better perceived. It clearly demonstrates that educated persons are more awakened and feel concern about the quality of water. They are fully aware that consumption of contaminated water is a major cause of illness. Obviously, education enhances the ability of individuals to perceive the environmental problems.

Users' satisfaction with water quality and supply

Although the nature has provided us plenty of water (4% of the world's water resources), even then due to poor water management practices. We are not getting adequate and continual supply of water of requisite quality for our uses. Therefore, it was thought imperative to probe the satisfaction level of the users with quality and water supply. Hence, the respondents were asked 'Are you satisfied with water quality and water supply?' Interviewees' responses were computed and analyzed in order to get an idea

about their concerns/ feelings. The perceived level of satisfaction is grouped into four categories: satisfied, partially satisfied, dissatisfied and indifferent. Of all the persons interviewed from sample households, 49.29 per cent reported that they are satisfied with the municipal water supply and its quality whereas nearly one-third are partially satisfied. However, 23.86 per cent are not at all satisfied with the arrangement of *Jal Sansthan*. The remaining (2.43 %) were indifferent to this query. There is found quite variation in respondent's satisfaction level from one sanitary ward to another (Fig.2).

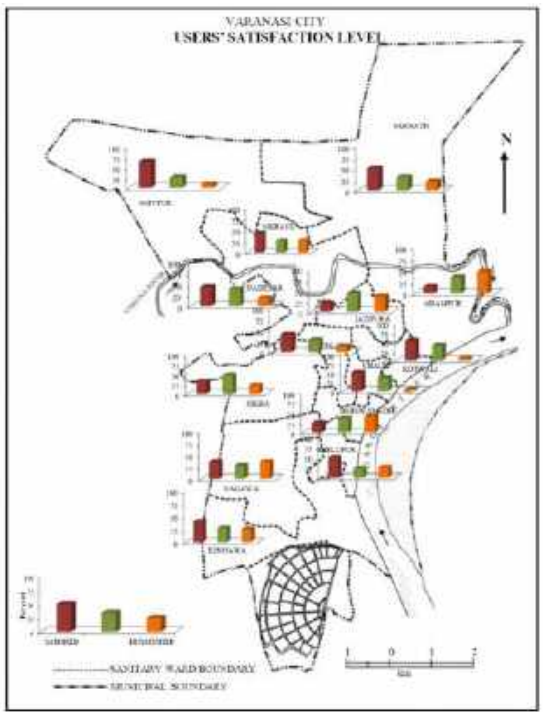

Fig. 2

The maximum number of respondents of Shivpur (64.0%) are satisfied with the efficiency of *Sansthan* whereas its percentage was recorded minimum in Adampur (16.0%) followed by Jaitpura (20.0%) and Dashaswamedh (24.0%) wards.The lowest number of respondents (20%) who are not satisfied with the water supply and quality of water belong to Adampur, Jaitpura and Dashaswamedh wards. It may be attributed to irregular and shorter duration of water supply combined with poor chlorination. The other reasons may be casual approach of Municipal Corporation regarding the problems. The above analysis indicates that neither municipal corporation nor *Jal Sansthan* is serious in providing requisite quality of water in adequate amount to their citizens. As a result, the poor suffer the most often pay a lionshare of their income for water. It requires concerted efforts by civic authorities as some of the deadly diseases like cholera, diarrhea, dysentery, tuberculosis, jaundice etc are caused due to contaminated drinking water supply.

Attempt has also been made to assess

Table 5: Educational lavelwise responses about satisfaction with water quality and supply

Educational level	Satisfied	Partially satisfied	Dissatisfied	Can't say	Total
Illiterate	21(17.36)	42 (34.71)	55 (45.45)	3 (2.48)	121
Primary	10 (10.98)	35 (38.46)	38 (41.76)	8 (8.79)	91
J.H.S	21 (35.00)	14 (23.33)	25 (41.67)	0 (0.00)	60
High school	42 (42.00)	54 (54.00)	3 (3.00)	1 (1.00)	100
Intermediate	43 (48.31)	31 (31.83)	12 (13.48)	3 (3.37)	89
Graduation and above	145 (60.67)	58 (24.26)	34 (14.22)	2 (0.84)	239
Total	282 (49.29)	234 (33.43)	167 (23.86)	17 (2.43)	700

Note: Figures in parentheses are the percentage value
Surce : Based on Field Survey, 2008-2009

resident's response according to their educational level. Of the total respondents who reported that they are satisfied with the present condition of water quality and water supply, maximum (51.42 %) have 14 are more years of education whereas only 3.55 per cent respondents have received 5 or less years of schooling. It is notable here that of the total dissatisfied respondents, 55.74 per cent have been to school for 5 years or less. The analysis revealed that with an increase in education, the percentage of satisfied persons has increased (Table 5).

Respondent's satisfaction level has also been examined with reference to their income. It is apparent from Table 6 that among the satisfied respondents, higher income group (above Rs. 10,000) dominates whereas among dissatisfied people, poor and marginalized respondents dominate. The study demonstrates that it is the poor; mostly living in slums suffers the most.

Table 6: Incomewise responses about satisfaction with water quality and supply

Income Group (Rs.)	Satisfied	Partially satisfied	Dissatisfied	Can't say	Total
Below 1000	11 (9.1)	31 (25.6)	78 (64.5)	1 (0.8)	121
1000-2000	39 (30.7)	61 (48.0)	19 (15.0)	8 (6.3)	127
2000-5000	44 (36.4)	47 (38.8)	30 (24.8)	-	121
5000-10000	76 (58.5)	41 (31.5)	11 (8.5)	2 (1.5)	130
Above 10000	34 (65.4)	17 (32.7)	1 (1.9)	-	52
Income not stated	78 (52.3)	37 (24.8)	28 (18.8)	6 (4.0)	149
Total	282 (40.3)	234 (33.4)	167 (23.9)	17 (2.4)	700

Note: Figures in parentheses are the percentage value
Source: Based on Field Survey, 2008-2009

Hence, they expressed dissatisfaction with availability of piped drinking water. It is common to see that majority of the poor by virtue of occupying marginalized physical environment in the city have poor access to civic amenities and resources.

Perception towards water purification

Poor quality of drinking water is a major health hazard in cities and towns. Most of the fatal diseases are associated with it. Maximum diarrheal deaths, especially among the children are attributed to unsafe water supply, poor sanitation and inadequate hygiene. Piped drinking water is a dream for poor urban dwellers. Hence, to examine the level of awareness for safe drinking water among sample households in the study area a question, 'Do you adopt any device for water purification?' was asked. The responses bring to focus that 57.0 per cent households use the water after purification whereas 43.0 per cent households have not adopted any type of purification method or device. Four methods namely (i) boil (distillation) (ii) filter by cloths (iii) mechanical filter, and (iv) electronic filter are being used by the households for purifying water.

Of the total respondents who reported that they use a purification device, maximum households (26.0 %) have a mechanical filter. Fig. 3 shows that highest number of respondents (98.0 %) of Shivpur have adopted a device for water purification, in which 44 per cent households have mechanical filter, 32 percent electronic filter and 22 per cent households boil water for drinking. Close to it is Nadesar ward which has high percentage (74.0 %) of households using

some kind of water purification methods. Among these households, maximum (30.0 %) have mechanical filter, 26 per cent use electronic filter and 18 per cent households used boiled water. Contrary to it, the lowest number of respondents (34.0 %) of Nagawa ward have used the water purification devices. Among them, 10.0 per cent each use electronic and mechanical filters, while 22 per cent households are using boiled water for drinking purpose (Fig. 3).

Use of filter depends on economic status of the households. Hence, it was thought imperative to probe the relationship between use of purification device and income of the household. The maximum (94.2 per cent) percentage of respondents whose income is more than Rs. 10,000 uses some kind of purification methods (Table 7). Of them, 36.5 per cent respondents reported that they have electronic filter for producing clear tasting drinking water followed by mechanical filter users (32.7%). However, only 13.2 per cent respondents with income (below Rs 1000) are using the water purification method but none of them posses filters.

It is distressing to note that a significant proportion of households (43.0 %) continue to con-

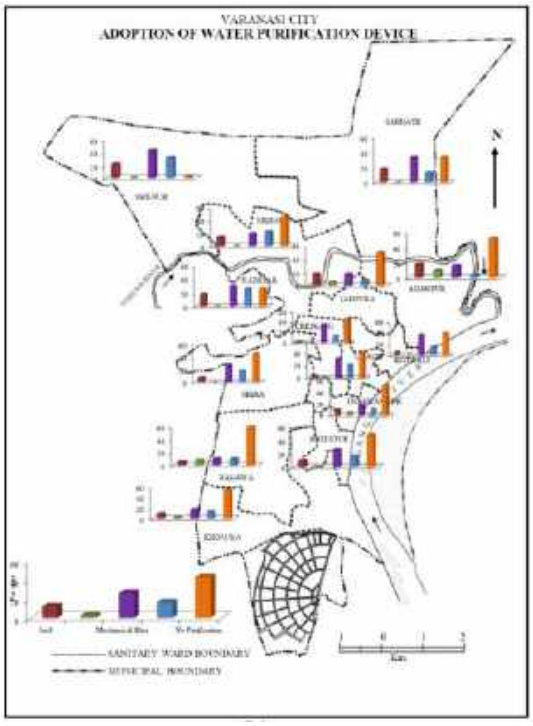

Fig. 3

Table 7: Responses about adoption of water purification device by income level

Income Group (Rs.)	Households Using		Used Purification device			
	Purification devices	No Purification device	Boil	Filter by cloths	Mechanical filter	Electronic filter
Below 1000	16 (13.2)	105 (86.8)	6 (5.0)	10 (8.3)	-	-
1000-2000	20 (15.7)	107 (84.3)	6 (4.7)	7 (5.5)	5 (3.9)	2 (1.6)
2000-5000	68 (56.2)	53 (43.8)	5 (4.1)	-	53 (43.8)	10 (8.3)
5000-10000	115 (88.5)	15 (11.5)	18 (13.8)	-	64 (49.2)	33 (25.4)
Above 10,000	49 (94.2)	3 (5.8)	13 (25.0)	-	17 (32.7)	19 (36.5)
Income not stated	131 (87.9)	18 (12.1)	35 (23.5)	-	46 (30.9)	50 (33.6)
Total	399 (57.0)	301 (43.0)	83 (11.9)	17 (2.4)	185 (26.4)	114 (16.3)

Note: Figures in parentheses are the percentage value

Source: Based on Field Survey, 2008-2009

sume water without using any water purifying method. Among them, a shocking share (86.8 per cent) belongs to lowest income group (below Rs.1000). It clearly shows that there is close relationship between adoption of water purify methods and income of residents. With the rise in income, the percentage of households using water purification method also increases (Table 7).

Data has also been compiled on the basis of educational status of the respondents (Table 8). It is interesting to note that of the total respondents who reported that they adopt purifying device to make water safe for drinking purpose, maximum percentage of respondents (76.2 per cent) have received 14 or more years of schooling. Among them, 32.6 per cent respondents use mechanical filter, another 28.8 per cent use electronic filter whereas families of 14.6 per cent respondents boil water to get good water. It is satisfying to note that 20.7 per cent respondents having no schooling at all reported use of purification device. However, only two respondents mentioned that electronic filter is used at their homes. The survey reveals that as the level of literacy increases, percentage of adoption of water purifying methods also increase. The households who are aware about the water related health risks are more likely to adopt water purifying measures. This empirical study proves that education and income are the key determinants in the use of safe drinking water.

Table 8: Responses about adoption of water purification device by educational level (number and per cent)

Educational Level	HH using Purification devices	Boil	Filter by Cloths	Mechanical Filter	Electronic Filter	No use of Purification device
Illiterate	25 (20.7)	6 (5.0)	9 (7.4)	8 (6.6)	2 (1.7)	96 (79.34)
Primary	31 (34.1)	6 (6.6)	4 (4.4)	17 (18.7)	4 (4.4)	60 (65.93)
J.H.S	38 (63.3)	5 (8.3)	1 (1.7)	22 (36.7)	10 (16.7)	22 (36.67)
High school	58 (58.0)	18 (18.0)	3 (3.0)	24 (24.0)	13 (13.0)	42 (42.0)
Intermediate	65 (73.0)	13 (14.6)	-	36 (40.5)	16 (17.9)	24 (26.9)
Graduation &Above	182 (76.2)	35 (14.6)	-	78 (32.6)	69 (28.8)	57 (23.8)
Total	399 (57.0)	83 (11.86)	17 (2.43)	185 (26.4)	114 (16.3)	301 (43.0)

Note: Figures in parentheses are the percentage value
Source: Based on Field Survey, 2008-2009

Change of stored water

Change of stored water is necessary from health and hygiene point of view. Hence, responses to the question 'After how many days do you change water?' are analysed. It brings to fore that of the sample households, respondents of 70.03 per cent households mentioned that stored water, especially in bucket earthen pot and mechanical filter is changed once in a day. The largest number of such respondents belongs to Sarnath (82%) followed by Kotwali

(80.0 %) and Chauk (80.0 %) whereas minimum (60.0 % each) in Jaitpura, Nagawa and Sikraul followed by Nadesar (62.0 %). Another 27.7 per cent respondents stated that stored water meant for drinking is changed in their families after two days. Maximum responses (40.0 %) to this effect came from Jaitpura and Nagawa followed by Adampura. Only 2.0 per cent respondents of sample households reported that the stored water is changed after one week. Maximum responses (8.0 per cent) were obtained from Nadesar ward.

The preceding analysis reveals the attitude of people towards cleanliness. If water is not changed for a couple of days, it may become unsafe owing to breeding of germs, foul smell and/ or poor taste.

Responses to the foregoing question are also examined according to educational level of the interviewees (Table 9). Interestingly, about 70.3 per cent respondents, irrespective of their educational background, opined that water is changed daily. Among them, the maximum respondents (42.4.0 per cent) are educated up to graduation level whereas 15.2 per cent respondents have either no schooling or few a years of schooling. Among the households where water is changed after two days, majority of respondents are either illiterate (40.72%) or poorly educated (24.74%). It shows that poorly educated people are not much concerned about the quality of water and hygiene.

Table 9: Educational levelwise responses about change of stored water

Educational Level	Once in a Day	After two Days	After one week	Total
Illiterate	35 (28.9)	79 (65.3)	7 (5.8)	121
Primary	40 (44.0)	48 (52.7)	3 (3.3)	91
J.H.S	46 (76.7)	14 (23.3)	-	60
High school	86 (86.0)	14 (14.0)	-	100
Intermediate	76 (85.4)	13 (14.6)	-	89
Graduation & Above	209 (87.4)	26 (10.9)	4 (1.7)	239
Total	492 (70.3)	194 (27.7)	14 (2.0)	700

Source: Based on Field Survey, 2008-2009

Attitude towards payment of water tax

Keeping in view the satisfaction and or dis-

Table 10: Incomewise responses about regular payment of water tax

Income group (Rs.)	Yes	Per cent	No	Per cent	Can't Say	Per cent
Below 1000	6	5.0	53	43.8	62	51.2
1000-2000	16	12.6	49	38.6	62	48.8
2000-5000	54	44.6	54	44.6	13	10.7
5000-10000	84	64.6	44	33.8	2	1.5
Above 10000	41	78.8	9	17.3	2	3.8
Income not stated	76	51.0	40	26.8	33	22.1
Total	277	39.6	249	35.6	174	24.9

Source: Based on Field Survey, 2008-2009

satisfaction about quality and water supply, it was thought imperative to know the people's attitude (willingness) towards payment of water tax. Data have been tabulated on the basis of income as well as educational status. Municipal water supply is largely subsidized and even then many of us do not pay for water and many who pay do not pay regularly and according to use. It is evinced from Table 10 that of the surveyed respondents, only 39.6 per cent pay water tax regularly. Among them, maximum percentages of respondents (78.0 per cent) belong to higher income group *i.e.* above Rs.10, 000. Only 5.0 percent respondents belonging to low income group pay the water tax regularly.

The analysis reveals that relatively well-off households pay water tax regularly and according to use whereas poor households do not pay water tax. Most of them use water either from municipal stand posts or roadside hand pumps for consumption. It may be noted here that with the rise in the income, the percentage of households willing to pay water tax also increases.

Further, of all the households who pay water tax regularly, the highest number of respondents (66.1%) belongs to those who have fourteen or more years of schooling (Table 11). However, only 6 illiterates (5.01%) respondents pay water tax regularly. The study shows that level of education has direct bearing on people's perception and attitude towards the payment of water tax.

With an increase in educational status, the number of water tax payers has also increased. The analysis evinces that educated people are more aware about the value of water delivery service and hence they pay water tax regularly. Besides, they are also willing to pay water tax according to its use. However, a disturbing fact is that a little over one- third households are not willing to pay for water whereas less than one-fourth households remained indifferent to this question. It may be noted here that success of water delivery service depends on regular payment of water charge by the consumers according to use. It is the responsibility of the municipal authority to provide the desired level of service with quality water irrespective to who lives where.

Conclusion

From the foregoing analysis it may be concluded that of the several critical variables, education and income account for variation in levels of perception to water quality and supply. It is further noted here that inadequate and irregular water supply is the common feature of the study area. It may be attributed to ever increasing population and human activities, expansion of residential areas, rapid increase in demand of water and over - abstraction of surface and ground water over the years. Many parts of the study area suffer from water borne diseases due to usage of contaminated water. The situation becomes more complex on account of leaking

Table 11: Educational levelwise responses about regular payment of water tax

Educational Level	Yes	Per cent	No	Per cent	Can't Say	Per cent
Illiterate	6	5.0	50	41.3	65	53.7
Primary	14	15.4	27	29.7	50	54.9
J.H.S	25	41.7	22	36.7	13	21.7
High school	30	30.0	49	49.0	21	21.0
Intermediate	44	49.4	36	40.4	9	10.1
Graduation & Above	158	66.1	65	27.2	16	6.7
Total	277	39.6	249	35.6	174	24.9

Source: Based on Field Survey, 2008-2009

taps and rotting pipelines. Keeping these issues in view, a few remedial measures are suggested for improvement in the urban water supply system such as proper treatment of water before supply, replacement of old pipelines with new ones, deep boring of hand pumps, coverage of maximum households with piped water at home, quick response/redressal to leakage in pipes/ taps and sincere public participation in water management programs. The municipal authorities and people should hold equal stakes in water supply governance to tackle the situation. Above all, awareness about right use of water and its harvesting should be translated into practice at grass root level. Since availability of sufficient safe water is directly linked to health and overall well-being, the health of urban residents, therefore, must precede all other concerns.

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Megacity Expansion, Recharge Deficit, Groundwater Depletion and City Sustainability in Ahmedabad

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Abstract

Indian megacities have massive population concentration due to rapid population growth in the wake of unprecedented globalization and reinforced tendency of economic centralization. India has eight megacities namely, Mumbai, Delhi, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad and Pune ranging in population from 5 million to over 20 million persons. These cities, together account for a huge urban population of nearly 100 million persons. Most of these cities sustain on the groundwater resources of their immediate environment. There is enormous water mining because the per-capita domestic water demand is highest in the megacities due to consumer oriented lifestyle and higher purchasing power of the people. In addition to it, the industrial-commercial water demand is also very high. On the other hand, the megacities have burgeoning built-up surfaces. The built-up surfaces induce run-off losses and prevent groundwater absorption and recharge. Consequently, the water discharge-recharge balance is heavily distorted. It leads to continuous groundwater depletion underneath and the immediate surroundings. Even more alarming would be the future scenario of diminishing water sustainability in the megacities of India. Further, most of these megacities are the capitals of their respective states. These are the prestigious cities of India. Acute water shortages would lead to social unrest and political instability in the developed states of India. The main objectives of this paper are to analyse the population growth and areal expansion of these cities to estimate the problems of water shortages and its consequences.

Keywords: *megacity expansion, recharge deficit, groundwater depletion, city sustainability, Ahmedabad*

Introduction

Basic water availability has remained a preliminary requirement for the location of settlements which subsequently groom into cities. A further sustained, ensured and qualitative water availability of diverse nature helps to develop them into megacities. Although many cities traditionally sustained on the water of lakes and rivers, however, modern big cities largely depend upon the groundwater resources. The present study examines the groundwater depletion in the megacity of Ahmedabad. The objective of the study is to identify a relationship between rapid population growth, extensive built-up area growth and the groundwater depletion. The underlying groundwater depletion or aquifer exhaustion has reportedly led to the sinking

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of the city surface in many megacities of the world. For example, Mexico City has sunk about 30 feet in the last 100 years (Rudolph, 2016). A similar problem has been identified about the aquifer system of Tokyo (Hayashi et al., 2009). The gradual city sinking problem has been noted for Seoul in South Korea (Kim et al., 2001).

The rapidly urbanising world has serious problems related to groundwater depletion (Geiger and Smith, 2011). Massive urbanization has made the sustainable yield of groundwater more complex in the major cities (Zhang, 2003). In India, the status of groundwater and its quality have degenerated in Bangalore (Reddy, 2003). Similarly, water sustainability problem has assumed a serious dimension in Chennai also (Srinivasan et al., 2010). Groundwater depletion scenario in the major cities of India is highly alarming (CGWB, 2011). A sustainable water resource development plan has been envisaged for Ahmedabad (Gupta and Nema, 1997). Ahmedabad has also witnessed the problem of groundwater exhaustion. It is a historical city which sustained for centuries on its abundant groundwater resources. The city of Ahmedabad was founded by Ahmed Shah, the ruler of Gujarat in 1411 A.D. He preferred the location of the city on the eastern bank of Sabarmati river for the ensured water supplies from the higher water table along the river as well as for its strategic advantages.

Data base and research methodology

The study has been conducted on the basis of mean annual rainfall data from India Meteorological Department, Pune. It has also utilised the groundwater data of Ahmedabad from Central Ground Water Board, Government of India. The periodic urban expansion data from 1961-2011 has been obtained from Ahmedabad Urban Development Authority. The corresponding data pertaining to demographic profile of the city has been taken from the Census of India, 1961- 2011. Simple statistical methods have been used for data analysis.

Ahmedabad city and environment

Ahmedabad's large city size and demographic changes have mostly taken place due to massive migration and marginally through natural population growth (Anon., 2002). Rapid migration to the megacity has led to urban sprawl towards its ever expanding periphery. This situation has led to an unprecedentedly higher pressure on the water resource availability in the city. The environment in the vicinity of Ahmedabad is healthy except in the congested walled city in the eastern half. In the walled city area the environmental conditions have deteriorated. Rapid growth of industries in the eastern part of the city and the growing number of automobiles has played a detrimental role to the quality of urban environment. Industrial effluent which is poured in the river has an adverse impact on the riverine ecosystem. It also inflicts an adverse effect on the health of people. Ahmedabad is a labour-intensive city in its domestic, industrial and service sector. Hence, there is high population and built-up density with scanty open spaces and green belts. The high density and labour intensive character depicts lack of modernization in the city.

The physiographic outlay of Ahmedabad, includes prominent water bodies, along with the city morphology. The built-up city morphology has a great bearing on the decreasing water recharge underneath the city landscape. As a result of increasing run-off and the decreasing percolation of water the groundwater level has progressively gone down. Ahmedabad urban agglomeration has a built-up area of 466 sq.km. The natural features which dominate the city morphology include the Sabarmati river and a few water bodies. Because of its levelled alluvial terrain the built-up city morphology of Ahmedabad is highly contiguous in its expanse.

Sardar Sarovar Dam on Narmada River has replenished the seasonal Sabarmati river into a formidable perennial river. Sabarmati runs through the heart of the city and bifurcates it into the old and new city along its impressive and recreational river front. The burgeoning megacity of Ahmedabad extensively straddles on either side of the river on its alluvial plains. The traditional old city east of 'Sabarmati Divide' has smaller buildings and is more congested. On the other hand, the western modern city looks more spacious. Higher per unit area infrastructural and municipal facilities like high-rise buildings and the resultant vertical growth have increased the built-up density in the modern city as compared to traditional sectors in the old city.

There are a number of large, medium and small lakes in Ahmedabad which do not have any significant influence on the water resource availability of the city. Chandola is the largest lake covering an area of 1200 sq.ha. followed by Kankaria lake (originally Qutub Hauz) which has an area of 31 sq.ha. with a circumference of 4.8 km. The lake has large greenery along its brim. The lake is now highly modernised. Its effect on the microclimate is evident from the pleasant evening breeze during the hot and longer summers.

Table 1 shows the decadal growth in the geographical extent of the megacity of Ahmedabad from 1961-2011. It also displays the changing demographic profile in terms of population, density and growth. The population size and growth determine the water demand and the per capita water availability in the city. Ahmedabad had a small geographical area of 63.1 sq.km. Its total population was 1.15 million persons. The average density of population was 18,225 persons per sq.km. This was a high population density. It depicts a higher congestion.

In 1971, Ahmedabad had recorded an areal growth to 108.2 sq.km. It depicts a net decadal area growth of 45.1 sq.km. The population growth in the corresponding period was to the extent of 1.75 million persons. The net population growth was 0.6 million persons. The population density showed a decrease from 18,225 persons in 1961 to 16,190 persons per sq.km. in 1971. This decreasing population density may be due to a proportionately larger built-up area growth. However, in the developing countries of rapidly growing urbanisation like India, when the city population densities appear to decrease from the previous decade it gives a false impression of decongestion of the city space. Infact, the population densities continue to rise in the inner, main parts of the cities. The apparent decrease in the population density is because of the sprawling peripheries towards the inner

Table 1: Ahmedabad: Area, population and density growth

City	Ahmedabad Urban Agglomeration				
Year	Area (sq. km.)	Growth of area (sq. km.)	Population (million)	Density (persons/sq. km.)	Growth percentage
1961	63.1	-	1.15	18,225	-
1971	108.2	45.1	1.75	16,190	52.17
1981	145.0	36.8	2.55	17,586	45.71
1991	190.8	45.8	3.78	17,355	48.23
2001	298.0	107.2	4.52	15,184	19.57
2011	466.0	168.0	6.35	13,631	40.48

Source: Computed from Census of India and Ahmedabad Urban Development Authority data.

rural-urban fringe. This fact is a clear evidence of the robust geographical law of core-periphery differential in operation. Another crucial aspect of the problem is that the water resource availability is lesser in the larger peripheries. It is because peripheries are scarcely provided with the infrastructural facilities. This again reaffirms another geographical law of distance-decay still in existence for explaining the scarce water resource availability in the city periphery.

In 1981, Ahmedabad had recorded an increase in its geographical extent to 145 sq.km. This was a net inter-decadal area growth by 36.8 sq.km. The total population of Ahmedabad was 2.55 million persons in 1981. The 1971-1981 aggregate decadal growth was 8,02,000 persons with an annual growth rate of 80,000 persons. The average population density increased to 17,586 persons per sq.km.

In 1991, Ahmedabad had recorded an increase in its geographical extent to 190.8 sq.km. There was a net area growth by 45.8 sq.km. The total population of Ahmedabad was 3.78 million persons 1991. The 1981-1991 aggregate decadal growth was 1,231,000 persons with an annual accelerated growth rate of 1,23,100 persons. This vividly indicates an urban take-off in Ahmedabad. The average population density maintained a high of 17,355 persons per sq.km.

In 2001, Ahmedabad had registered an increase in its geographical area to 298 sq.km. There was a net area growth by 107.2 sq.km. The total population of Ahmedabad rose to 4.52 million persons by 2001. The 1991-2001 aggregate decadal growth was only 7,42,000 persons with an annual growth rate of 74,200 persons. The considerably decreased aggregate population growth indicates a reduced in-migration due to stagnant sustainability of the city during this period. The average population density was still higher with 15,184 persons per sq.km.

In 2011, Ahmedabad had noted an increase in its geographical extent to 466 sq.km. There was the largest net area growth by 168 sq.km. during the decade 2001-2011. The total population of Ahmedabad increased to 6.35 million persons by 2011. The 2001-2011 aggregate decadal growth was of very high order by 1,831,000 persons with the highest ever annual growth rate of 1,83,100 persons. This reveals a clear sign of urban culmination in the wake of globalization in India. This considerably increased aggregate population growth indicates a re-invigorated trend of migration to qualify Ahmedabad as a megacity. Because of very large area growth the average population density reduced to 13,631 persons per sq.km.

The geographical extent of Ahmedabad currently ranges from 22^0 52' 58" N to 23^0 09' 47" N and 72^0 25' 40" E to 72^0 46' 16" E. Figure 1 illustrates a decadal urban expansion of Ahmedabad from 1971 to 2011. The city in the beginning had a compact and almost squarish orientation. Subsequently, it extended on either side of Sabarmati river. A little over one-third of the urban expanse was to the west of Sabarmati while the remaining two-thirds of the urban extent were east of the river. As the city of Ahmedabad originated and largely evolved to the east of the river, it depicts a higher urban and industrial gravity on the eastern side. This is evident from the subsequent urban expansion predominantly on the eastern side. The earlier ratio of the east-west growth still continues. The city expansion did not witness a take-off stage till 1991.The present hand-shaped areal expansion of Ahmedabad reveals its expansion on all sides along the radiating highway lanes. In the last forty years during 1971-2001, Ahmedabad recorded a net areal growth of 357.8 sq.km. It was a 331 per cent urban area growth. The highest built-up density in Ahmedabad lies in the inner nuclei of the city. The built-up density has a tendency to decrease towards the fringe. Hence, there is an apparent core-periphery differential in the built-up density of Ahmedabad. The high-

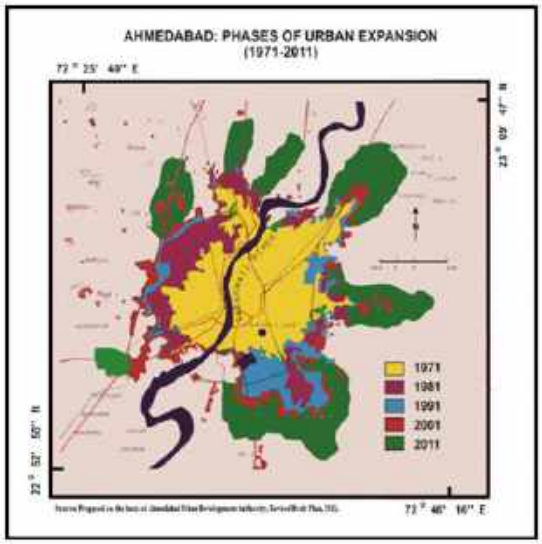

Fig. 1

est built-up densities in Ahmedabad are in the traditional areas to the east of the river. There is only one high built-up density pocket lying to the west of the river while there are a number of high to very high built-up density nuclei in the old city east of Sabarmati. This is because over 65 per cent of the population of Ahmedabad is concentrated to the east of Sabarmati in the old city.

Groundwater potentials and availability

According to climatic data of India Meteorological Department, the megacity of Ahmedabad receives a mean annual rainfall of 792 mm. Although, this is a fairly moderate amount of rainfall in terms of water potentials, the vast expanse of built-up surfaces reduce the groundwater absorption and induce the run-off losses. Harnessing the groundwater resources has a close relationship with the groundwater potentials. The location and distribution of groundwater is largely determined by the geographical factors such as the upper plains, middle plains and the lower flood plains. The highest groundwater potentials are in the flood plains of Sabarmati. In addition to it, the Palaeo channel in the eastern vicinity of Sabarmati has further enhanced the groundwater potentials. Above all, the long-lasting water supplies are furnished by the geologically formed aquifers in this region.

Flood plain and palaeo channel

Sabarmati river has a broad and well defined flood plain that gets occasionally inundated with flood water during the robust monsoons in above normal rainfall years. Other rivers like the Meshwa and Khari have narrow flood plains. The Palaeo channel of a past tributary of the Sabarmati river may be a potential source of groundwater. This palaeo channel is a feature on the far eastern part of the Sabarmati river. The Palaeo channels provide unconfined source of groundwater with excellent prospect.

Ground water prospects

In 2001, the water demand of Urban Industrial sectors were over 22.17 million cubic metres per year (MCM/Yr). In 2011, the demand for water was well over 301.7 MCM/Yr. The present source of water within Ahmedabad Urban Development Authority (AUDA) mainly includes tubewells/borewells and periodically released water from the Dharoi reservoir. Other minor sources are tanks and small streams. The borewells/tubewells are the most vital contributing source of water. Tubewells and borewells mainly comprise the privately owned and Ahmedabad Municipal Corporation (AMC)/ Panchayat Tubewells. The water released by the Dharoi reservoir is being collected and supplied by Dudheshwar Water Works.

An aquifer is a body of permeable rock with unconsolidated gravel or sand stratum. It is capable of storing significant quantities of water. It is underlain by impermeable material. A confined aquifer is sealed above and below by impermeable material. A perched aquifer is an unconfined groundwater body. The unconfined aquifer has nearly been rendered waterless and the current water demand is mainly met by the confined aquifer system being tapped by numer-

ous tube wells. The groundwater in Sabarmati basin occurs in the confined and semi-confined conditions (Kumar, 2005). Because of the phenomenal growth of Ahmedabad the usage of both the groundwater and Sabarmati water is continuously increasing (Shah, 1999). Hence, the water levels have been declining fast over the years. This is due to uncontrolled pumping, over-exploitation and above all, the lack of proper legislation on groundwater utilization. As a consequence there is an ever increasing threat to the quantity and quality of the groundwater.

The groundwater in the study area is omnipresent. The aquifer system comprises both, unconfined as well as confined aquifers. There is little ground water left in the unconfined aquifers due to heavy withdrawal in the past. The confined aquifers are main source of industrial and domestic water supply. The main limiting factor of potable water is quality of groundwater in some areas as it is impregnated with arsenic elements and dangerous contaminants such as pesticides which have chronic effects on the health of the inhabitants in the affected areas. It also includes heavy metals such as lead and zinc.

Groundwater resource availability

One can estimate that these aspects affect the groundwater depletion underneath the large built-up surface of Ahmedabad. The megacity of Ahmedabad has a population over 7.45 million people. The people of large industrial, commercial cities have higher water consumption level. Table 2 shows the water resource availability and groundwater discharge in the city. Ahmedabad Urban Development Authority daily provides more than 1,060 million litres of water to the city. This accounts to less than 167 litres of per capita water

availability. However, there are large core-periphery water availability differentials in the city. The lesser per capita water availability is understandably in the city's large slums.

There are a large number of 143 water distribution stations in the city. The water distribution network measures a total length of over 3,830 km. These 143 ground tanks have 857 million litres capacity. While the overhead tanks 141 in number provide about 63 million litres of water on the daily basis. The capacity of a large ground tank is 12 to 15 times larger than that of an overhead water supply tank. Prior to the surface water supply, for the quality control, it tends to pass through four major water treatment plants namely, Kotarpur, Dudheshwar, Jaspur and Raska localities of the city. Kotarpur has a capacity of 715 million litres per day while its utilization is 650 million litres per day. Jaspur has a capacity of 275 million litres per day while its utilization is 220 million litres a day. Raska has a capacity of 220 million litres per day with a daily utilization of 110 million litres. Dudheshwar is smallest with a capacity of 70 million litres a day and it has a very meagre utilization.

Table 3 shows compulsive changes in the groundwater availability vis-a-vis alternative surface water provisions in the burgeoning megacity of Ahmedabad. During the period 1970-1980, the groundwater was a major source of a bulk 87 per cent water supply to the city while surface water was required to contribute only 13 per cent of water supply in Ahmedabad. During 1980-2000, due to groundwater depletion the groundwater supplies reduced to 61 per cent of the total requirement and the surface water supplies had to be enhanced to 39 per cent of the water demand.

From 2000-2006 groundwater supplies were further reduced to only 21 per cent of the total and 79 per cent water supply was met by surface water sources. The continuous groundwater depletion is further evident from the fact that during 2006-2011 the groundwater sources could supplement only a meagre 10 per cent of the city water supplies while the bulk of the remain-

Table 2: Ahmedabad : City population and water availability

Sl. No.	Water availability attributes	Quantity/Capacity/Number
1.	Total City Population	6.35 million persons
2.	Total Daily Water Supply	1,060 million litres
3.	Per Capita Average Water Availability	167 litres
4.	Water Treatment Plants	4
5.	Water Distribution Stations	143
6.	Water Trunk Mains (Length)	250 km.
7.	Water Distribution Network (Length)	3,830 km.
8.	Surface Water Supply	90 per cent
9.	Groundwater Supply	10 per cent
10.	Ground Tanks (143)	857.40 Million Litres
11.	Overhead Tanks (141)	62.69 Million Litres

Source : Adapted from Ahmedabad Urban Development Authority.

ing 90 per cent water requirement was made available by alternative surface water supplies. This clearly indicates that the groundwater resources have considerably depleted underneath the massive built-up surface of the megacity. Although it is a subject of satisfaction with reference to the conservation of the groundwater, yet it remains a matter of debate and discussion that 90 per cent of the city water supply is met by the surface water sources and only a small 10 per cent water supply is available from the depleting and meagre groundwater sources. The major source of surface water supplies is the prestigious Sardar Sarovar Dam on Narmada River.

Conclusion

In the present study, the water resource availability and groundwater discharge in Ahmedabad has been analysed. Sustainable water supply, both in qualitative and quantitative measure, is a major problem in the megacity of Ahmedabad. As its population has grown to an enormous size of 6.35 million persons the water demand has considerably increased. Moreover, the people in this megacity, due to higher purchasing power and life style, have much higher per capita daily water consumption of over 176 litres. Apart from it, the city has a burgeoning built-up surface comprising over 466 sq.km. This large built-up surface induces run-off and curtails the rainwater percolation and the consequent recharge of the aquifer underneath. Hence, there is a twin problem of increasing water demand and depleting groundwater supplies. Ahmedabad Urban Development

Table 3: Ground water depletion and its decreasing availability vis-à-vis surface water

Duration (yrs.)	Ground water (%)	Surface water (%)
1970 - 1980	87	13
1980 - 2000	61	39
2000 - 2006	21	79
2006 - 2011	10	90

Source: Adapted from Ahmedabad Urban Development Authority.

Authority daily provides more than 1060 million litres of water to the city. Around 143 ground tanks have 857 million litres capacity. While the overhead tanks 141 in number provide about 63 million litres of water on the daily basis. The water supplies from groundwater sources had to be reduced from 87 per cent of the total water supplies in 1970 to merely 10 per cent of the total water supplies from groundwater sources by 2011. This is an ample empirical evidence of the depleting groundwater reserves underneath the city. There has remained an enormous imbalance between the groundwater discharge and the groundwater recharge in the city of Ahmedabad.

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Water Quality Assessment of Pond Water in Jaunpur City

Dipak Prasad[1] and Srabani Sanyal[2]

Abstract

Urban ecosystem services are generated in a diverse set of habitats, including: green spaces, such as parks, urban forests, cemeteries, vacant lots, gardens and yards, campus areas, landfills; and blue spaces, including streams, lakes, ponds, artificial swales, and storm water retention ponds. The wetlands, ponds, swales and trenches for water storage can encourage the biodiversity of aquatic organisms by providing a safe haven in the urban environment. Natural and manmade ponds are potential source of drinking water, ground water recharge and aesthetic beauty with their untouched view for their locality. Aquatic urban biodiversity cannot persist with anthropogenic stressors likewise an array of anthropogenic pollutants (sewage flow, solid waste, road salt and heavy metals etc.), invasive species, and active mismanagement-particularly the removal of riparian vegetation. Today growing density of household in urban areas also results confiscation of open areas, low land, pond and water bodies. Day by day areas of water bodies like ponds, lakes etc. are corrugating, which results the heavy load of sewage water and solid waste in absence of sewerage connection or negligence of waste collection in the city.

India is one of the developing country having prosperous fresh water resources in the form of rivers, kunds/ponds and lakes etc. Jaunpur is an old city and is popularly known for its ponds. The rapid development, urbanization and load of the various pollutant sources lead to deterioration of ponds. The city, situated on the bank of River Gomti which bisects the city of Jaunpur (located between 25°44' to 25°46' North latitude and 82°40' to 82°43' East longitude) in the north and south directions. Population growth and urbanisation rate in the city is very high during last few decades. There are about nine to ten ponds located within the city. This study aims to investigate the physico-chemical properties and estimate WQI of some urban ponds in the ecological system of Jaunpur city which is located within the municipal area of the city.

Keyword: *water pollutants, physico-chemical characteristics, water quality*

Introduction

Water is imperative element for life and well being of human beings. Natural water system provides fisheries, aquifer replenishment, water quality improvement and bio-diversity. Fresh wa-

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ter is the decisive, finite, vulnerable, renewable resource on the earth and plays an important role in our living environment, without it, life is impossible. Lakes and ponds are the habitat of great importance to humans as they provide water for domestic, industrial and agricultural use. A large number of people use this surface water for bathing, cleaning and for their other requirements. Inspite of their fundamental importance to humans, fresh water systems are adversely affected due to different set of stressors at local level, which causes many water borne diseases among inhabitants. There are different types of inland surface water which includes freshwater lakes, village ponds/tanks, countryside ponds, reservoirs, marshes, paddy fields, dams, canals, rivers and streams.

`Ponds' are generally described as small water bodies having areas of clear water and emergent macrophytes around their edges (Ian and Breen, 1993). Pond water serves domestic, livestock water supplies as well as for irrigation of high-value crops and vegetables. Ponds offer the opportunity to rear fish and other aquatic organisms (Miller, 2009).

Urban India depends heavily on various types of surface water bodies like rivers, lakes, ponds etc. to meet its daily uses of water. But the recent scenarios of urban areas are in worse condition due to rapid and unmanaged development process. All the aspects of urban environment are defiance by human economic activities. Thus, water bodies in urban areas are polluted up to the severe level.

The pond water is heavily polluted in India with surfactant and microbes from anthropogenic activities such as bathing, washing and mixing of runoff and municipal waste (Yadav, 2016). Quality of ponds is further degraded due to discharge of city sewage, agriculture and urban runoff and continuous dumping of waste materials especially sanitary waste (Bhatt et al, 2009). Like any other Indian cities Jaunpur city is encountering degradation of urban pond as reported by Central Water Commission (2011).The DO, TDS, TSS, nitrate, nitrite and other parameters in surface water are beyond the permissible limit and is not suitable for beneficial uses without conventional treatments (Singh et al, 2016). The present paper attempts to analysis the physico-chemical characteristics *i.e.* Temperature, pH, BOD, DO, Conductivity, Total Hardness, Chloride, Alkalinity, TDS and Turbidity and evaluate water quality based on Water Quality Index (WQI) of sampled ponds in the ecological system of Jaunpur city.

Material and method

Study area

The Jaunpur city, 25°43'30" and 25°46'30" North latitude and 82° 40' and 82° 42' 30" East longitude is one of the oldest cities among the three cultural capitals Ayodhya, Kashi and Prayag. City is historically known as *Sheeraz-e-Hind* having its historical dates from 1359, when the city was founded by the Sultan of Delhi Feroz Shah Tughlaq. The topographic monotony is interrupted by river bluffs and stream channels. Five major rivers flowing through the city are Gomti, Sai, Varuna, Pili and Basuli. River Gomti divides the city into two parts. The maximum elevation of 81.7 meters above sea level with slope less than 1 m is found in north-west to south-east direction.

As per Census 2011, the total population of Jaunpur city is 1, 80,362 of which 93,718 are males and 86,644 are females, density of 1,113 people per km^2, literacy rate at 82.83% and sex ratio of 925 female per 1000 male. The city is well-connected with other parts of India by National Highway 56, State highway 36.

Water quality

Water is perfectly transparent, colourless, tasteless and odourless, liquid at normal temperature and chemically neutral in reactions and a universal solvent for many compounds. If all

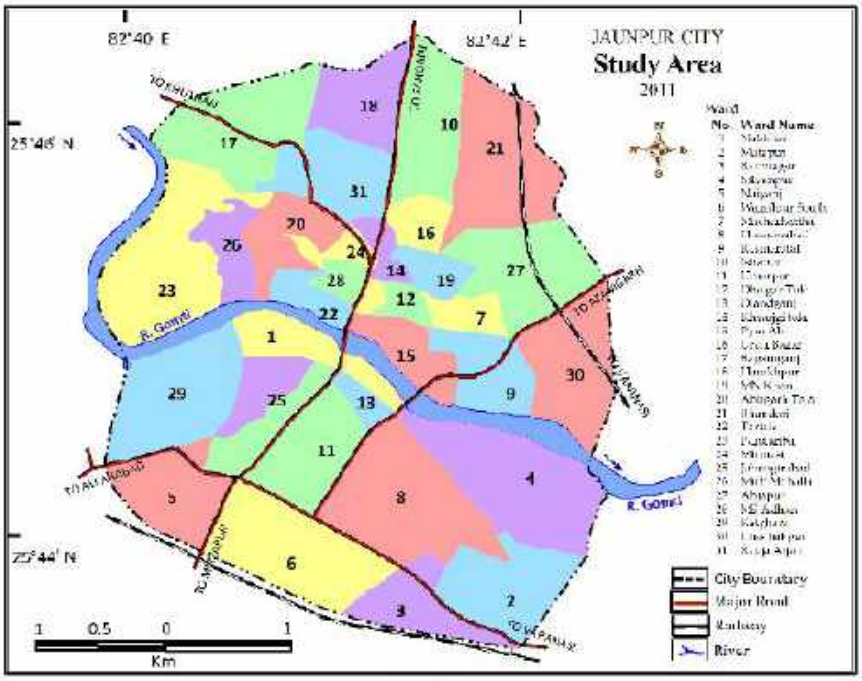


Fig. 1

these properties are met it is temed 'pure' in quality otherwise not. Assessing physical, chemical and biological characteristics of water can reflect its quality. Quality of water can be also assessed through Water Quality Index (WQI) which deals with summarising of water quality for reporting to the public in a consistent manner. It is similar to the UV index or an air quality index, and tells us, in simple terms, what the quality of water is.

Water quality index (WQI)

The indices of Water Quality Index (WQI) represent level of water quality (Horton, 1965). The rating of these parameters reflects the composite influence of different water quality parameters on overall quality of water (Ziauddin and Siddiqui, 2007) Selection of too many parameters widens the water quality index, therefore, parameters should be selected depending on the intended use of water (Sisodia, and Moundiotya, 2006).

WQI is calculated using standards for drinking water quality as recommended by World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR).Weighted Arithmetic Index Method is used for calculating WQI (Chauhan, and Thakor, 2012). For calculating Pond Water Quality Index (PWQI) the same method is applied. Further, quality rating or sub index (Qi) is calculated using the following expression.

$$\text{Quality rating (Qi)} = 100 \left[\frac{vn-vi}{sn-vi} \right] \quad \text{----- (i)}$$

Whereas,

Vn = Estimated value of the nth parameter at a given sampling.

Vi = Ideal value of nth Parameter in pure water.

Sn =Standard permissible value of nth parameter.

Ideal values in most cases Vi= 0 except in some parameters like pH and dissolved oxygen. Calculation of quality rating for pH and dissolved

oxygen (Vi ≠ 0) is 7.0 and14.6 mg/L respectively.

Calculation of quality rating for pH

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5

Therefore, the quality rating for pH is calculated from the following relation:

Qi (pH) = 100 [(Vn (pH) -7.0)/ (8.5 -7.0)] ---------- (ii)

Where, Vn (pH) = observed value of pH

Calculation of quality rating for dissolved oxygen

The ideal value for dissolved oxygen is 14.6 mg/L and standard permitted value for drinking water is 5 mg/L.

Therefore, quality rating is calculated from following relation:

Qi (DO) = 100 [(Vn (DO) - 14.6)/ (5 - 14.6)] ---------- (iii)

Calculation of Relative weight (Wi)

Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard value Si of the corresponding parameters.

Relative weight (Wi) = $\frac{1}{si}$ ---------- (iv)

Where, Wi = Unit weight for the nth parameter.

Si = Standard value for nth parameter.

1 = Constant for proportionality

The overall Pond Water Quality Index (PWQI) is calculated by aggregating the quality rating with the unit weight linearly using the following equation:

Pond Water Quality Index (PWQI) = $\frac{\Sigma W\text{-}Qi}{\Sigma Wi}$ ----------(v)

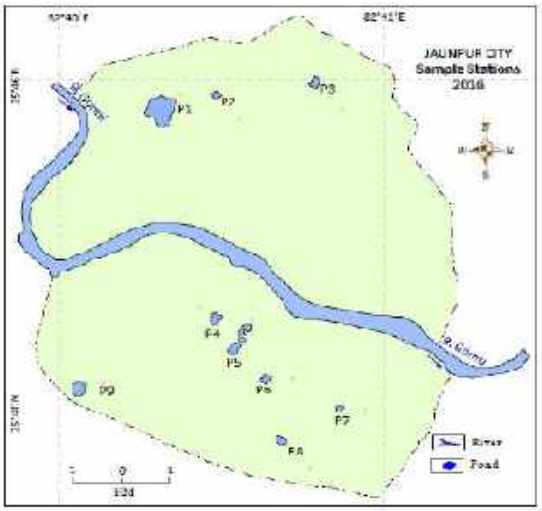
Water Quality Parameters

For the assessment of water quality of urban ponds in Jaunpur city, ten parameters selected are Temperature, pH, Biological Oxygen Demand (BOD), Dissolve Oxygen (DO), Conductivity, Total Hardness (TH), Chloride (Cl), Alkalinity, Total Dissolve Solid (TDS) and Turbidity.

Sampling

To determine water quality, 9 sample points (p1 to p9) are selected. The sample points p1 to p3 are located in the left bank of Gomti river (Trans-Gomti Region) and rest of the sample points (p4 to p9) are all in the right bank (CIS Gomti region). Water quality parameters are analysed for both pre and post monsoon period for all these sample points. p1 sample point covers 10.34 hec. of area in Nawagarh Begamganj and is largest in Jaunpur city, whereas, p2 in Rauja Arjan ward encomprises 0.49 hec. is 400 metres from p1 in North-east direction. Sample point p3 located in Sultanpur ward (0.55 hec. of area) is located about 1.4 km from sample station p1 in the North-east direction. The sample points p4 (0.87 hec.) and p5 (2.78 hec.) are located in Pratap Colony ward. p6 is located in T.D. College campus in Hussainabad ward which covers 0.4 hec. of area. Its depth ranges between 2-3 m. The rest of the three sample points (P7 to P9) are all located in the residential area within the city.

Water Quality Index (WQI) of pond water gives a comparative analysis of water quality at different sample stations for both pre and post monsoon seasons. The WQI ranges from 0 to 100, based on WQI water quality is categorized into excellent (0-25), good (26-50), poor (51-75) and very poor (76-100). WQI more than 100 or above is unsuitable for any purpose and values below 100 incessantly changes into good quality water (table 1).



Sample Stations

Pond Code	Area Type	Ward	Locality	Area in Hec	Population
p1	Residential	Dagamganj	Nawajgeh	10.34	2587
p2	Residential	Rauja Anjan	Chak Hata	0.49	7935
p3	Residential	Ishepur	Sultanpur	0.55	6420
p4	Resid. Cum Commercial	UmarPur	Pratap col	0.87	6656
p5	Resid. Cum Commercial	Umarpur	Pratap col.	2.78	6656
p6	Resid. Cum Commercial	Hussainabad	Tiladhari College	0.40	6084
p7	Residential	Hussainabad	Pakka Pok.	0.46	6884
p8	Residential	Ram Nagar	Bhagawati Colony	0.60	4034
p9	Residential	Naiganj	Jaunpur city Rly Station	1.34	4034

Fig. 2

Table 1: Water quality index and status of water quality

Water Quality Index (WQI)	Quality
0 -25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor

Source: Mishra, 2005.

The summary of Pond Water Quality Index (PWQI) for both pre and post monsoon seasons at different sample stations is presented in Table 2. Water quality is considered good with PWQI below 110, moderate (110 to 130), poor (130 to 150) and very poor (above 150).

Table 2: Pond water quality index (PWQI), Jaunpur City, 2018

Sl. No.	Range	Quality
1	Below 110	Good
2	110-130	Moderately poor
3	130-150	Poor
4	Above 150	Severe

Source: Calculated by the authors, 2018

Result and discussion

Physio-chemical characteristic of pond water

Water cannot be simply defined as pure in its chemical sense or cannot be regarded as polluted. It contains some measurable quantities of dissolved nutrients and other chemicals which changes. Its physical, chemical and or biological characteristics determination of its quality becomes unsafe to man for domestic needs and for other aquatic life. There is a need for scientific study of measuring particulates important for assessing characteristics to manage and control water composition.

Drinking water in Jaunpur city is mainly supplied through submersible wells, river water, hand pumps and wells. U.P. *Jal Nigam* is responsible for supplying drinking water for urban population in the city. The water requirement for habitants is met through surface water sources (Jal Kal water supply) or through other source like mainly shallow and deep tube wells from where water is supplied through pipe lines and taps in the city other than these there are some ponds which are used for domestic uses, but these is no doubt that these ponds are highly polluted.

Table 3 : Pond water quality during pre-monsoon period, Jaunpur City, 2017

Parameter/ Pond Code	CPCB Standard	p1 (Nawajgah pond)	p2 (Chak Hata Pond)	p3 (Sultan pur)	p4 (Pratap colony)	p5 (Pratap colony)	p6 (Tiladhari College)	p7 (Pakka Pokhra)	p8 (Bhagawati Colony)	p9 (Jaunpur city Rly St.)
Temp.		28.5	24.8	25.5	32.5	30.2	29.6	28.5	26.5	27.5
pH	6.5-8.5	7.3	7.2	7.3	7.8	7.9	7.7	7.8	7.7	7.6
BOD	6	13.1	12.8	12.6	19.6	22.4	19.3	21.8	17.6	16.6
DO	5	3.6	3.9	4	2.5	2.1	2.9	2.3	3.5	3.8
Conduct.	300	470.5	447.3	432.4	489.8	510.6	485.3	476.5	462.5	466.3
T. Hard.	500	515.6	445.2	432.6	586.4	598.3	558.7	563.3	502.5	520.3
Chloride	250	60.4	52	57.5	78.3	72.3	68.2	64.3	58.6	61.6
Alkalinity	200	278.6	257.8	258.5	328.6	315.58	305.5	291.5	260.5	280.5
TDS	500	610.5	588.8	578.6	703.3	698.3	665.4	630.3	612.8	619.4
Turbidity	5	7.4	6.1	6.27	8.5	8.4	8.1	8.0	7.4	7.6

Source: Field Survey, 2016-17

Among all parameters pH level is observed high at all sample points, ranging from 7.2 to 7.9 during pre-monsoon season to 6.9 to 7.6 during post-monsoon. High pH level is probably due to anthropogenic factors such as washing of clothes, use for cattle, regular laundry work at a large scale and also due to direct draining out of sewage lines all along the river bank. The tropical and humid climate further deteriorates the condition with average temperature ranging between 24.8º C to 32.5º C and 22.5º C to 31.1º C during pre and post-monsoon period respectively (table 3 and 4).

Table 4 : Pond water quality during post-monsoon period, Jaunpur City, 2017

Parameter/ Pond Code	CPCB Standard	p1 (Nawajgah pond)	p2 (Chak Hata Pond)	p3 (Sultanpur)	p4 (Pratap colony)	p5 (Pratap colony)	p6 (Tiladhari College)	p7 (Pakka Pokhra)	p8 (Bhagawati Colony)	p9 (Jaunpur city Rly St.)
Temp.	-	26.9	22.5	23.2	31.1	29.9	29.3	26.2	24.4	25.7
pH	6.5-8.5	7.5	6.9	7.1	7.4	7.5	7.5	7.6	7.3	7.4
BOD	6	12.9	11.1	11.9	17.5	20	17.3	18.5	15.3	15.6
DO	5	4.1	4.5	4.4	3.4	2.9	3.6	2.9	4	3.9
Conduct.	300	449.2	425.6	410.8	477.5	487.3	463.5	454.7	442.2	444.3
T. Hard.	500	483.6	412.5	400.8	553.3	565.4	525.8	530.1	469.9	487.7
Chloride	250	55.7	47.2	52.5	73.6	67.5	63.3	52.6	51.9	52.9
Alkalinity	200	242.5	221.9	222.4	242.7	275.68	259.6	255.1	224.5	264.6
TDS	500	544.7	523	512.1	627.5	633.1	559.6	534.5	547.6	523.6
Turbidity	5	5.3	4.4	4.6	6.9	6.3	6	5.6	5.3	5.5

Source: Field Survey, 2016-17

The Biological Oxygen Demand (BOD) level indicating extent of pollution level in water bodies ranges between 12.6 to 22.4 mg/l during pre-monsoon and 11.1 to 20.0 mg/l in post-monsoon in the study area. The BOD level is observed to be very high as per the permissible limit of BOD level 2.0 mg/l (ISI) and 6.0 mg/l (CPCB) for drinking water, and tolerance limit for irrigation water of 500 mg/l (ISI). The result further reveals declines in BOD level during post monsoon period due to low temperature, lesser amount of suspended or dissolved solids in water as well as higher level of microbial population (Shardendu and Ambust, 1988).

The Dissolve Oxygen (DO) at sample points ranges from 2.1 to 4.0 mg/l with average 3.17 mg/l during pre-monsoon period, whereas, during post-monsoon it is 2.9 mg/l to 4.5 mg/l and average of 3.74 mg/l (table 1&2). Among all the sample points the DO level is observed highest in two, Chak Hata (P^2) and Sultanpur Pond (P^3) because of low population density. The P^4 and P^5 sample points in Pratap Colony and P^6 near Tilakdhari College in older part of the city

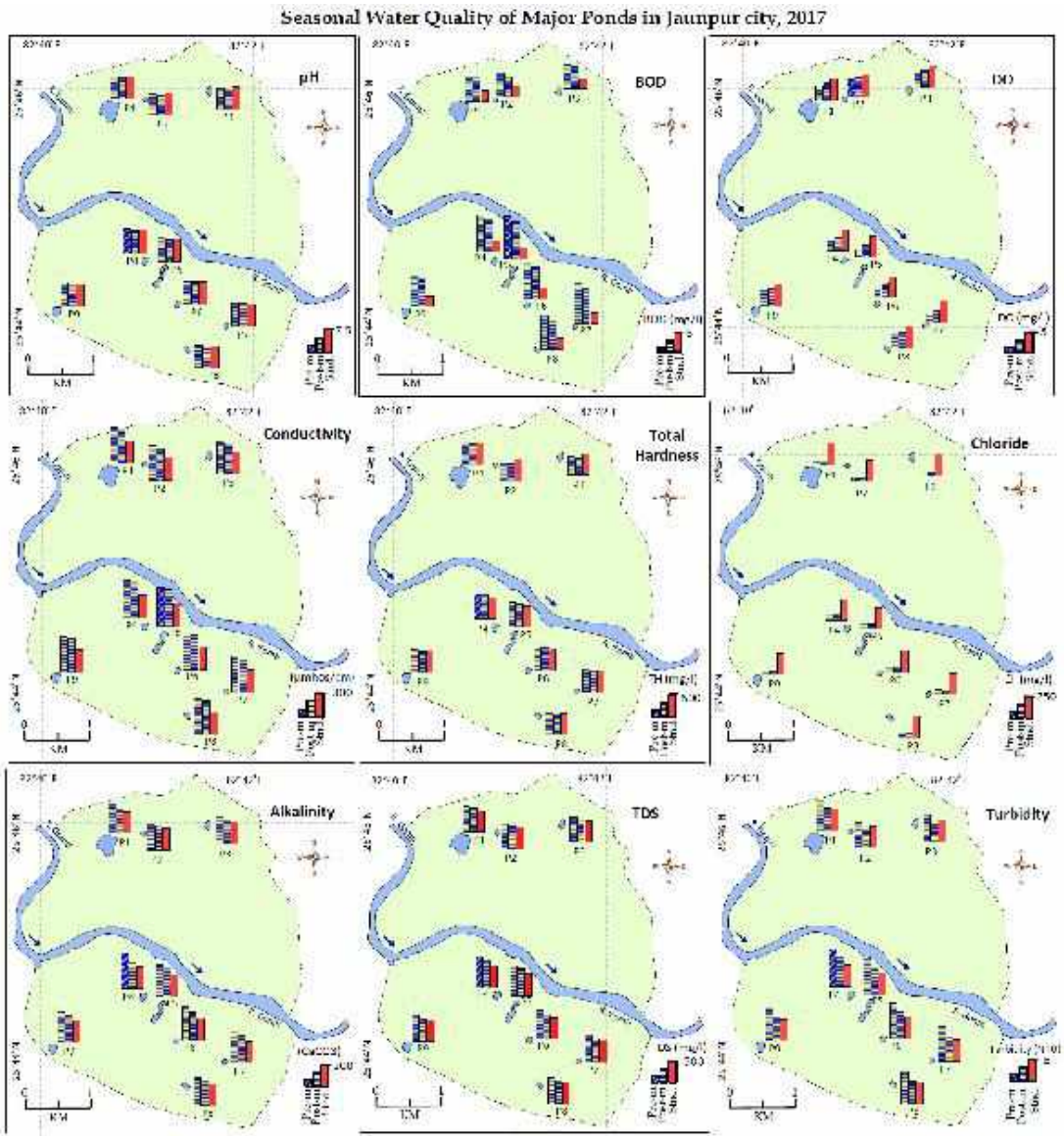


Fig. 3

have low DO level in pond water indicating poor water quality because the pond is located in the older part of the city.

Conductivity ranges between 432.4 (µ mohos/cm) to 510.6 (µ mohos/cm) with an average of 471 (µ mohos/cm) during pre-monsoon, whereas during post-monsoon period it ranges between 425.6 (µ mohos/cm) to 487.3 (µ mohos/cm) with an average of 450 (µ mohos/cm) (Table 1 and 2), these are much above the prescribed standard by CPCB. The variation in conductivity is due to influx of storm water runoff, sewage effluent etc. in pond water.

Total hardness (TH) ranges between 432.6 (mg/l) to 598.3 (mg/l) with an average of 524.76 (mg/l) during pre-monsoon, whereas, in post-monsoon it ranges between 400.8 (mg/l) to 565.4 (mg/l) with an average of 492.1 (mg/l) (Table 1

and 2). The Total Hardness (TH) exceeds maximum permissible limit at seven out of ten sample points as per CPCB standard because the amount of calcium and magnesium is high were drains are directly connected to ponds. The Chloride concentration ranges between 52.00 mg/l to 78.36 mg/l during pre-monsoon and between 47.2 mg/l to 73.6 mg/l during post-monsoon. The Alkalinity ranges between 257.8 mg/l to 328.6 mg/l with an average of 286.34 mg/l during pre-monsoon and 221.9 mg/l to 275.68 mg/l with an average of 245.44 mg/l during post-monsoon which is beyond the prescribed standard of CPCB.

Study reveals that TDS level in both the seasons are well above the permissible level. During pre-monsoon season it ranges between 578.6 mg/l to 703.3 mg/l with an average of 626.13 mg/l while during post-monsoon season it ranges between 512.1 mg/l to 633.1 mg/l with an average of 556.18 mg/l (Table 1 and 2). TDS in water originates from natural sources, sewage, urban and agricultural run-off and industrial wastewater. Turbidity ranges between 6.14 NTU to 7.68 NTU with an average of 7.58 NTU during pre-monsoon while during post-monsoon it ranges between 4.4 NTU to 6.9 NTU with an average of 5.54 NTU (Table 3 and 4). High turbidity declines the aesthetic quality of lakes and streams and harm recreation and tourism industry.

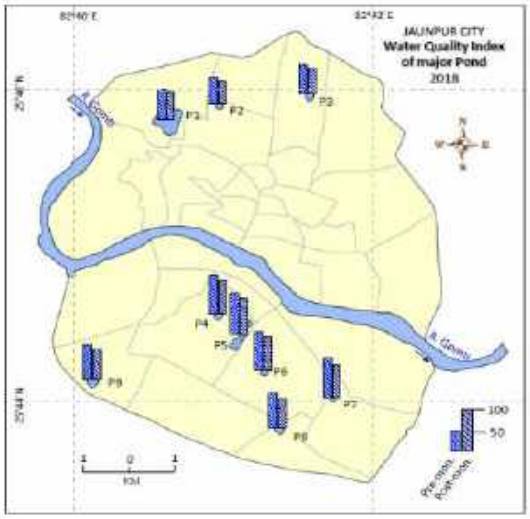


Fig. 4

Water quality assessment of pond water in Jaunpur City

The surface water e.g. river, pond, reservoir etc. receive sewage water directly from different sources. The quality of pond water depends on characteristics of soil and major chemical processes such as respiration photosynthesis and decomposition. The composition changes constantly, depending on climate, seasonal change and use of pond water. Physico-cultural and bacteriological analysis of surface water in Jaunpur city indicate it for drinking purposes and causes harmful effect to human health. Waste water in Jaunpur city contains significant amount of organic matter which are highly biodegradable in nature. The total BOD load of river Gomti is as 42 mt/ day due to discharge of waste water containing organic matters in suspended, dissolved and colloidal directly into river Gomti. River water quality is not fit for drinking and other domestic uses without treatment (Singh, 2002). The pond water is also highly polluted due to degrading nature.

Water quality index for all nine sampled ponds in Jaunpur city is represented in Table 3 and Fig. 4. The pond water quality ranges from good (below 110), moderate (110-130), poor (130-150) and very poor (above 150) based on Pond Water Quality Index (PWQI) in Jaunpur city. The PWQI above 100 is unsuitable for any domestic purpose and below 100 incessantly changes into good quality as recommended by WHO.

The WQI for pre-monsoon season ranges between 112.64 (Chak Hata Pond) to 162.18 (Pratap Colony pond) indicating very poor water quality, with an average of 139.25. The sampled pond P^1 is having good water quality in

compare to rest of the sampled ponds because it is located in Harakhpur ward in the outer periphery of the city having low population density and domestic activities.

Table 5: Water quality index, pond water, Jaunpur City, 2018

Sampled Pond	Ward	Pre-monsoon	Post-monsoon
p1 (Nawajgah pond)	Bagamganj	121.07	112.70
p2 (Chak Hata Pond)	Rauja Arjan	112.64	95.81
p3 (Sultanpur)	Ishapur	114.26	101.77
p4 (Pratap colony)	UmarPur	152.84	135.13
p5 (Pratap colony)	Umarpur	162.18	140.01
p6 (Tiladhari College)	Hussainabad	150.15	131.42
p7 (Pakka Pokhra)	Hussainabad	157.15	130.95
p8 (Bhagawati Colony)	Ram Nagar	142.33	119.31
p9 (Jaunpur city Rly St.)	Naiganj	140.60	122.34

Source: Calculated by the authors, 2018

Whereas, other sampled ponds located in the central part of the city or in CIS Gomti region have PWQI above 130 indicating poor water quality. Degraded pond water quality during pre-monsoon in Jaunpur city is mainly due to anthropogenic activities like disposal of domestic waste and waste water directly into lowlands and ponds.

According to PWQI, the water quality during post-monsoon season is moderate to good because of huge influx of fresh water in ponds after heavy rainfall. The PWQI ranges between 95.81 (Chak Hata Pond) to 140.01 (Pratap Colony) with an average of 121.04. The reasons for significant poor water quality at some of the sampled ponds during post monsoon period is probably due to intermingling of waste scattered along roads and vacant places with storm water in the city. The ponds located along semi-metalled roads with bare surface get easily washed off with surface runoff and get polluted.

Conclusion

India face serious problem of control and management of natural reservoirs especially water due to rapid population growth and economical conditions. Ponds are subjected to natural process like hydrologic cycle with unprecedented developmental activities. Sewage is just one aspect of water pollution, as frequent industrial, domestic and natural sources of pollution also discharge pollutants and contaminants surface water bodies. The impact of these on environment are far-reaching in India in reference to water resources, is, health and quality of human lives threatened.

In Jaunpur city surface run-off cause sewage entrance into water and degrades pond water due to discharge of domestic and other wastes. Other than these, domestic activities also pollute pond water. The water is not suitable for any beneficial uses without conventional treatments. It is also found those ponds located in and around commercial and densely populated residential areas within the city have degraded more than the CPCB or WHO standard. Therefore, need of the hour is to revaluate the water quality assessment and management procedure to help to rejuvenate the ecology of pond ecosystem system in Jaunpur city. There is also a quick requirement of governmental and public support to improve the quality of water.

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Environmental Impact Assessment of River Ganga along the Ghats of Varanasi City

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Abstract

Water is the most important element in the biosphere because on the one hand it is vital for the maintenance of all life forms and on the other hand it helps in the movement, circulation and cycling of nutrients in the biosphere. Water is also essential for power generation, navigation, irrigation of crops, disposal of sewage etc. Increased demand of water consequent upon increasing population and industrial expansion has degraded the quality of water considerably. Though water like other natural substances has self purifying mechanism during recycling process but when the amount of foreign undesirable substances added by the man to the water exceeds the tolerance level and self purifying mechanism of water, it gets polluted. Varanasi, the most ancient city in the world also suffers from the problem of water pollution. The main sources of water pollution in Varanasi city is the domestic waste water which flows through sewers and open drains. Total volume of domestic wastewater generated in the city is estimated to about 300 MLD of which only 102 MLD is treated in sewage treatment plants (STPs) and the remaining 198 MLD is directly discharged into river Ganga and Varuna through open drains. The STPs do not work efficiently or properly during rainy season and many other reasons increase the pollution load of river Ganga and Varuna. Regular huge quantity of domestic wastewater either drains into river Ganga without any treatment or disposed on open lands further polluting underground water through seepage which affect the quality of water and human health also. To assess the human responses towards the problems of water pollution a total number of 540 respondents were interviewed by using the structured questionnaire blended with suitable open-ended questions.

Keywords: *Pollution, domestic waste water, fecal coli form, human health*

Introducation

Ganga which is the lifeline of millions of people and of great religious significance is being polluted by both domestic sewage and industrial pollutants that are being dumped into river untreated. This causes risk of health hazards for over millions of people who directly and indirectly use the river water in their daily lives. According to the report of UPCB, 60% diseases are water related in Varanasi since Ganga is the major source of drinking water supply in Varanasi. Quality of river Ganga water in Varanasi is found to be far below the ISI stan-

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dards and even after 17 years of implementation of Ganga Action Plan (GAP), some researchers held the view that Ganga water in Varanasi is not even fit for human bathing at some of their ghats (Tripathi, 1984).

In Varanasi, it was observed that coliform counts are as high as 100,000 per 100 ml. elsewhere in the river, they range from 4,500 upstream to 120,000 downstream. So, not surprisingly, water related ailments like amoebic dysentery, gastroenteritis; tape-worm infections, typhoid, cholera and viral hepatitis are extremely common in the Gangetic region. Occurrences of enteric diseases are significantly related with many hazardous chemical and fecal coliform. So it is quite likely that the drinking water used by the city dwellers may be causing the enteric diseases. Since even if the treatment at the water works is properly done, contamination may take place due to seeping old supply pipelines or use of raw river Ganga water by same, due to bathing and drinking at the time of religious festivals. People living at the bank are in direct contact of the polluted river water for daily use purpose and the people living far from the river are depended on the municipal water. Since municipality is also taking the water from Ganga and due to lack of proper treatment they are supplying some time polluted water to the different parts of the city.

Objectives

1. To evaluate the sources of water pollution in the city.
2. To assess the spatial pattern of water pollution.
3. To evaluate the people's perception towards the problem of pollution and its effect on their health.
4. To suggest remedial measures to control the problem of water pollution in the city.

Data base and methodology

Present study represents a cross-sectional survey of different group and to assess the existing status of water quality and pollution in the city. A total number of 540 peoples were interviewed by using the special questionnaire blended with suitable open-ended question on sources, effect, reasons of the increasing of pollution problems, recreation and suggestions to remove the problem of water pollution. The data was analyzed using SPSS 12 version. Regarding the human responses to water pollution, the categories of respondents have been grouped into different occupation, income, and education etc. Secondary data has been collected from various sources such as Municipal Corporation, Varanasi Development Authority, U.P. Pollution Control Board, Jal Sansthan, Jal Nigam, Bhagwanpur Jal Nigam Office, Siddhgirirbagh, Sankat Mochan Foundation, Tulsighat etc. for analysis purposes.

Study area

The ancient city of Varanasi is situated (Latitude $25^0$15´N to $25^0$22'N and Longitude $82^0$57'E to $83^0$1´E) on the left bank of the river Ganga . Varanasi is well connected by road, railways and airways with other parts of the country. It's unique in its architectural, artistic and religious expressions of traditional Indian culture even today attract large number of people from different parts of the country. Varanasi city is the district headquarter of the Varanasi district and the major part of the urban area, delimited by the Census as 'Varanasi Urban Agglomeration' (VUA; 82^0 56'E - 83^0 03'E and $25^0$14'N - $25^0$23.5'N), covering an area of 112.26 sq. km and consisting of 7 urban sub units. Varanasi is often said to be located between two confluences: one of the river Ganges and river Varuna, and other of the river Ganges and river Assi, which having always been a rivulet rather than a river. It causes more pollution pressure to the city resulting increasing level of water.

Keeping this in view it becomes essential to monitoring pollution levels and awareness among people towards problem of water pollution.

Spatial patterns of water pollution in the Varanasi City

Among the various natural resources essential for life on the earth water is the very basic and most important among them (Kayastha, 1986). It will not be wrong to say that there is no life without water rather the life beings with water. Water is being used for drinking, bathing, cooling, irrigating the plants, producing energy besides transportation and recreations.

Human environment is highly dependent on the availability of fresh water resources. Demand of good quality of water is increasing spheres of human activities and industrial expansion while on the other it is being contaminated due to untreated discharge of waste water into water bodies which created a great threat to aquatic life and to human health. Thus, it becomes essential to given serious attention to study the various facts to understand the nature and effects of water pollution and also its control.

In India, water pollution comes from three main sources: domestic sewage, industrial effluents and run-off from activities such as agriculture (Kayastha, 1966). The large-scale use of pesticides may have revolutionized food production, but these chemicals are responsible for more than 2 million human poisonings every year with a resultant 20,000 deaths (WHO, 1986). According to WHO (1996) "any foreign material either from natural or other sources which may change the composition of water supply and may be harmful to life, because of their toxicity, reduction of normal oxygen level of water, aesthetically unpalatable effects and spread of epidemic diseases". According to the scientists at the National Environmental Engineering and Research Institute, a staggering 70 per cent of the available water in India is polluted. Only five states (Maharashtra, Gujarat, Delhi, Uttar Pradesh and West Bengal) generate more than 63 per cent of the total wastewater in India as they lack treatment facilities (Down to Earth, 2005). Patel (1993) in his paper describes the status of water quality of river Sankh of the Western Orissa in India, analyzed parameters revealed that water of this river is not suitable for drinking purpose with respect to total solids, excess iron and cadmium. Gupta (1994) observed the contamination of Fluoride in ground water at Agra. Kumra (1997) keeping in his study not only to evaluate the effectiveness of the GAP, but also evaluate varied human responses to water pollution and their concern in restoring the primitive value of the river water in respect of Varanasi city. Anand, et al. (2006) study reveals the impact of diverse anthropogenic activities as well as the monsoon effect on the bacterial population of river Yamuna in Delhi stretch. Dey, et al. (2005) were assessed various physio-chemical parameters on the samples drawn from the river Koel, Shankha and Brahmani selecting strategic points. It was observed that dilution during rainy season decreases the metal concentration level to a considerable extent. However the enrichment of these metals by bio-magnification and bio-accumulation in edible components produced in water is accepted to produce a remarkable effect on the water of the river Brahmani which is of deep public concern. Kelkar (2005) evaluated the Impact assessment of Ganga Action Plan on river quality at Varanasi near the bathing ghats and in the midstream, suggested for suitable measures to improve the water quality in the river.

The Ganga water is heavily polluted in Varanasi. In Varanasi, river Varuna and Assi have been polluted beyond recognition that now they flow not as rivers but just torrent of sew-

age and waste water mixing at the start and end of the holy city of Varanasi (Varuna Assi). About 71 large and small sewer drains discharge about 15 MG/D (million gallons per day) of effluents from the city to Ganga (Hamner, 2006). According to study conducted by UPPCB in Varanasi dissolved oxygen (DO) is less than the permissible limit of 5mg/l and BOD is as high as 8.8mg/l which is much higher than the permissible limit of 3mg/l (Table 1).

Table 1: BOD and fecal coliform presence at different points (2016)

Locations/Parameters	Biochemical oxygen demand (mg/l.)	Fecal coliform count/ 100ml.
At beginning of Varanasi city	3-8 mg/l.	20,000-100,000 per 100 ml
near Assi/Tulsi ghat downstream of the Varanasi city	20-50 mg/l.	1,000,000-2,000,000 per 100 ml.
Varuna confluence with Ganga permissible limits for bathing	Less than 3 mg/l.	Less than 500 per 100 ml.

Note: Higher the BOD, higher is the pollution (conversely there is more DO needed to make the water safe)
Source: Swatcha Ganga Research Laboratory, Varanasi, 2016

The problem peculiar to Varanasi arises from the Hindu belief that the dead cremated here attain 'moksha' (salvation). This results in more than 100 of dead bodies cremated at ghats every day. According to the survey conducted by B. D. Tripathi (BHU, Varanasi) about 23,000 to 32,000 dead bodies are burnt every year at different ghats mainly Manikarnika and Harishchandra ghats. About 10,000 to 15,000 tonnes of woods are used to burn these dead bodies. This amounts to nearly 15,000 tonnes of ashes per month, which is dumped into the river. Thus ashes of burnt woods, partially burnt woods, unburnt portion of dead bodies (weighing about 150 tonnes of flesh of partially burnt human dead bodies) and unburnt or partially burnt skeletons are thrown into the river which heavily pollute the river water near several ghats. The study further reveals that out of total dead bodies burnt at two ghats about 47% are brought from outside Varanasi in the belief that if burnt at Varanasi the departed soul would go directly to the heaven. The wood required to burn dead bodies at Varanasi alone results in the deforestation of 15 to 115 hectares of forests each year (Tripathi, 1984). Besides, about 7000 dead animals are also thrown into the Ganga near Varanasi every year. The burning of dead bodies in these two ghats raises the water temperature between 30-35^{0}C which reduces the dissolved oxygen by 30%-50% (Tripathi,1984). This causes deaths of many aquatic creature every year. The pollution problem of the Ganga at Varanasi is further complicated by effluents from the diesel locomotive works located in the city. It is estimated that Varanasi is responsible for one-fourth of Uttar Pradesh's contribution of pollutants to the Ganga.

It is estimated that out of total pollution load runoff reaching the river stream, the load from point sources (urban waste water and industrial effluents) is significantly high (94%) including 79% load from municipal sewage and 15% load from industries. The industries are mostly dying industries, which are associated with making of banarasee sari and are located in old city area. The remaining 6% is observed to be contributed by non-point sources such as agricultural and forestry runoff, livestock, rural households etc. Total sewage generated in the city is about 300 MLD of which only 102 MLD is treated in sewage treatment plants (STPs) and the remaining 198 MLD is directly discharged into river Ganga and Varuna through open drains.

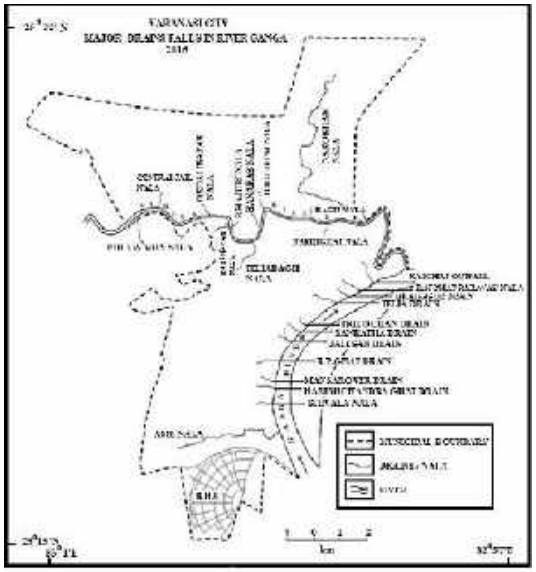

Fig. 1

The STPs do not work efficiently or properly during rainy season and increase the pollution of river Ganga and Varuna. The areas without connection with sewerage system the sewage discharge directly into the Ganga, Varuna or Assi nalla, polluting the river.

There are 29 open drains and big nalas flowing throughout the city. Out of 29 open drains and nalas (Table 2& Fig.1) shows the concentration of various pollutants in 15 drains and nalas based on the secondary data collected from Jal Nigam, Bhagwanpur. It is evident from the above that the temperature of the nalas water varies from 19.4 0c Harishchandra Ghat nala to 19.8 0c Varuna. The pH level found fluctuating within a range of 8.46 to 9.4 revealing alkaline nature of water. The DO is recorded at U/S Ganga river mid stream (10.99 ppm) while 4.44 ppm at Vasanta college D/S (Konia).

Human responses wards problems of water pollution

About 60,000 people take a holy dip in the Ganga at the ghats each day. There may be a

Table 2: Samples of drains and nalas

Location	pH	DO (ppm)	Temperature in ^{0}C
U/S Nagwa nala	8.88	10.40	19.5
U/S Ganga river (mid stream)	8.95	10.99	19.6
Shivala nala	9.01	10.00	19.7
Harish Chandra ghat nala	8.96	9.71	19.4
Rajendra Prasad ghat nala	9.04	10.56	19.8
Jalasen ghat nala	9.03	11.07	19.7
Panch Ganga ghat	8.95	9.63	19.5
Gai ghat	8.99	9.91	19.7
U/S Telia nala	8.87	10.09	19.5
Bhainsasur ghat (Rajghat)	9.01	10.34	19.7
Konia by-pass U/S	9.00	9.56	19.6
Vasanta College D/S (Konia)	8.46	4.44	19.7
Varuna River D/S	8.46	9.01	19.8
Ganga River D/S	8.49	5.16	19.7
Scindhia Ghat (mid stream)	9.03	10.20	19.7

Source: Jal Nigam, Bhagwanpur, 31.01.2015 (8:00 a.m. to 10:00 a.m.)

few thousand people among them for whom Ganga is the medium of life. They have immense faith in the Ganga, are committed to her and cannot be separated from her. They want to have a 'darshan' of the Ganga, touch its water, submerge their body into its water and get ecstatic contentment by sipping its water. They cannot bear anybody saying that Ganga is sick and polluted. The culture and the faith related to the Ganga have survived for thousands of years because of these practicing Hindus. They are ignorant of the present processes of development, science and technology. The maximum population density of the city near Shri Vishwanath Temple is 100,000 per km2. Usually people have pet animals in their houses but no arrangement exists for solid waste disposal, including disposal of the animal carcasses. Firewood is becoming costlier every day. It is difficult for the 'Shmashan Ghat' (cremation ground) to cope with the pressure of increasing number of cremations done on the river bank. The result has been abuse of mother Ganga. The total sewage and industrial effluent of Varanasi is flowing into the river along the Ghats of Varanasi. Garbage, dead bodies of animals and unclaimed human bodies, plastic bags, etc. are also thrown into the river where people take a holy dip (Tripathi, 2014).The visible and non-visible pollutants causing deterioration in water quality have changed the perception of people towards the river Ganga during recent years . In order to assess the responses towards pollution of river Ganga, the data recorded for the question "Do you feel that the River Ganga is polluted?" analyses in Table 3.

The analysis reveals that the out of the total respondents, 86.3 per cent respondents, of which 36.9 per cent from business class, 24.6 per cent from others, 15 per cent from service class, 7 per cent from daily wager and low proportion of 2.6 per cent respondents from pandas reported that the river Ganga has become more polluted due to different sources viz., discharge of municipal sewage and some small and large size of open drains and nalas and waste from dying industries which situated in the central city directly into the river. Unscientific disposal of solid waste along the Ghats of river and floating dead bodies of human and animals which are the major causes of pollution in the river which effect human health badly. Further it is observed that about 13.9 per cent of respondents felt that they don't feel any pollution problems in the river. According to them that Ganga River is most ancient and sacred river and it can't be polluted. It is observed from the above analysis that responses towards the pollution of river Ganga is highly significance on

Table 3: Responses to the question on pollution of river Ganga

Occupation	Yes (%)	No (%)	Total (n)
Business	36.9	3.5	218
Service	15.0	2.0	92
Daily Wage Earner	7.0	1.2	44
Others	24.6	2.4	146
Pandas	2.6	4.8	40
Total	86.1	13.9	540

Note: (n) Number of respondents, chi-square significant at P = 0.001

Source: Based on personal survey, 2016

chi-square test. The responses to the question "Do you feel any changes in river water quality for concerned purpose"? Responses were recorded in Table 4.

It is observed from the table 5 that out of the total respondents, about 81.7 per cent, of which 35.4 per cent from the occupation of business class, 22.8 per cent from others group, 14.1 per cent from service class, 7 per cent from daily wage earner and about 2.4 per cent from pandas group reported that there is major change in water quality due to different ways of which discharge of municipal sewage and storm drainage and open nalas directly falls into the river which changed the quality of river water. Further it is observed that about 18.3 per cent of respondents felt that they don't feel any change in quality of the river Ganga. Above analysis towards the change in river water quality, by profession of respondents is highly significance on chi-square test.

And "which type of change perceived through?" were also tabulated. It is evident during the survey that 83.2 per cent respondents revealed 'yes' that there are many changes come into the river through different ways in her transparency. And about 16.8 per cent reported that they don't feel any type of change in the quality of river water. It is observed from the above table that occupation is highly significance on chi-square test.

Table 4: Distribution of responses towards the changes in river water quality by profession of respondents

Occupation	Yes (%)	No (%)	Total (n)
Business	35.4	5.0	218
Service	14.1	3.0	92
Daily Wage Earner	7.0	1.2	44
Others	22.8	4.3	146
Pandas	2.4	5.0	40
Total	81.7	18.3	540

Note: (n) Number of respondents, Chi-square significant at P = 0.001

Source: Based on personal survey, 2016

Responses were also tabulated (Table 5) on the basis of different educational level of respondents as to know about awareness regarding main sources of water pollution in the city. In the graduate level category of 33.7 per cent respondents, 20 per cent have perceived that sewage disposal directly into the river are the main source of pollution problem whereas 4.3 per cent is of the opinion that washing cloths and using detergents along the ghats making problem of water pollution. About 4.1 per cent respondents reported that floating of dead bodies and 3.1 percent said disposal of solid waste directly into the river and remaining 1.7 per cent felt that throwing of flowers into the river as a religious purpose everyday in the city is the major sources current problems of the city. In low educational level up to primary (9.8%), 5.7 percent respondents revealed that the discharging of sewage into the river is the main source and about 1.1 percent respondents reported that washing cloths and using detergents and throwing of flowers, about 0.9 per cent said that floating of dead bodies and disposal of sewage along the ghats or directly into the sewer are responsible for create pollution problem into the river. The analyses confirm that with increasing

Table 5: Responses to the question on sources of water pollution

Education level	Washing Cloths & Using Detergents	Throwing of Flowers	Sewage Disposal	Floating of Dead Bodies	Disposal of Solid Waste	Total (n)
Illiterate	-	-	3.5	1.1	0.9	30
Up to Primary	1.1	1.1	5.7	0.9	0.9	53
H.S	1.5	0.9	10.2	1.3	1.3	82
Inter	3.9	2.2	21.5	3.5	4.6	193
Graduate and above	4.3	1.7	20.0	4.1	3.7	182
Total	10.7	5.9	60.9	10.9	11.5	540

Note: (n) Number of respondents
Source: Based on personal survey, 2016

educational level concern about sources of water pollution also increasing among peoples. The responses to the question "How frequently are you associated with River Ganga?" and responses were recorded in Table 6.

Responses recorded in Table 6 reveals that about 25.9 per cent respondents, of which 10.2 per cent from the occupation of business group, 7.8 per cent belonging to the occupation of others, 4.4 per cent from service class, 2 per cent from daily wage earner and remaining 1.5 per cent from pandas along the bathing ghats, said that they associated with river through bathing on the ghats. About 10.9 pert cent, 4.8 per cent from business class, 2.8 per cent from others group, and 2 per cent from service are associated with site scene from river Ganga. In all, about 5.9 per cent of which, 1.5 per cent respondents from business group and pandas, about 2 per cent belonging to the occupation of others, and 0.9 per cent daily wage earner from different ghats use river water as a source of drinking water. Out of the total respondents, the highest proportion (50%) of respondents of which 20.9 per cent from business group, 9.1 per cent from service class, 12.8 per cent from others, 3.3 per cent from pandas and remaining 3.9 per cent from daily wage earner reported

Table 6: Responses to the question on association of people with river Ganga

Occupation	Bathing	Site scene	Drinking water	Religious purpose	Any other	Total (n)
Business	10.2	4.8	1.5	20.9	3.0	218
Service	4.4	2.0	-	9.1	1.5	92
Daily wage Earner	2.0	1.3	0.9	3.9	-	44
Others	7.8	2.8	2.0	12.8	1.7	146
Pandas	1.5	-	1.5	3.3	1.1	40
Total	25.9	10.9	5.9	50.0	7.3	540

Note: (n) Number of respondents, Chi-square significant at P = 0.001
Source: Based on personal survey, 2016

that they associated with River Ganga through religious purpose. And remaining about 7.2 per cent respondents from different occupational group ranging from 1.1 percent to 3 percent respondents that they associated with river Ganga through any other purpose. It is observed from the above analysis that responses to the question on associated with River Ganga based on occupation is highly significant on chi-square test. The responses to the question "What is the seriousness of Ganga river pollution?" Based on different occupational group shown in table 7.

Table 7 revealed that in view of 77.6 per cent, respondent from different occupational group, of which 29.4 per cent belonging to the occupation of business group, 22 per cent of respondents from others (including house wives, pensioners and students), 15.4 per cent from service class, 6.7 per cent from daily wage earner, and about 4.1 percent from pandas who said that the river water is seriously polluted. They also pointed out that direct discharge of municipal sewage into the river is the main cause of river pollution along the ghats of Varanasi. Out of the total respondents 18.1 per cent respondents from different occupational group, of which 8.5 per cent respondents belonging to the occupation of business group, 1.7 per cent respondents from service class, 4.1 per cent from other (including students, housewives, & pensioners etc.), 2.4per cent from pandas and remaining 1.5 per cent from daily wage earner perceived river pollution to be somewhat serious. There are very low proportions of respondents from different occupational group 4.3 per cent felt that this problem is not very serious

Table 7: Responses to the question on seriousness of Ganga river pollution.

Occupation	Serious	Somewhat serious	Not very serious	Total (n)
Business	29.40	08.50	2.4	218
Service	15.40	01.70	-	92
Daily Wage Earner	06.70	01.50	0.1	44
Others	22.00	04.10	0.9	146
Pandas	04.10	02.40	0.9	40
Total	77.60	18.10	4.3	540

Note: (n) Number of respondents, Chi-square significant at P = 0.001

Source: Based on personal survey, 2016

problems, of which 0.1 per cent from daily wage earner, 2.4 per cent belonging to the occupation of business, and .9 per cent from others (including students, housewives, & pensioners etc.) and pandas group reported that it not to be serious. It is observed from the above analysis that responses towards cleaning the Ganga River at Varanasi by occupation are highly significant on chi-square test. The responses to the question "Which type of change perceived through?" the responses recorded Table 8.

Responses were recorded on the basis of income group. It is evident that in view of 49.7 per cent respondents, of which 18.9 per cent respondents from the income group of Rs.5000 to Rs.10, 000, 13.5 per cent from the income group of below Rs.5000, 11.7 per cent respondents from Rs.10, 000 to 20,000 and about 5.6 per cent respondents from higher income group reported felt that there is major change through color in water quality due to discharge of municipal sewage and storm drainage and open

Table 8: Responses to the question on type of change perceived through.

Income (monthly)	Colour	Smell	Both	Transparency	Total (n)
Below 5000	13.5	-	9.6	4.8	151
5000-10,000	18.9	1.3	12.8	3.9	199
10,000-20,000	11.7	0.9	9.6	2.8	135
Above20,000	5.6	-	3.7	0.9	55
Total	49.7	2.2	35.7	12.4	540

Note: (n) Number of respondents
Source: Based on personal survey, 2016

nalas directly falls into the river which changed the color of river water. About 2.2 per cent respondents, of which about 1.3 per cent from the income group of Rs. 5,000 to 10,000 and 0.9 per cent from the higher income group of Rs. 10,000 to 20,000 reported that they felt change in quality of river water through smell. While 35.7 per cent respondents, 12.8 per cent from the income group of Rs.5000 to 10,000, 9.6 per cent of respondents belonging to the income group of below Rs. 5000 and from the income group of Rs.10, 000 to 20,000 and remaining 3.7 per cent respondents from the highest income group of above Rs. 20,000 felt problem in bathing into the river water. During the course of survey that 12.4 per cent respondents, 4.8 percent from below Rs.5000, 3.9 percent from the income group of Rs. 5,000 to 10,000, 2.8 per cent respondents from the income group of Rs.10,000 to 20,000 reported lower transparency in the water quality of river Ganga (Table 8). Responses to the question "What type of actions will you take against pollution of the River Ganga?" were recorded in table 9.

The analysis of Table 9 revealed that about 31.5 per cent persons from different educational level, of which 11.1 per cent from the education of graduation and above, 10 per cent from the inter level, 5.7 per cent from the education of H.S, 2.8 per cent from up to primary level and 1.9 per cent from illiterate preferred to not allow the people dumped waste into the river Ganga. Similarly, about 24.3 per cent, of which, about 9.1 per cent respondents in the higher group of graduate and above education, 7.8 per cent belonging to the education of inter level, 3.7 per cent from H.S level, 2.6 per cent from the education of up to primary and 1.1 per cent from the illiterate revealed to do voluntary actions like cleaning the terraces, advising people not to use soaps and detergents and terrace for defecation etc., for restoring the purity of the river (Table 10). About 21.3 percent respondents, 9.4 per cent from the education group of inter level, 7 per cent from the higher education group of graduation & above, 2 percent from H.S., 1.9 per cent from up to primary level and .9 from illiterate group reported that they lodge complaints with the government in this regard. In their view the government is liberal and working under the vested political pressures even at the cost of environmental degradation. Out of the total respondents about 8.3 percent respondents from different educational group, of which 3.7 per cent respondents from inter level, 2 from graduation and above, 1.5 per cent from up to primary level, and 1.1 percent from H.S. preferred to participate in some active participation to serve pollution of river Ganga. As from the above perceptions it was observed that mostly literates have participated in some activities for abating pollution. Presently, a few Bathing Ghats of Varanasi are being cleaned

Table 9: Peoples responses towards cleaning the Ganga River

Education	Not allowing wastes into Ganga	Making complaint to Government	Voluntary action	Immediate action	No response	Total (n)
Illiterate	1.9	0.9	1.1	-	1.7	30
Up to Primary	2.8	1.9	2.6	1.5	1.1	53
H.S	5.7	2.0	3.7	1.1	2.6	82
Inter	10.0	9.4	7.8	3.7	4.8	193
Graduate and above	11.1	7.0	9.1	2.0	4.4	182
Total	31.5	21.3	24.3	8.3	14.6	540

Note: (n) Number of respondents, Chi-square significant at P = 0.001

Source: Based on personal survey, 2016

only because of active participation's of people. It is observed from the above analysis that responses towards cleaning the Ganga River at Varanasi by education are highly significance on chi-square test.

Conclusion

The main sources of water pollution in Varanasi city, is the domestic waste water which flows through sewers and open drains. Total volume of domestic waste water generated in the city is estimated to about 300 MLD of which only 102 MLD is treated in sewage treatment plants (STPs) and the remaining 198 MLD is directly discharged into river Ganga and Varuna through open drains. So the STPs do not work efficiently or properly during rainy season and increase the pollution load of river Ganga and Varuna. Regular huge quantity of domestic wastewater either drains into river Ganga without any treatment or disposed on open lands further polluting underground water through seepage. The recent estimated total requirement of water is 280 MLD of which total production is 277 MLD is quite higher than the requirement. The dense network of sewers which is equally old and leaky, criss crosses the water supply mains and domestic connections mainly the reason of water pollution in the older city. This results sometimes into contamination of drinking water. Some other special problems could be seen that there are two major cremation Ghats namely Harishchandra and Manikarnika Ghat where on an average 125 bodies are cremated each day using traditional firewood. Contamination of river water by ash generated and throwing burn/un-burnt human and animal dead bodies in to the river Ganga. Several people live very close to the Ghats they are poor and have no toilet facilities. They defecate on the Ghats and create serious problems of water pollution and enteric water-borne diseases. To know the pollution level of Ganga River at various bathing Ghats it is essential to know the present concentration of organic and inorganic pollutants in Ganga water. For this purpose 7 Ghats at 5m across from the bank of river Ganga from a depth of 25cm below the water surface has been selected for analysis of pH, TDS, Turbidity, BOD, DO and biological quality of water for Fecal coliform count.

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Methodology and Applications of Remote Sensing and GIS in Environmental Mapping and Monitoring

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Abstract

This review article introduces the characteristics of geography information system (GIS) and remote sensing (RS) environmental monitoring applications. The authors explicate GIS applications in ecological monitoring, water monitoring, air monitoring and environmental noise monitoring etc., then illuminate the vital role of remote sensing and GIS in environmental protection., The development and application of an integrated environmental monitoring information system will enable the sharing of information resources based on GIS and remote sensing. It will also effectively enter and analyze the spatial data and the attribute data. It will provide the information for decision-making and promote scientific analysis and decision-making in environmental protection. Remote Sensing and GIS applications in environmental monitoring are ascendant and its application in information management of environmental monitoring will bound to the cause of environmental protection to a new historical process.

Keywords: *remote sensing, GIS, environment monitoring, ecological monitoring*

Introduction

The changing environmental condition of the Earth are emerged as a serious concern from local to global scales with the rapid economic development and increased pollution level mainly caused by anthropogenic activities (Thies et al., 2014). It brings great threat to the social sustainable development and the health of human beings. Environmental protection is complex and dynamic process involving spatial information from multi-sectoral, multi-region and multi-field and a lot of data processing. An effective environmental protection information system is needed so that many factors hidden in the complex relationships will become clear and visually. Environmental data is stored, transmitted, processed and analyzed in order to achieve scientific management using advanced information technologies (Liu and Tian 2005).

Environmental monitoring is the process of determining the various signs data of quality of environment. It is categorized into three sorts including research monitoring, surveillance monitoring and particular purpose monitoring. Its task is to identify and test the contaminants compo-

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sition in the environmental sample, and to study the nature, composition and structure of the environmental quality within a certain historical period and a certain space (Dan and Ma, 2009: Huang and Zhou, 2001).

Remote Sensing (RS) technologies are used to identify and characterize earth surface features and estimation of their geo-biophysical properties with the help of electromagnetic radiation as a means of interaction. Satellite remote sensing at present has drawn a lot of interest with the launch of Landsat in 1970s for civilian applications (Roy et al., 2017). Advanced RS technologies have high potential in mapping and monitoring of environmental processes with the development of sensors ranging from high to medium resolution optical RS and from hyperspectral to microwave remote sensing (Avtar et al., 2017). The integration of RS data from different sensors along with ancillary data from different sources is also serving to develop an enhanced Geographical Information System (GIS). It is a new technology emerging with the development of geographical science, computer technology, remote sensing technology and information science. According to actual needs, GIS combines location and associated attribute information and shows real time and illustrative information to the user. The spatial information of environmental protection is very large. The management and analysis of spatial information is the major advantage of GIS. Therefore, GIS is the ideal choice to a government department in pollution monitoring and environmental resources protection (Li and Feng, 2004).

An integrated approach of remote sensing, GIS, GPS and advanced technologies can be used to develop potential environmental monitoring information system. It will enable the sharing of information resources, enter and analyzing effectively the spatial data (vector and raster data) and the attribute data (indicators of environmental pollution) obtained from GPS and RS by GIS, and will study the characteristics and the composite effects of environmental pollutants. It will provide the information for decision-making and promote scientific analysis and decision-making in environmental protection (Huang and Zhou, 2001).

Objective

In this paper, various remote sensing and GIS applications are reviewed related to different environmental applications.

RS and GIS applications in environmental monitoring construction

GIS used in ecological monitoring

Ecological monitoring, also known as the ecological environment monitoring based on ecology methods and means, measures the spatial and temporal patterns of ecosystem structure and function in different scales. It is obtained mainly by the monitoring the conditions, changes, reflections and trends because of the environmental pressure. Ecological monitoring platform is the basis for the macro monitoring systems. It must be supported by GIS, GPS and RS technology and must have sufficiently large capacity computers and aerospace information processing device. The three techniques form a complete technical system for space observation, space positioning and spatial analysis of the earth, which can reflect the changes and mutual relationship of various elements of the ecosystem in global scale. The mathematical model based on the RS and GIS will support the transition from qualitative description to quantitative analysis, promote the transfer of space from the wild into the indoor, and promote the development of time from the research on the past and the present to the quantitative prediction in three-dimensional space. The potential mapping capability of GIS allows users to easily obtain accurate position and informative thematic maps (Li and Feng, 2004). The establishment of environmental information sys-

tem not only provides important background data for future, but also formats a unified environmental information network with the relevant information systems of other departments and relates systems of international networking. 3S technology is the direction of macro-environment monitoring development. Through a great deal of research and practice on micro-ecological monitoring and macro-remote sensing monitoring by 3S technology, Xinjiang Ecology Environmental Monitoring Central Station sought out an ecological environment monitoring method. It is consistent to environmental regional characteristics of Xinjiang. They established ecological monitoring index system and comprehensive evaluation which combined of macro and micro, monitoring and investigation and collection of data (Huang and Zhou, 2001).

GIS used in water monitoring

Water environment information has obvious spatial attributes and levels attributes, so the use of GIS will reveal the different regions of the water environment more clearly, reflect the water environment quality trend in space, and monitor flood disasters, forecast the development trend of flood. It will also reflect directly the spatial distribution of environmental elements such as sources of pollution, sewage outfall and monitoring sections. GIS can also use in the water quality prediction, water environmental capacity, pollution prediction, the distribution of the amount of pollutant reduction. It can provide multi-faceted and multi-form support with table and graphics for the water environmental management decisions.

"Digital River" construction integrated used of 3S technology, network technology, multimedia technology, virtual reality and other modern high-tech. It can provide a basin-wide unified integrated information platform to achieve visual query various types of information in watershed and virtual reproduction of the whole basin in the computer. For example, the "Digital River" platform established on GIS technology for "Danjiang Reservoir" environmental monitoring, the relevant data including: Danjiang Reservoir satellite images obtained on RS technology (raster data), the geographic information data obtained on GPS technology (vector data), all kinds of water information (property data). GIS provides a variety of methods of spatial data entry. The data organization is an effective form of database management, updating, maintenance, fast search and inspection. It can output geospatial information in many ways. And using of the model function and the spatial dynamics prediction capability of GIS, it can provides the management and decision support for environmental protection together with expert systems, decision support systems and other technology (RS and GPS). Relying on "digital watershed" basic platform, to promote the process of virtual reality digital environment monitoring will be very important for the scientific management of the water environment (Huang and Zhou, 2001).

Remote sensing and GIS used in atmospheric pollution monitoring

Atmospheric pollution continuous automatic monitoring system relies on the GIS platform. Its main task is to monitor the pollutants in the air continuously and automatically, accessing continuous instantaneous information of air pollution and analyzing the data. At the same time, we can also control air pollution status and weather conditions through continuous instantaneous monitoring when the atmospheric pollution accident happens. It will provide first-hand information for the analysis of the pollution incident and provide the basis for verifying the air pollutant dispersion model and air quality management.

In recent years, for preventing, controlling and eliminating the harm of environmental emergencies effectively and standardizing all kinds of emergencies emergency work, basing on es-

tablishing automatic mechanism for monitoring and forecasting air quality, many city governments established atmospheric environmental emergency monitoring system, which was composed mainly by the emergency command center, on-site command vehicle, emergency environmental monitoring vehicles, air quality monitoring network and environmental emergency monitoring plan, a list of libraries of major pollutants dangerous goods, electronic maps and other components. Atmospheric environmental emergency monitoring system made full use the advantages of GIS. In the event of accidental pollution incidents, environmental protection departments could rush to the scene to monitor and analyze concentration of harmful substances in the atmospheric quantitatively and qualitatively. We can grasp of the pollution of pollution incidents timely and accurate, identify the nature of the incident and the harm, and provide the technical basis to decision-making for the development of contingency measures. In addition, the system can also provide services for the environmental quality assessment, prediction, warning and enforcement in the regional environment and major projects, do the background measurement for the major events predicted air pollution, and provide the basis for subsequent conclusions.

GIS used in environmental noise monitoring

Urban environmental noise pollution is a kind of energy pollution, which is instantaneous in the time and discontinuous in the space. Only multipoint sampling measurement and to monitor frequently as possible will reflect average the level of regional noise pollution more really. Most of the cities in the world have followed the noise monitoring methods that is monitoring some frequencies and some hours every year. Environmental noise automatic monitoring system has the character of no staff on duty and continuous operation. It is a great solution to the current noise monitoring problem such as time-consuming, laborious, and poor representation. It not only can provide timely and low cost data but also to have information about the quality and the reliability of these results. The reliability of the results depends upon the accuracy and quality of the source data and the validity of the noise models used. Techniques for dealing with data inadequacies and for disclosing the quality of the results should be applied in noise effects studies. These techniques include: z taking the errors in the data and the models into account by methods of error propagation z exposing the quality of the results by estimating and quantifying potential errors z replacing visualization of exact noise contours by contours with uncertainty bandwidths z replacing exact figures by gradual judgments.

Noise levels are computed precisely by imposed methods in noise computer models, while on the other hand an indisputable instrument to quantify noise effects is lacking. This can lead to different decisions with different noise effect studies. The standardization of noise effect studies will be enhanced when the methodology and the level of detail to quantify noise effects will be laid down in directives. These procedures can be implemented in a GIS-application. The aim is to obtain an unambiguous device to uniquely quantify noise levels. Results will no longer vary with the used methods. Since noise policies rely on the results of noise studies, this standardization will support a consistent and indisputable noise policy.

Environmental noise enforcement, evaluation and treatment, but also can provide timely and accurate means of environmental noise monitoring for the implementation of quiet works in large and medium cities of many countries around the world. Environmental monitoring data and statistical information have spatial attributes besides temporal and dynamic attributes. It is best suited to express by GIS. And noise

prediction can be achieved through the analysis.

Remote sensing and GIS in land degradation

FAO/UNEP/UNESCO (1979) had used direct observations, parametric methods on a global level at 1:5 million scales for the assessment of land degradation with remote sensing techniques.

- Remote sensing provides a rapid, relatively inexpensive means to gather land information where no other
- Sources are available or where the quality of available information is low
- It permits an exact delineation or clear physiographic boundaries
- It gives the opportunity for repetitive, annually or seasonally multi-spectral examination
- Interpretation of satellite imagery can be at several levels of intensity / scales

Land degradation mapping

The following section provides outlines of the procedure involved in mapping land degradation using satellite data which consists of input data, preparatory work and methodology (Fig.1).

The methodology normally adopted for mapping at any scale consists of preparation of base map, on -line visual interpretation of satellite data, development of legend, ground truth collection, analysis of soil samples, classification of degradation classes and finalization of maps in light of field information and analytical data. The methodology is given in the form of a flow chart (Fig.1).

Input data and its preparation

For delineation and mapping of land degra-

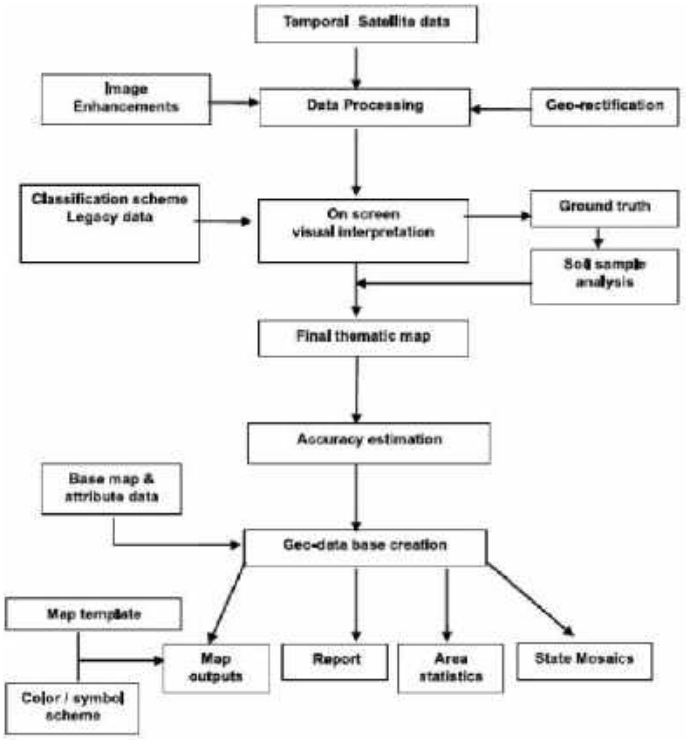

Fig. 1: Methodology of land degradation

dation classes, multi-temporal geo-rectified data acquired during major cropping seasons like kharif, rabi and zaid seasons are used. Such a temporal data set helps to address the seasonal variability in intensity of problem in degraded lands. The satellite data is geometrically corrected for further processing, like visual interpretation, ground truth collection and land degradation map preparation. Any legacy data sets in the form of maps can also be used for substantiating land degradation process.

Monitoring of land degradation management

Repetitive nature of satellite data enables to monitor land degradation process over a period of time in any geographical location. The methodology consists of the geometric correction of multi date satellite data. Then the satellite data is corrected for Sun elevation angle effects and atmosphere influences. Subsequently the data is normalized for their radiometric differences. By studying soil profiles and

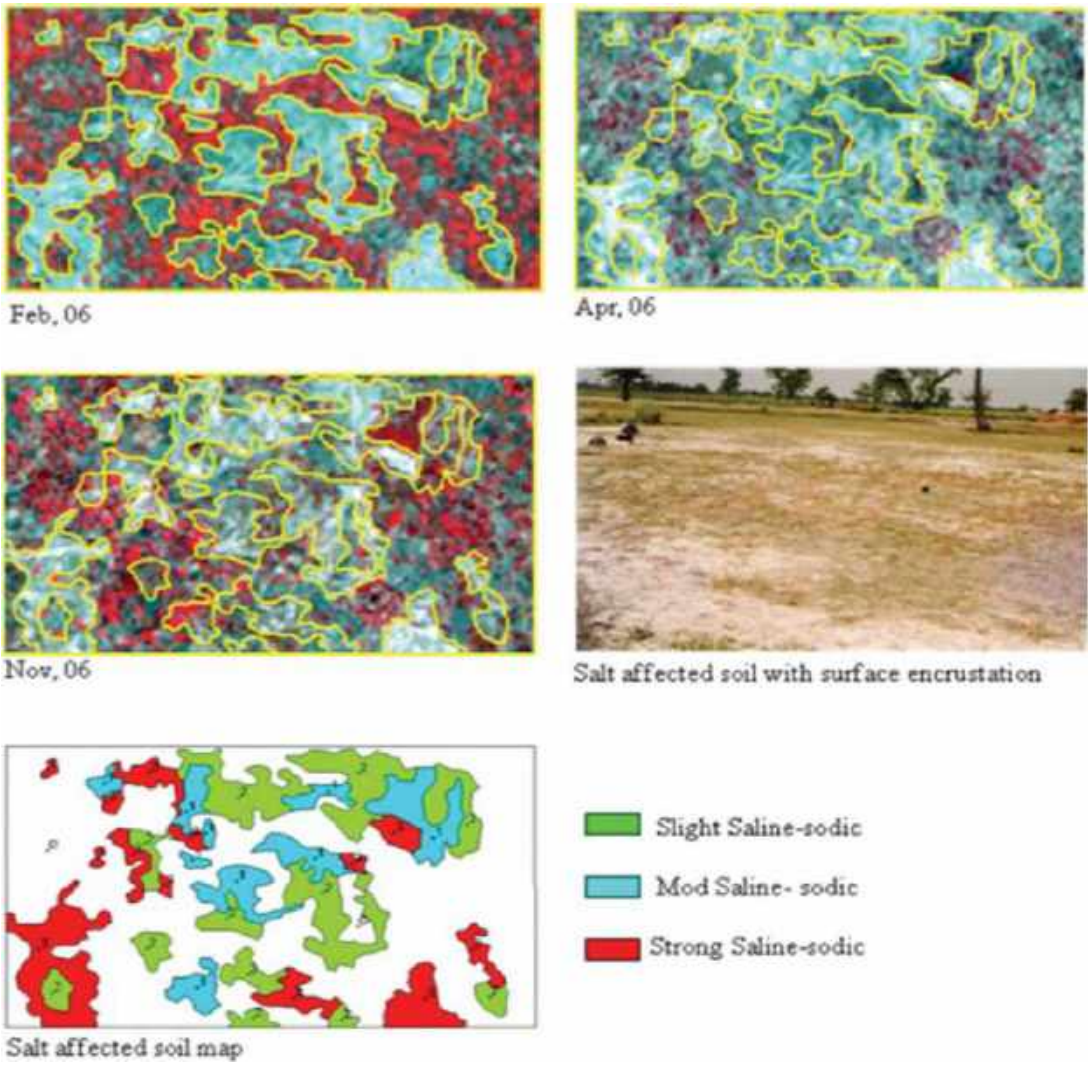

Fig. 2 : Land degradation mapping-salt-affected soils

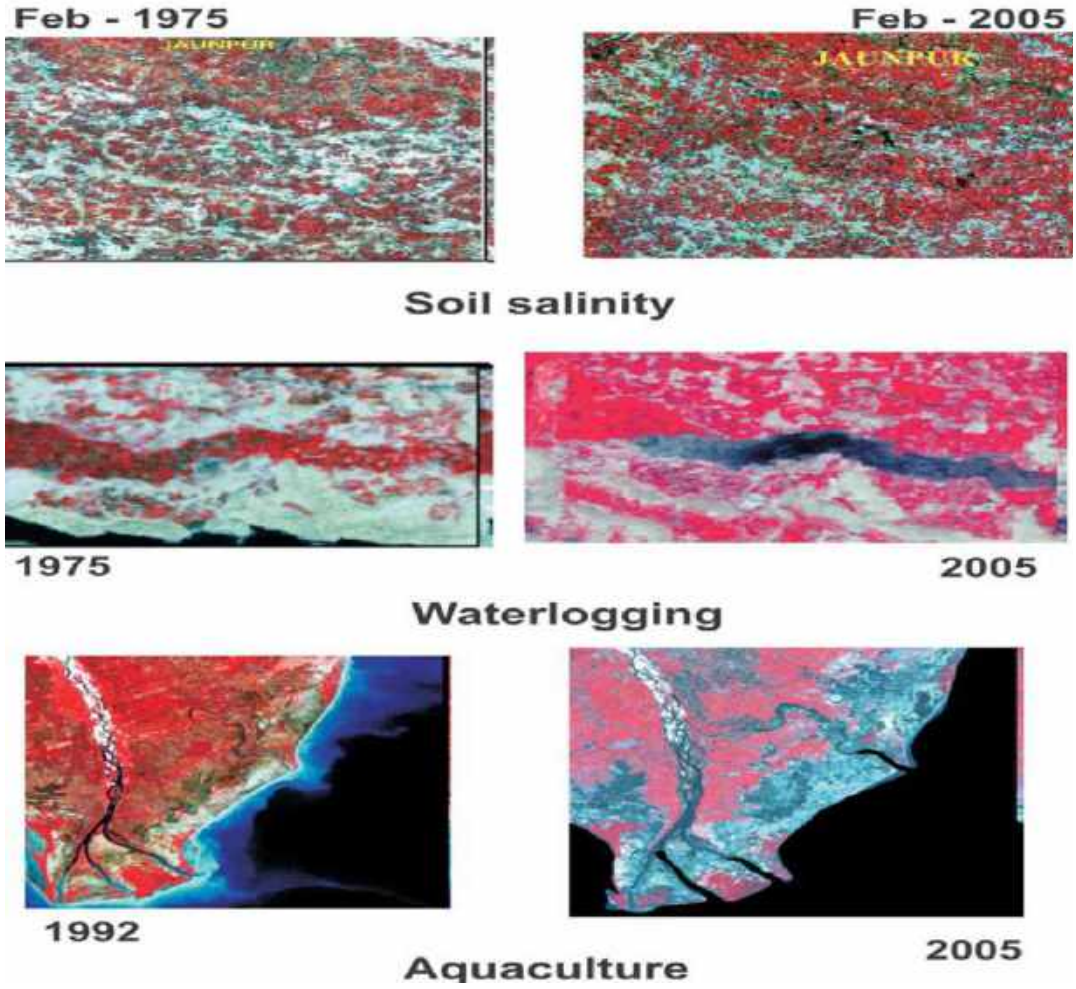

Fig. 3 : Monitoring land degradation using temporal remote sensing data

surface observations, the soil samples are analysed for various chemical and physical properties. Based on the ground truth and ancillary information, the signatures are established for various land degradation classes. Using the other ancillary information and ground truth information, the signatures are extrapolated to other dates. The changes that have been observed in the satellite data are verified also on the ground (Fig.2). Fig. 3 shows the monitoring of land degradation using temporal Landsat data.

Remote sensing in drought monitoring

In recent years, the occurrence of hydro-meteorological hazards that account for 90% of the natural disasters cause the greatest threat to food safety, the ecological system and economic development by destroying vegetation (including crops and pasture), water resources, livestock and infrastructure in Sub-Saharan Africa. The images provided by remote sensing satellites have gained a lot of popularity to study these events in real time to near-real time (Yan et al. 2016).

The use of multi-date remote sensing satellite data enables us to identify drought and its

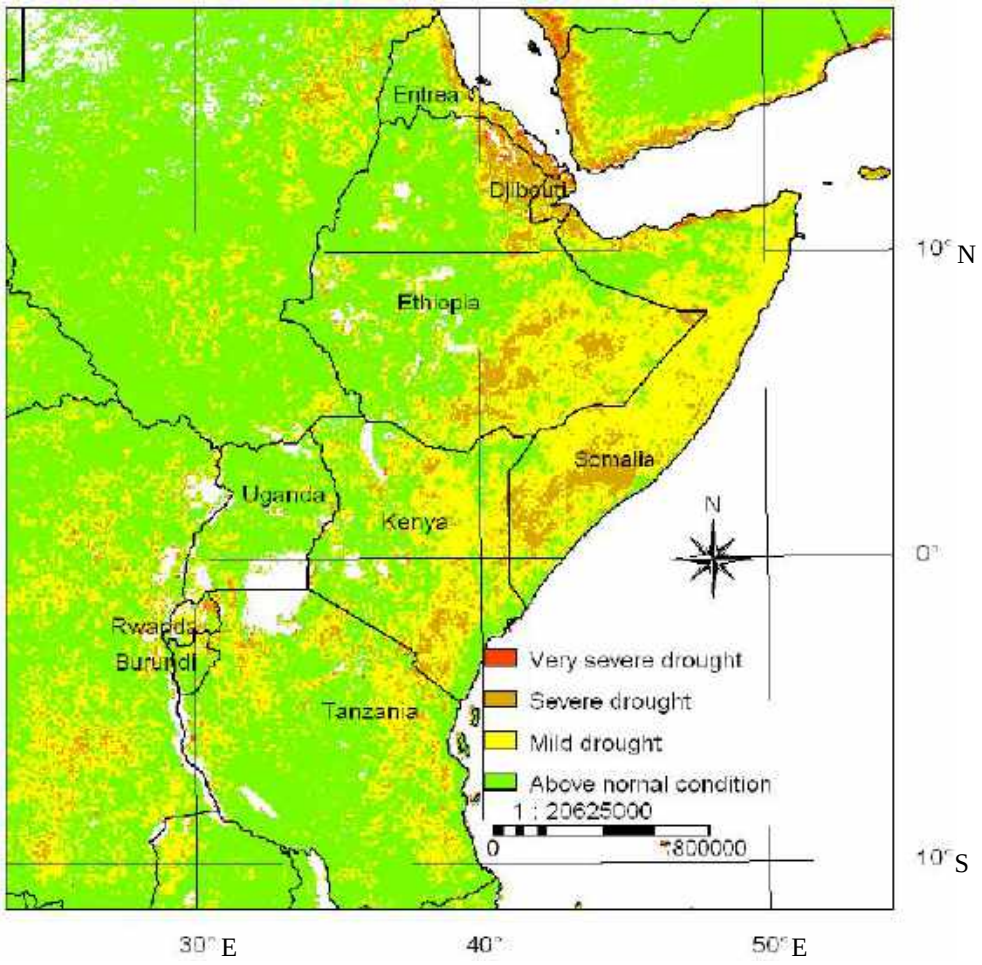

Fig. 4 : Remotely sensed processed image depicting drought severity over Eastern Africa for the first decade (10 days) of September - October - November 2007 rainy/growing season. The white areas include water bodies and clouds.

(Source:https://www.wmo.int/pages/prog/www/IMOP/.../IOM.../P1(32)_ Aribo_ Uganda.doc)

impacts on agriculture prior to harvesting using different vegetation indices such as normalized difference vegetation index (NDVI) and vegetation condition index (VCI) (Kogan, 1995; Yan, 2016). These indices as proxies of drought and vegetation health/condition are very important in early warning for food security, disaster awareness and environmental protection. Remotely sensed data provided by organizations including National Oceanic and Atmospheric administration (NOAA), EUMETSAT, is often a low priority for decision and policy makers in developing countries such as Eastern African region.

A study is therefore conducted to demonstrate the application of integrated AVHRR and MSG data for drought assessment over eastern Africa as input for monitoring and early warning system for disaster management, at relatively low cost.

Data used and methods in drought monitoring

(a) AVHRR instrument (onboard NOAA series of satellites) during (1982-2006) were downloaded from the USGS website

(b) Level 1.5 data of MSG-SEVIRI (Spinning Enhanced Visible and Infrared Imager) for the same season 2007, obtained from Institute for Geo-Information Science and Earth Observation (ITC), in Netherlands.

The MSG data was imported and converted into ILWIS raster format using MSG data retriever with the aid of a Geospatial Data Abstraction Library (GDAL)-driver that reads raw compressed MSG data and facilitates easy geometric and radiometric calibrated data retrieval into formats commonly used by remote sensing packages.

Long-term (24 year) maximum NDVI, minimum NDVI and NDVI for the first 10 days of September 2007 were computed from the data set. Vegetation condition index for the September 2007 was then calculated to determine the vegetation health according to Kogan (1995), hence detect drought which was reclassified according to different severity.

The different drought severity according to NDVI derived vegetation condition indices over different parts of Eastern Africa are shown in Fig.4. It is revealed that some parts of north eastern Ethiopia, south eastern Eritrea and a small area in northern Somalia experienced very severe drought. Most parts of Djibouti and Somalia, south eastern Ethiopia; parts of eastern Kenya (Fig.4), eastern and northern Tanzania and Rwanda had moderate to severe drought (Kogan, 1995).

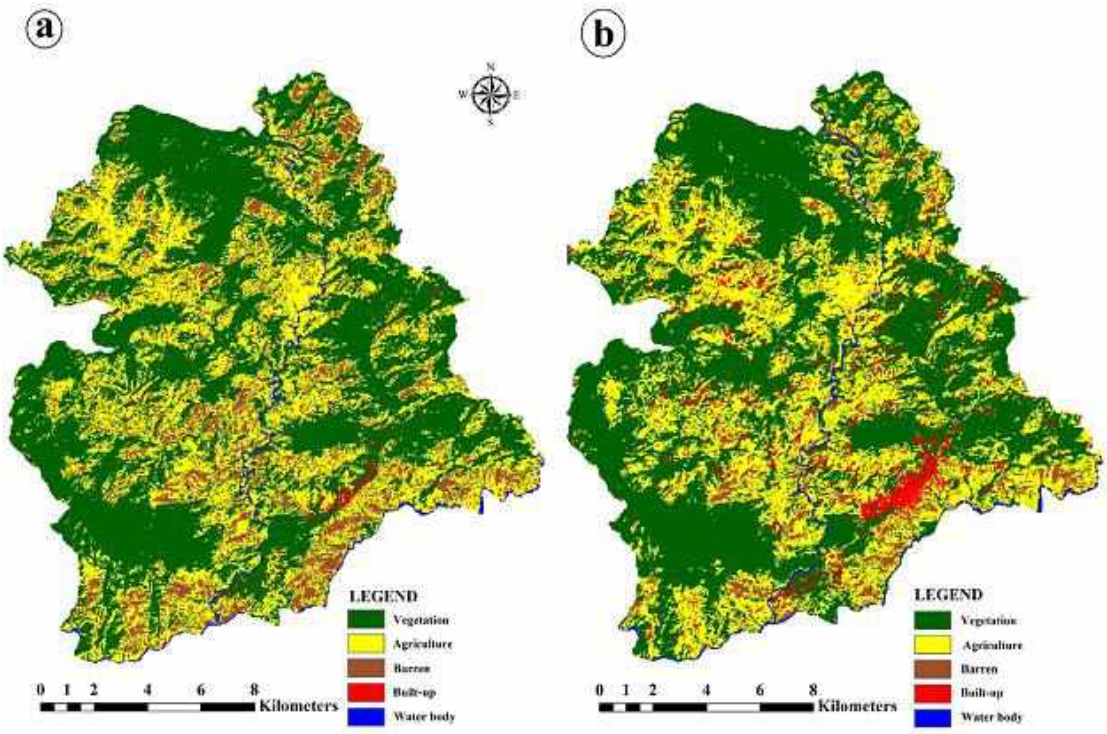

Fig. 5 : LULC status of the Hawalbagh block; (a) in 1990, (b) in 2010 (based on Landsat-TM Imagery) (Source: Rawat and Kumar, 2015)

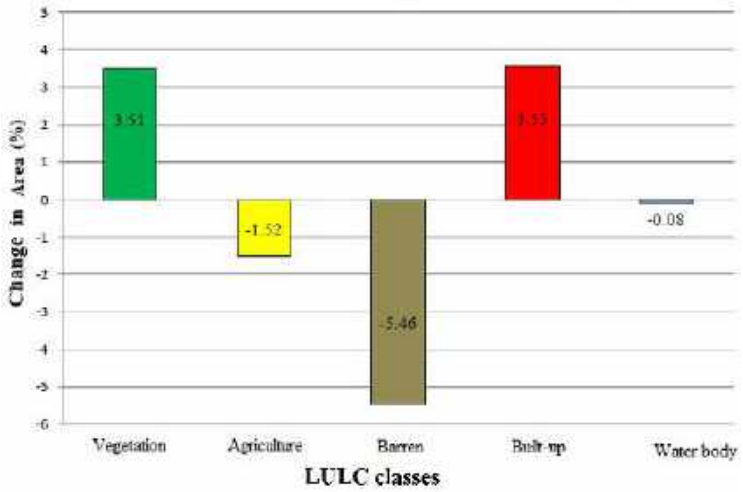

Fig. 6 : Diagrammatic illustration of LULC change (in %) during (1990-2010) in the Hawalbagh block (Source: Rawat and Kumar, 2015)

Remote sensing and GIS in land use/land cover (LULC) change monitoring

The LULC pattern of an area is an outcome of natural and socio-economic factors and their utilization by human being in time and space. LULC Information is essential for the selection, planning and implementation of land use schemes. The LULC change detection is very essential for better understanding of landscape dynamic over a time period having sustainable management (Rawat and Kumar, 2015).

With the development of remote sensing and GIS tools, LULC mapping and change analysis has given a helpful and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region (Kilic, 2006). Multi-temporal remotely sensed data are helpful to study the changes in LULC in less time, at low cost and with improved accuracy in association with GIS that provides suitable platform for data analysis, update and retrieval (Chilar, 2000). The images from Landsat-TM series satellites offer valuable and continuous records of the earth's surface during the last 3 decades (USGS, 2014). The pre-processing steps (i.e., data selection, co-registration, radiometric calibration and normalization) are very important in performing accurate and reliable change detection analysis. Different remote sensing indices, i.e., normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and the modified normalized difference water index (MNDWI) are also valuable for quantifying the changes in LULC (El-Asmar et al., 2013).

The study area viz., the Hawalbagh block is one of the development blocks of District Almora of the Uttarakhand state. LULC map of the the study area are prepared through temporal remote sensing data (Fig.5).

The vegetation class has been increased by 3.51% (9.39 km2) while the agricultural land was decreased by 1.52% (4.06 km2) due to conversion in vegetation, barren land and built-up land. The area covered by barren land has been decreased by 5.46% (14.59 km2) due to conversion in agriculture, vegetation and built-up land. The built-up land has increased by 3.55% (9.48 km2) during the last two decades (1990 -2010) due to mainly expansion of the Almora town area (Fig. 6).

Conclusion

It was evident from different case studies that the integration of remote sensing and GIS technologies are ascendant in the studies of environmental monitoring and assessment. Its direction is to combine the work with the state information, to base on e-government related projects, to promote GIS application in management of environmental monitoring, to develop to specialization, to progress the environmental assessment, monitoring, tracking analysis, to accelerate the application of geospatial technology integration, to drive technical and software development. Remote sensing and GIS technology will apply significant information of environmental monitoring, but also bound to the cause of environmental protection to a new historical process. RS and GIS technologies will be even more effective tool for providing adequate information of environmental condition with the improved methodological development and cost effective resources. It can also provide decision-makers with information on a clear evaluation of various types of environmental services to grasp the amount of finite natural resources in a sustainable manner.

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