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Editor : S. Subbiah

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GPS Survey in Progress in Maravakkadu Mangroves, Vedarnyam Wetlands, Tamil Nadu

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The Canon of the Climate Change

Aleksandar Petrovic
Board for the Climate Dynamics and the Work of Milutin Milankovic
Serbian Academy of Science and Arts, Belgrade, Serbia

The Serbian Academy of Science and Arts organized an exhibition, Astronomical Canon of Milutin Milankovic, in Belgrade for four months beginning from January 2009. Mysteries of Ice Ages, Earth Climate Dynamics, and astronomical theory of Milutin Milankovic are the focal themes of the exhibition. Milankovic developed a theory, Canon of Insolation, to assume climate changes as a cosmic problem. Idea of Ice Age from the geologists was the beginning of the thinking on climate change. Milankovic postulated mathematically that three astronomical cycles - variation in eccentricity of the Earth's orbit around sun, variation in obliquity, and precession of the equinoxes - change the Earth's orbital dynamics and bring out differences in insolation of our planet, resulting in periodical climate changes in the geological time scale. Thus he made the only one theory of climate change that could be proved nowadays.

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UNESCO has been celebrating the Year 2009 as the International Year of Astronomy, and also the Year 2009 is the year of 130th Anniversary of the Milutin Milankovic, the well-known Serbian mathematician. To commemorate these great events of the Year 2009, the Gallery of the Serbian Academy of Science and Arts organized an exhibition, *Astronomical Canon of Milutin Milankovic,* in Belgrade from January 28, 2009 to the end of April, 2009. The Exhibition focused on the questions of the solving of mystery of the Ice Ages and Earth climate dynamics, history of astronomical theory of climate change, and works of famous Serbian mathematician and climatologist,

□ Published in June 2009

Milutin Milankovic who is considered by the NASA as one of the most important fifteen Earth Scientists the World has ever had [1].

Milutin Milankovic (1879 – 1958), (Fig.1) Professor of Applied Mathematics at Belgrade University in Serbia, is famous for his propositions towards an understanding of climate change dynamics. At the beginning of 20th century he emphasized climatology as an exact science, initiated numerical modeling of the climate, facilitated mathematical interpretation of long quasi-periodic climate changes, and created a basic frame for the understanding of the Earth's Ice Ages which is one of the main scientific challenges today. He was the first one who proved the interrelatedness of celestial mechanics and the Earth sciences, and enabled consistent transition from celestial mechanics to the Earth sciences. Considering seasonal and latitudinal distribution of the Earth's insolation, caused by changes in the Earth's orbital geometry, Milankovic formulated the astronomical theory of climate as a generalized mathematical theory of insolation - the only theory of climate that can be verified mathematically and tested geologically.

This theory is a revolutionary achievement: it lays on his understanding of climate change as a cosmic problem. Unlike to the French mathematician Joseph Adhemar and the Scottish naturalist James Croll, who in 19th century originally postulated astronomical theory of the Earth's climate, he was not concentrated solely on the Ice Age problem.

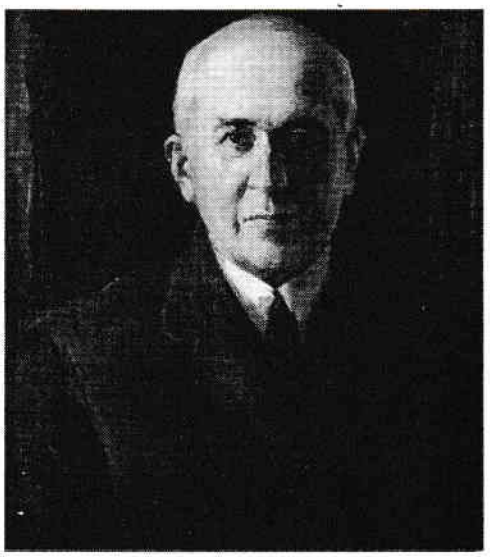

Fig. 1 Portrait of Milutin Milankovic (Paja Jovanovic, 1943)

His basic intention was an attempt to encompass climatic change as a general Sun – planet relationship. In this frame he revived, refined and completed the idea that three secular orbital cycles, eccentricity, obliquity and precession, force planet's insolation, initiate climatic change and prepare conditions for the Ice Ages to happen. He had the major vision of climate modeling of all solar system planets with hard crust where the Earth is a special case only. In the heart of this attempt was situated Sun, not Earth and its peculiar position, and therefore what Milankovic created has been one more cardinal heliocentric theory. On this way he was the very first who calculated climatic conditions on Mercury, Venus, Mars and Moon, and his results were reliably confirmed by different space missions (13).

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[1]The authors of the exhibition are Professor Aleksandar Petrovic, academician Djordje Zlokovic and designer Ljiljana Radosavljevic. It was opened by the President of the Serbian Academy of Science and Arts, Nikola Hajdin, Vice-Dean of the faculty of Civil Engineering from Vienna, Prof Helmut Rechberger, and Dr. Fabrizio Antonioli, Institute ENEA, Roma.

Following this approach, Milankovic created his famous *Canon of Insolation* (9,11), a general astronomical theory of climate applicable to planets with a solid crust. It is a comprehensive mathematical picture of the effect of Sun's radiation on planets' solar climates (the theoretical climate of a planet determined only by insolation) in which the Earth is observed as a particular case. Since the explanation of insolation dynamics was obtained by astronomical calculations similar to the predictions of solar and lunar eclipses (usually called the canon of eclipses), Milankovic gave the name *Canon of Insolation* to his work. It connected Sun and Earth, celestial mechanics and Earth sciences, and reconstructed of the past and prediction of the future. By introducing advanced mathematics into descriptive Earth Sciences, thus transforming them into exact ones, Milankovic built a bridge that was missed before him, and established the new integral scientific horizon founded on reliable mathematical principles.

Milutin Milankovic was born 130 years ago in the Serbian family in the village of Dalj, at the bank of Danube, the biggest European river. His village was situated in the southern Europe, in the then Austria-Hungary, where his ancestors had settled at the end of the seventeenth century after the great migration of Serbs from Kosovo and Metohija provinces escaping Turkish oppression. His family was wealthy, and through the centuries, the family had philosophers, inventors, professors, lawyers, and civil servants. Milankovic's father, Milan, was a merchant who died early, leaving behind his wife and six children, Milutin being the youngest of them. Tutored by his mother, Jelisaveta and uncle Vasa Muaèevic, Milankovic was thoroughly educated at home and at high school. His teacher of mathematics, Vladimir Varicak, later a member of the Yugoslav Academy of Sciences, was the first one who tried to merge geometry of Lobachevsy and Einstein's theory, noticed his exceptional abilities and versed him in mathematical sciences, remaining as his lifelong friend and adviser (12, 14).

In 1896 Milankovic enrolled at the Technical School in Vienna, with a major in civil engineering. Eight years later he gained a PhD in technical sciences with a thesis titled *Theory of Pressure Curves*, published in 1907. In 1909 he came to Belgrade University and became a citizen of the Kingdom of Serbia. He taught a specific course in Applied Mathematics, uncommon for European universities, which included three seemingly diverse subjects: rational mechanics, celestial mechanics, and theoretical physics. It was this approach which, in his opinion, helped him establish climatology as an integral, holistic science.

Milankovic's work was interrupted constantly by turbulent historical events. He started working on the astronomical theory of climate in 1912 when his first paper was completed in the same moment when the First Balkan War broke out. In 1914, when World War I begun the Austro-Hungarian authorities arrested him while he was spending his honeymoon in Dalj. But during the war he succeeded in completing his first book, *Théorie mathématique des phénomènes thermiques produits par la radiation solaire*, because he was interned in Budapest, where he was allowed to work in the library of the Hungarian Academy of Sciences (8). In spite of all these and many forthcoming obstacles (Austrian plunder of Belgrade University during World

War I, German demolition of the National Library of Serbia at the beginning, and of the library of the Mathematical Institute of the Serbian Academy of Sciences founded by him at the end of World War II, when he was also forced to leave his home for several months because of the severe Allies' bombings of Belgrade), he was constantly elaborating his theory for nearly four decades. He published about forty important papers until 1941, when he combined them in his masterwork *Canon of Insolation and the Ice-Age Problem* which was written in German and published in Belgrade by the Royal Serbian Academy of Science (9). It was also released under dramatic circumstances, saved by a miracle from the destroyed printing office at the beginning of the World War II.

The idea of climate changes emerged in the European scientific community almost two centuries ago when geology found evidence for the existence of the Ice Age. After that, it took a few decades for the Earth Sciences to assure itself, by geological data, in the existence of several "ice ages" which froze vast areas of Eurasia and Northern America, significantly lowering the level of the oceans and seas. As soon as the idea became plausible, the earth scientists started developing hypotheses to explain it. Many trials had been made: some almost immediately proved to be wrong, some were partially successful and lasted for some time; and some were completely undisputable, suitable neither to be proved, nor to be opposed. The most of those hypotheses were dealing with processes observed (or supposed to be possible) on the Earth: high content of volcanic dust in the atmosphere, perturbations of the Earth's magnetic field, fluctuations in the distribution of carbon dioxide between atmosphere and the ocean, changes of the deep circulation of the ocean, and so on.

Abreast, there were also several attempts to explain the climate change by the influence of astronomical forces (the most comprehensive of them was the theory by James Croll in 60s' of 19th century). But, due to many scientific, personal and social circumstances, none of them could prove to be accurate. Moreover, the imperfection of such theories was understood as inaptitude of any astronomical factor to be the cause of climatic change. Therefore the riddle of ice ages remained unsolved for another several decades.

Milankovic directed his main efforts towards astronomical explanation of the origin of the Pleistocene Ice Age. He calculated the impact of the Earth's secular orbital cycles (eccentricity, obliquity, precession) on Earth's insolation and consequent effect on the process of climate change. These perennial orbital variations that he took into consideration, along with their influence on planets' climates, are today called Milankovic cycles. In his 1912 article, "On the Mathematical Theory of Climate", and after that in six papers published until 1914, Milankovic introduced, for the first time, advanced mathematics into climatology.

Milankovic's position at the University, where he taught three diverse subjects, put him in a non-specialized, holistic culture of university education in Serbia at the beginning of 20th century, and allowed him to work at the intersection of scientific fields. It provided him with a broad vision of an integrated cosmic science that could be applied to very specific problems in geophysics and climatology,

including the problem of past ice ages, and the temperatures of other planets. "Acquiring unity among the sciences" in the university education was in complete dissonance with the then prevailing scientific specialization-driven culture of European system of higher education at that time. But without that cultural peculiarity, the problems, he correctly solved, would not even have been posed or proposed. Milankovic himself was believed that the mystery of the ice ages had not been resolved yet because its solution was hidden somewhere in the interstices and intricacies between many individual disciplines.

He wrote in his memoirs: "The reason for that lays in the fact that one has, in order to get to the bottom of the problem, to solve a set of rather complicated component problems which really belong to different sciences that are sharply separated one from the other... Therefore, the question was not answered, and it was left amid a triangle between spherical astronomy, celestial mechanics and theoretical physics. The chair at Belgrade University offered to me included all the three sciences which were separated at other Universities. Therefore I was able to discern that cosmic problem, to see its importance and to start with its unraveling"(12).

This methodological approach, substantially different from other universities, forced him to set appropriate, firm ground for understanding the core of the climate problem. "That coincidence, which enabled me to adhere to the given problem, it was not pure accident although it looked like that. Exactly because I was involved in all the mentioned sciences, it was possible for me to smell out that problem and to estimate its importance" (12).

He was aware that divided scientific experience, and separated astronomical and geological thinking made the comprehension of the climate impossible. It was a blind way which ultimately should be replaced by a new, open methodology - the triangle which couples sciences to frame Proteus like climate dynamics. He worked on issues of ever changing climate by looking into the previous theories for their faults and shortcomings. Milankovic tried to continue the work of his predecessors, but in a basically different way: he was not searching for the causes of the Earth's ice ages, but trying to develop a general mathematical theory of climate applicable to all planets. His aim was an integral, mathematically accurate theory which connects thermal regimes of the planets to their movement around the Sun. He wrote: "...Such a theory would enable us to go beyond the range of direct observations, not only in space, but also in time..." (12). It would allow reconstruction of the Earth's climate, its predictions as well, giving us in the same time the first reliable data about the climate conditions on other planets.

In the center of his theory Milankovic put the Sun, the only source of heat and light in the Solar system. The planets orbit the Sun moving along the slightly elongated paths that even change due to the gravitational force (which depends on their masses and distances). Such changes in the geometry of an orbit lead to the changes in the insolation (incoming solar radiation), quantity of heat received by any spot at the surface of a planet. And, Milankovic concluded, the overall sum of such changes must lead to the change of the thermal regime of the whole planet. So, he tried not only to prove his idea, but to calculate the exact value

of the thermal change. Consequently, his theory has two parts, the astronomical and the physical one.

In the astronomical part of his work Milankovic calculated the changes of the insolation of the uppermost layer of the Earth's atmosphere depending on the changes in the Earth's distance from the Sun (i.e. on the shape and magnitude of its orbit), and on the declination of Sun's rays relative to that surface unit (i.e. on orientation and inclination of rotation axis, and geographical latitude). In his investigation he incorporated three major astronomical periodicities(Fig.2):

1. Variation in eccentricity of the Earth's orbit, from an almost exact circle to a slightly elongated shape, with the periodicity of about 100,000 years, which influences seasonal differencesWhen the Earth is closest to the Sun, it receives more solar radiation. If that occurs during the winter, the winter is less severe. If a hemisphere has its summer while closest to the Sun, summers are relatively warm. In addition, a more eccentric orbit will change the length of seasons in each hemisphere by changing the length of time between the vernal and autumnal equinoxes.
2. Variation in obliquity,i.e., the tilt ,of the Earth's axis away from the orbital plane, from 22.1° to 24.5° with a periodicity of 41,000 years. At higher tilts, the seasonality at high latitudes becomes more extreme; changes in tilt have little effect in the tropics, and maximum effect at the poles. For 1° of obliquity increase, the total energy received by the summer hemisphere increases by -1%. Presently, the Earth's tilt is 23.5°.
3. Preciscion of the equinoxes, i.e. revolution of the Earth's axis, where one revolution is completed in about 23,000 and 19,000 years. It is a rather complex phenomenon, caused by two factors: a wobble of the Earth's axis, and a turning-around of the elliptical orbit of the Earth itself. It affects the direction of the Earth's axis, not its tilt. Because the direction of the wobble is opposite to the

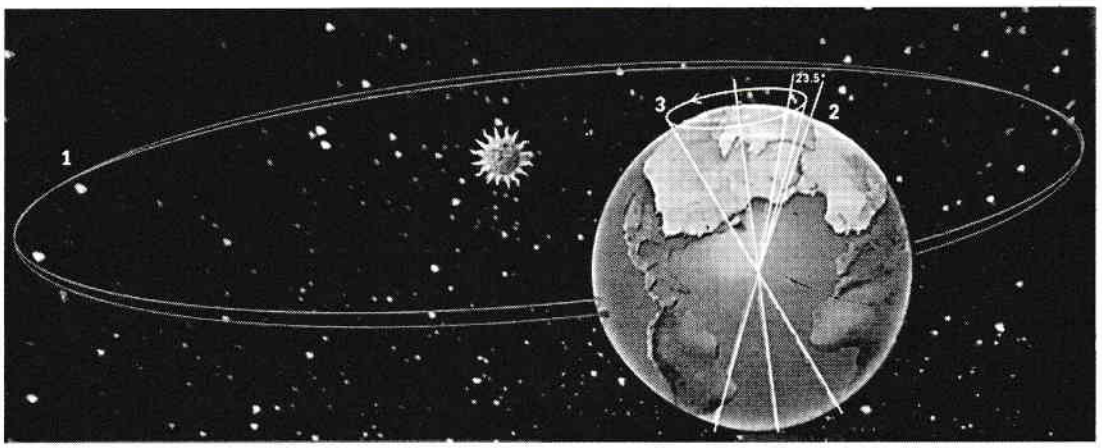

Fig. 2 Three Astronomical Cycles that force Climate Change on the Earth
1. Changes in Orbit's eccentricity 2. Changes in obliquity 3. Preciscion of the equinoxes

movement of the Earth around the Sun, thus, for example, 11,000 years from now, the North Pole of the Earth will not be pointing towards the North Star, but will be pointing away by an angle of about 47°, close to the star Vega. The combined and complex wobbly motion of the Earth has the following result: the equinoxes do not keep occurring during the same day of the calendar, but slowly shift. As a result of this migration of equinoxes we have today relatively short, warm winters in the northern hemisphere and relatively long, cool summers; and on the contrary, 11,000 years ago the opposite was true. This is the principal manifestation of the precession - the relative length of the seasons varies cyclically with time.

These three variations, superposed, constantly change the Earth's position relatively to the Sun, and, consequently, the insolation of any given spot on its surface.

In the second, physical part of the theory, Milankovic had to make use of a number of physical laws in order to discover the relations between irradiation and temperature of the planets. He had to introduce various parameters for determination of the atmosphere and the ground influences on transformation of incoming radiation. Milankovic here went deeply into the realm of meteorology and climatology, endowing them with a set of valuable and much needed new insights and parameters for successful use of the mathematical apparatus. First, he did not take into consideration the currents caused by the unequal heating of the atmosphere and the oceans, and so the climate he had computed corresponded to the so-called solar climate. For additional insight, he determined the mean annual solar temperatures of all the latitudes 0° - 90°, their vertical structure at radiation equilibrium, and the influence of the mean content of water vapor upon it. Then, he mathematically described the exchange of heat in the ground, being aware that ground plays an important climatic role as a reservoir of incoming solar radiation, and thereby he went on to determine the average annual heat balance of the atmosphere.

The Earth's envelope of water and air is a heat engine powered by sunlight heat arriving mainly at the equator and is carried by air and water towards both Polar Regions. Changes in the amount of heat received, and the way it is redistributed, alter global climate and cause ice ages. Polar land masses are ideal for glaciation because they receive less direct sunlight than lower altitudes. Although land masses are more easily glaciated than ocean basins, sea water or large lakes are essential to glaciation since evaporated water provides the snowfall necessary for building ice sheets.

With these, when the most important problems of the theory were solved, and a firm foundation for a further work was built, Milankovic published his *Mathematical Theory of Thermal Phenomena Produced by Solar Radiation* in 1920. It attracted the attention of climatologist Wladimir Köppen and his son-in-law, geophysicist Alfred Wegener. In 1922, they invited him to cooperate in their work *Climates of Geological Past*. His task was to find out, using his method, the secular changes in insolation during the past 650 millennia. Being convinced that a reduction in summer insolation at these latitudes is needed for a southward movement of the ice boundary, Köppen suggested to have a special attention to secular changes in summer insolation at

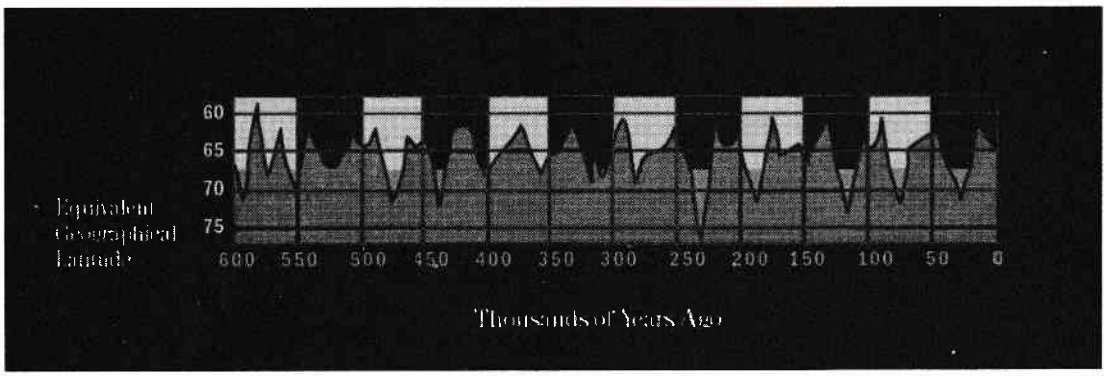

Fig. 3 Milankovic's Curve of Insolation for the past 600 millennia
(The changes of summer insolation of 65 degree north are shown as fictitious shift of latitude)

latitudes around 60°N. Another key was the insight that the insolation at high latitudes in the northern hemisphere is prevalent because most of the land that can support expanded ice accumulation belongs to this hemisphere.

With these considerations in mind, and using his method, Milankovic calculated the amplitudes of secular changes which had occurred in the summer insolation at the latitudes of 55° N, 60° N and 65° N during the last 650,000 years, transforming his numerical results into fictitious oscillations in latitudes in order to obtain a vivid graphical picture (Fig.3). The quantities of heat supplied to individual latitudes by radiation during the caloric half-years were presented in canonic units in *Canon's* Table XXV. This table, with 5,600 numbers, "mathematically represent[ed] the history of insolation for the past 600 millennia - a so called Canon of Insolation" (9). Accordingly "with this canon one could attempt to study the phenomenon of the Ice Ages"(12).

The table, transformed to a jagged line, later called 'Radiation Curve' or 'Curve of Insolation' was shown for the first time in Wegener – Köppen's book, published in 1924. One of the most important results of that publication was that Köppen in radiation diagrams recognized the evolution of then believed to have happened four glacial periods. After that, the radiation curves gained wide publicity and served as a starting point for other basic studies by climatologists and geologists. A few decades later it was realized that the four glacial periods (Günz, Miindel, Riss, Würm) proposed by German geographers Penck and Briickner, in fact did not exist; however, the relevance of Milankovic's Curve of Insolation was verified when new evidences for the cyclicity of glaciations were obtained from the records left in deep-sea sediments (3).

In his subsequent work Milankovic extended his curve to cover the past million years, and with this, he reexamined the accuracy of ice-ages chronology by renewed computations of secular changes of astronomical elements, on the basis of more accurate determination of planets' masses. New calculations were not different very much from

the previous ones. Subsequently he presented continuous radiation curves for the entire surface of the Earth and computed variations of insolation at eight northern and eight southern latitudes, for both the winter and summer half-years and for top of the atmosphere as well. He showed that seasonal differences in insolation caused by the precession cycle are prevalent at the lower latitudes than at the higher ones, where the influence of variations in axial obliquity is dominant. He also deduced that the altitude of the snowline was highly dependent (correlation factor of 0.996) on the radiant energy received during the caloric summer half-year. He made tables for easy determination of the displacement of snowline at individual latitudes caused by their changes in solar insolation. Going further, he calculated the changes of the polar ice caps, which reflect a considerable part of incoming heat into outer space. He established a mathematical relationship between enlarged ice caps of the Earth and their cooling action, and showed that such diminishing of insolation represents a secondary effect, but still sufficient (when added to secular changes of insolation) to cause the great glaciations of prehistoric times in their full extent.

The most important results of Milankovic's thirty years of research were summarized, completed, and presented to scientific public in his monumental work,*Canon of Insolation.* World War II events were not favourable for continual scientific work, but Milankovic was not upset, because he considered his theory capable to live on its own. Indeed, the development of climatology confirmed persuasively that *Canon of Insolation* is not only the most reliable approach to the climate change problem, but also it is the pivotal point of revolutionary reversal of the old earth sciences' paradigm. Historically Milankovic's revolution was prepared by the first attack on the "normal" geological paradigm performed by the Swiss naturalist Louis Agassiz who delivered his famous *Neuchatel lecture* at a conference of the Swiss Society of Natural Sciences in 1837(1). He pointed at "erratic boulders" of granite resting upon limestone of the Jura Mountains - huge stones which were detected at geologically not adequate sites. The phenomenon of "erratic boulders", huge stones transported by the glaciers, had shaken the "stationary" geology because it was incapable to explain them in any reasonable way. Rejecting Agassiz's explanations, geologists considered the idea of glaciers which transport stones as "mechanically senseless". Alexander von Humboldt promptly advised Agassiz to leave this research and to return to his exploration of fossil fishes (5).

Another serious objection on normal geological paradigm happened in 1912, the same year when Milankovic started rehabilitation of astronomical theory of climate change (Fig.4). Austrian scientist Alfred Wegener, who got his PhD in astronomy, and performed his research in meteorology, questioned dominant geological beliefs, renouncing the ruling concept of sink-bridges between continents, and arguing in favour of continent's drifting. Milankovic was not a trained meteorologist as well, but he realized that "most of meteorology is nothing but a collection of innumerable empirical findings, mainly numerical data, with traces of physics used to explain some of them... Mathematics was even less applied, nothing

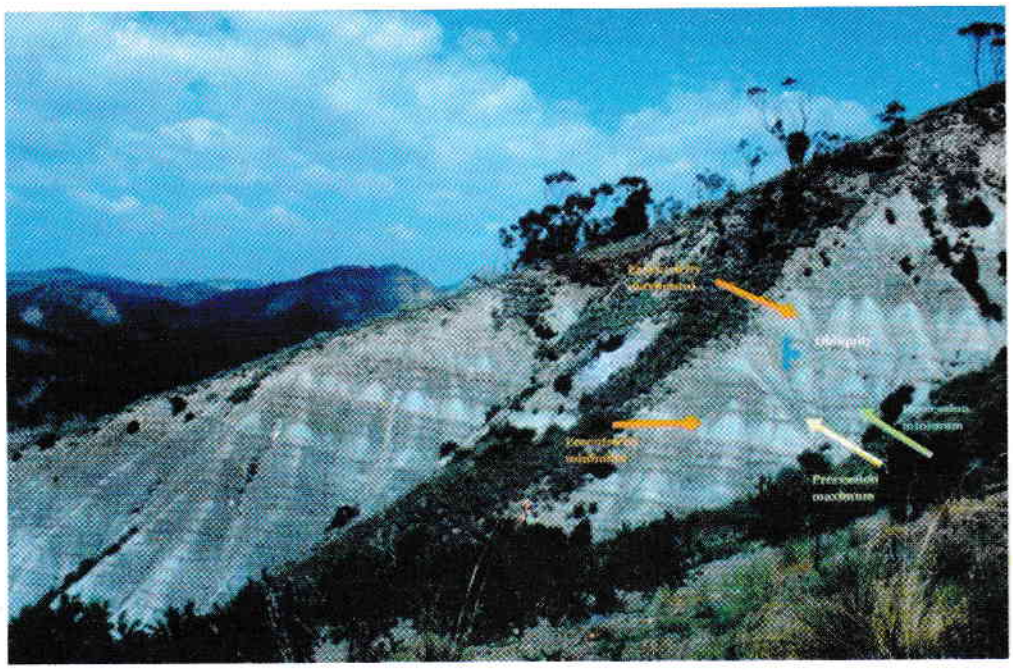

Fig. 4 Geological Response to Insolation shows clearly the Effect of Milankovic's Cycles. Here it could be seen in the Sedimentary Records of Late Miocene Age at Gibliscemi Section, Sicily, Italy (Frederik Hilgen, 2005)

more than elementary calculus... Advanced mathematics had no role in that science..." (12). He understood clearly that is not possible to solve the problem of climate change from the ground of specialized science. Leaned on the celestial mechanics, theoretical physics and spherical astronomy, he established climatology as an exact science. He realized that the astronomical theory before him had fallen into disrepute not because of any intrinsic weakness, but because of insufficient knowledge of celestial mechanics, imperfect mathematical skill, and lack of reliable stratigraphic records.

It was one among the most powerful and productive revolutions of Earth sciences at the beginning of the 20th century. As it was said, "the formulation and step-wise confirmation of the Milankovitc's theory is one of the great scientific success stories of our century" (2). Owing to his theory became evident that there has been multitude of ice ages during the Earth history. Especially the last million years were marked by many cycles of continental glaciations and melting. Changes in global temperature caused massive glacial advances and retreats. That insight was confirmed definitively through the major paleo-climatological projects CLIMAP, COHMAP and SPECMAP which mapped out the patterns of global climate change. They have

demonstrated the central role of Milankovic forcing, along with the response of the climate system, and made transparent that the climate system appears to act in response to insolation forcing in each Milankovic's cycle.

In the past several decades new researches and logical conclusions brought out a series of new questions which challenge Milankovic's theory as well. There are geological evidences which raise questions and models which dispute it because of difficulties in reconciling theory with certain singular observations and the presence of non-orbital spectral peaks in the climate record. The detailed mechanism involved in the transformation of orbit parameter variations into climate variations are not yet known, and consequently the accurate determination of the response time between astronomical forcing and climate change is still eluding.

Nevertheless the Milankovic's theory still can be tested and it is frequently confirmed by making a "simplest possible" assumption: that frequencies in the system input (orbital variations) appear linearly in the system output (climate variations). Many independent investigators appear to see clear evidence of such astronomical forcing, thereby suggesting that climate system responds nonlinearly to all Milankovic frequencies.

Climatic shifts are seen in ocean floor sediments as changes in the kind of shells and minerals deposited. Because sediment accumulation is continuous and undisturbed in much of the deep sea, layered oceanic cores provide an unbroken record of climatic change (Fig.4). Analysis of cores from many areas may be combined on a map to show the geographical extent of these climatic shifts and different ice ages. Oxygen isotopes ratios in the ice can be related to the atmospheric temperature at the time the snow crystallized and fell. We are now in a relatively warm period (interglacial follows one of several glacial periods). It is not certain when the present interglacial end, but even minor climatic changes could affect the world's population in major ways.

All existing uncertainties don't disregard validity of *Canon of Insolation* as a method on which the contemporary climatology is based. It is unavoidable that Milankovic put back almost discarded astronomical theory of climate on rail, and established a firm buckle, linking the exact sciences (celestial mechanics, spherical astronomy, mathematical physics) and descriptive sciences (geology, meteorology, geography, oceanography, glaciology). He set a reliable method for reconstruction and prediction of climate, which is basically still valid. "It remains, however, that the basic of all sciences involved in any theory of paleoclimates can be found in the Milankovic's *Canon*. Critically read, it will remain for ever a milestone in climate science. It is owing to the careful work by Milankovic that we may expect to understand how the Earth system is responding to the astronomical forcing and how it might behave in the future" (Fig.5).

Unfortunately, despite the persuasive results of the astronomical theory of climate change, in the last decades, "uncanonical" approach has become prevalent. For instance, summarizing the wide spread beliefs, the United Nation's International Panel for Climate Change (IPCC) concludes that the present climate dynamics is "unlikely to be entirely natural in origin" and that it's "at least 90% certain" that human

emissions of greenhouse gases rather than natural variations are warming the planet's surface.

But lack of "orbital hypothesis" and escape of Milankovic's cyclicity inevitably enhances inability to "predict the frequencies of glacial fluctuations" and consequently blur theoretical horizon where very often contradictory data could be drawn in for conclusion. It is *déjà vu* situation: the complexity of the Ptolemaic cyclical and epicyclical mechanisms had to increase in step with the increased accuracy of the observations, in order to maintain the calculated planetary positions close to the observed positions, and normal science of that time. Similarly, IPCC methodology, promoting the causes of green house gases for global warming, brings back climate problem again to the poor theoretical level. This reductive perspective, basically unlinks celestial mechanics and the Earth sciences. Without any doubt, loss of astronomical perspective is bigger problem than the relative gains from trapping the climate problem into the greenhouse, because that approach leads climatic science back to the pre-astronomical era. Contrary to this, more reliable opinions related to the long term prediction of the future climate evolution, although provide different

Fig. 5 Scene from the Exhibition, Canon of Milutin Milankovic, housed in the Gallery of the Serbian Academy of Science and Arts (2009)

scenarios (6,7), have Milanovic's cyclicity as a background.

Prophetic view over this situation was formulated back in 1951 by the German climatologist Walter Wundt, Professor at Freiburg University, in his letter to Milankovic. "Their opposition, however, it is not yet based on objections against results of celestial mechanics – such a dispute is possible no more – but on a notion that congruity with reality is not great enough as in fact could be expected. Therefore, all stay fairly at their own profiles, measured and analyzed minutely, once determine that it was a glacial period, next time interglacial, but integral view and explanations are less interesting for those people. They rather hold on their minutes, even if they fall into collision among themselves. Therefore, there is not integral picture. We can rather speak about transitory postures; but with more materials being collected and the theory supplemented, the curve of insolation will continue its victorious campaign." (10).

What could be the conclusion? Simply speaking, IPCC-style Earth sciences tend to darken solar horizon of climate change. It tries implicitly to restore geocentric causality and put astronomical theory of climate change out of social and scientific focus. This is basically an attempt to split again climate research into parts and make them basically ambiguous in its predictions. Going this way Earth science slowly but inevitably will muffle the sense for the Milankovic's revolution from 1912. And this is one of the main reasons that encouraged authors in dedicating exhibition to the history of the astronomical theories of climate change and to the celebrations of 130th Anniversary of Mulutin Milankovic.

References

1. Agassiz L (1840). *'Études sur les glaciers'*, Aux frais de l'auteur, Neuchâtel.
2. Berger W, T.Bickert, E.Jansen, G.Wefer and M.Yasuda(1993). 'The Central Mystery of the Quaternary Ice Age: A View from the South Pacific', "Oceanus".
3. Hays J. D, J.Imbrie, and N.J.Shackleton (1976). 'Variations in the Earth's Orbit: Pacemaker of the Ice Ages', *Science*, 194, pp.1121–1132.
4. Hilgen, Frewderik *et al.* (2005). 'Mediterraneasn Neogene Cyclostratigraphy and Astrco-chronology', in A.Berger *et al.* (eds.). *Paleoclimate and the Earths's Climate System*. Belgrade: Serbian Academy of Sciences and Arts, pp. 73 – 88.
5. Humboldt A (1852). *Cosmos*. volume IV, Bohn.
6. Kukla G and J. Gavin (2005). 'Did Glacials start with Global Warming?', *Quaternary Science Reviews*, 24, pp.1547-1557.
7. Loutre M. F and A.Berger (2003). 'Marine Isotope Stage 11 as an Analogue for the Present Interglacial', *Global and Planetary Change*, 36, pp.209-217.
8. Milankovic M (1920). *Théorie Mathématique des Phénomènes Thermiques Produits par la Radiation Solaire*. Gauthier-Villars et Cie (ed.). Paris : Académie Yougoslave des Sciences et des Arts.
9. Milankovic M (1941). *Kanon der Erdbestrahlung und Seine Anwendung auf das Eiszeitenproblem*. Belgrade: Königliche Searbien, Akademie, (Special Publication V 132: Section of Mathematics and Natural Sciences).
10. Milankovic M (1951). 'Letter of Glaciologist Walter Wundt to Milutin Milankovic from Feb 1, 1951'. Accessed at the Archive of the Serbian Academy of Sceince and Arts, 10131-II-625.
11. Milankovic M (1969). *Canon of Insolation and the Ice-Age Problem*. Washington: U.S. Department of Commerce and the National Science Foundation. (English Translation from Israel Program for Scientific Translations)

12. Milankovic M (1997). *Mémoires, Expériences and Knowledges.* Belgrade: Agency for Textbooks, Belgrade. (in Serbian).

13. Petrovic A (2004). 'Milankovic – The Founder of the Cosmic Climatology', in A.Berger *et al.* (eds.). *Milutin Milankovic's Anniversary Symposium: Paleoclimate and the Earths's Climate System.* Belgrade: Serbian Academy of Sciences and Arts, pp.199–200.

14. Petrovic A (2009). *Cycles and Records – Opus Solis of Milutin Milankovic.* Belgrade: Serbian Academy of Sciences and Arts.

Land Use/ Land Cover Classification and Mapping of Pilibhit District, Uttar Pradesh, India

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Visual interpretation of satellite imagery provides an important and practical method for land use/ land cover classification and mapping. However the challenge lies in accurate mapping at higher spatial scale. Data merging of medium resolution multispectral imagery (IRS LISS-III) with higher resolution panchromatic imagery (Landsat ETM+PAN) is one of the cost effecting methods for generating higher resolution data, which has been employed here for land use/land cover feature extraction. A comparison with Forest Survey of India (FSI) statistics has shown better result that can be attributed to the higher mapping scale and the visual interpretation technique, which is object-based in nature.

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The usefulness and success of land use and land cover mapping depends on the choice of appropriate classification scheme for feature extraction. There are basically two categories for extracting features from satellite images. In one category, software needs the user inputs such as number of classes, standard deviation, mean DN value, variance, threshold value etc., to carry out the classification called digital classification. In another category, using the software the interpreter applies his knowledge for extracting features from the imagery on the screen, which is commonly known as onscreen visual interpretation.

Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM^+) data have been largely employed since 1972, the starting year of Landsat Programme in studies towards the determination of land cover (2). Since 1988 onwards the IRS (Indian Remote Sensing) series of satellites have been providing valuable data for studying land use and vegetation cover of the country. IRS P6 (Resourcesat) provides excellent data, and has been widely used for wide range of applications in varied fields. In the field of land use/land categorization using satellite data, a rule-based expert system was developed using visual interpretation keys coined by NRSA (National Remote Sensing Agency), India (8). Myint obtained a classification to identify tornado-damaged areas from Landsat TM Data (5). Utility of computer-added interpretation allows more than one different region with same colour visibility to fall into one class. e.g.,

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some typical areas of open forest and the agricultural lands abide with same colour properties. Hence it is needed to give attention on the other characteristics of the image such as texture, shape, phenology, association, pattern, shadow etc., at the time of classification.

The onscreen visual interpretation technique depends on biology and geosciences rules and the interpreter's experience and knowledge together for making a sense with the image characteristics (tone/color, texture, shape, phenology, association, pattern, shadow). For the extraction of features from remotely sensed images, and for detecting individual objects from aerial photographs and satellite imageries, onscreen visual interpretation technique has been a common method (5, 1). Prasad obtained a land use/land cover map using onscreen visual interpretation technique (8). Wang used onscreen visual interpretation classification technique for urban planning of some districts in Beijing and the result was reasonable and correct (11).

It is easy to interpret a naturally-coloured image, but due to the high spatial resolution of the images, the terrain features produce intricate patterns, and so it is quite difficult to identify the objects from the false coloured composite (FCC) image. In order to overcome this problem and to make the boundary extent more visible and identifiable, data merging techniques with Intensity-Hue-Saturation (IHS) transformation are applied. The IHS transformation is one of the most common methods used to facilitate the generation of hybrid products with high spatial resolution (12). The method is related to the parameters of human colour perception, defined in terms of intensity (brightness of the colour), hue (dominant colour like red, green, blue, and colour mixtures), and saturation (purity of the colour). The procedure involves the transfer of the colour parameters from images originally displayed in the red-green-blue domain, to the IHS colour space. The reverse transform to the RGB domain permits the IHS images to be replaced by new images. Thus it allows the most detailed separation of structures and objects. Carper used IHS transformation for merging SPOT panchromatic and multispectral images data, and obtained image with better boundary visibility (3). Nasr obtained an integrated composite image of improved information and enhanced interpretability using IHS transform (6).

In the present study, the IRS P6 LISS III data were merged with the Landsat 7 ETM PAN data using IHS transformation technique. Further, onscreen visual interpretation technique was done for LUVC classification of the Pilibhit district. Finally, the area statistics was compared with that of Forest Survey of India report (9).

Study Area

The district of Pilibhit is located in north-eastern part of Uttar Pradesh, which is situated in the sub-Himalayan belt. The district shares its boundary with the kingdom of Nepal. It lies between the parallels of 28°06' N and 28°53' N latitudes and 79°57' E and 80°27' E longitudes. Udhamsingh Nagar district and the kingdom of Nepal lie on the north, Shahjahanpur district lies on the south, Bareilly district lies on the west, and on the east the district is flanked for a short distance by district Kheri and for the remaining distance by the Shahjahanpur district (Fig. 1).

Topographically the district may be divided into several distinct tracts. The district is traversed with a number of streams and canals, and Sharda canal is the main one. Gogra river runs along the northern boundary and Gumti river, through the middle of the district. A large portion of the district is enclosed by dense forest. Open forest and scrubs too are found here and there. In the upper part of the district the soil is sandy, while in the lower part it is clayey. Moisture content of soil is quite high in most parts of the year. Dry and barren lands are found only in a few pockets of the district.

Methodology

The detailed methodology includes feature extraction of six broad land use/ vegetation cover classes and classification using higher resolution merged images (Fig. 1).

Data Used - Satellite and Ancillary Data

Two Linear Imaging Self Scanning (LISS III) scenes of Indian Remote Sensing (IRS) satellite data were procured to accommodate the Pilibhit district (Table 2). LISS III has four spectral bands i.e., 0.52-0.59 µm, 0.62-0.68µm, 0.77-0.86µm & 1.55-1.70µm. Two Enhanced Thematic Mapper (ETM) scenes of Landsat MX and PAN data were downloaded from ESDI to accommodate Pilibhit district (Table 1). ETM Landsat images have 10 m PAN data. Toposheets (1: 50,000 scale) for reference purposes, and socioeconomic data and other ancillary data for historical interpretations were also used.

Data Merging

The three multispectral bands*viz.*Red, Green and NIR were merged with the PAN band of the ETM Landsat data [IRS LISS-III(23.5m MSS) + Landsat ETM (10m PAN)] to make easy the boundary extent more visibility, applying Intensity-Hue-Saturation (IHS) transformation technique. The IHS transformation is one of the most common methods used for data merging. The IHS system offers the improvement that the separate channels outline certain colour properties, namely intensity (I), hue (H), and saturation (S). The intensity describes the total colour brightness and exhibits as the dominant component. This transformation consists of two basic steps. In the first step, RGB colour values for three selected multispectral bands *viz.*Red, Green and NIR bands are converted to intensity, hue and saturation colour components. Mathematical functions are used to convert RGB values to IHS values. The higher-spatial resolution image is constantly

Table 1
Satellite Data Specifications

Satellite	Sensor	Path	Row	Date of Pass	Special Resolution
IRS P6	LISS III	98	51	18-Nov-05	23.5 m
IRS P6	LISS III	99	51	13-Oct-05	23.5 m
LANDSAT 7	ETM+PAN	144	40	9-Nov-99	10
LANDSAT 7	ETM+PAN	145	44	15-Oct-99	10

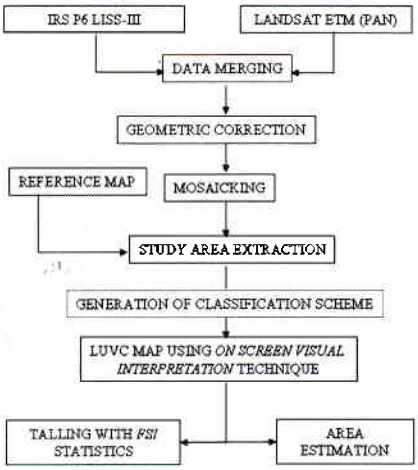

Fig.2
Methodology flowchart of the study

Fig. 1 Methodology

Table 2
Interpretation Key used in the On-screen Visual Interpretation Method for the LUVC Mapping

Classes	Tone	Texture	Shpae	Phenology	Association	Pattern
Dense forest	Dark red/Dark brown to red	Smooth	Regular	Brown	Everywhere	Contiguous
Open forest & Scrubs	Bright red	Smooth to Course		Brown	Open forest, forest gaps, degraded forest, scrubs	Scattered
Agricultural/ fallow land	Red/ Light pink to bright pink/Gray	Smooth				Contiguous
Moist land	Pale green	Medium Smooth				Contiguous
Dry barren Land	White/ Whitish blue	Medium Coarse				Scattered
Water body	Blue/Black	Smooth				Contiguous

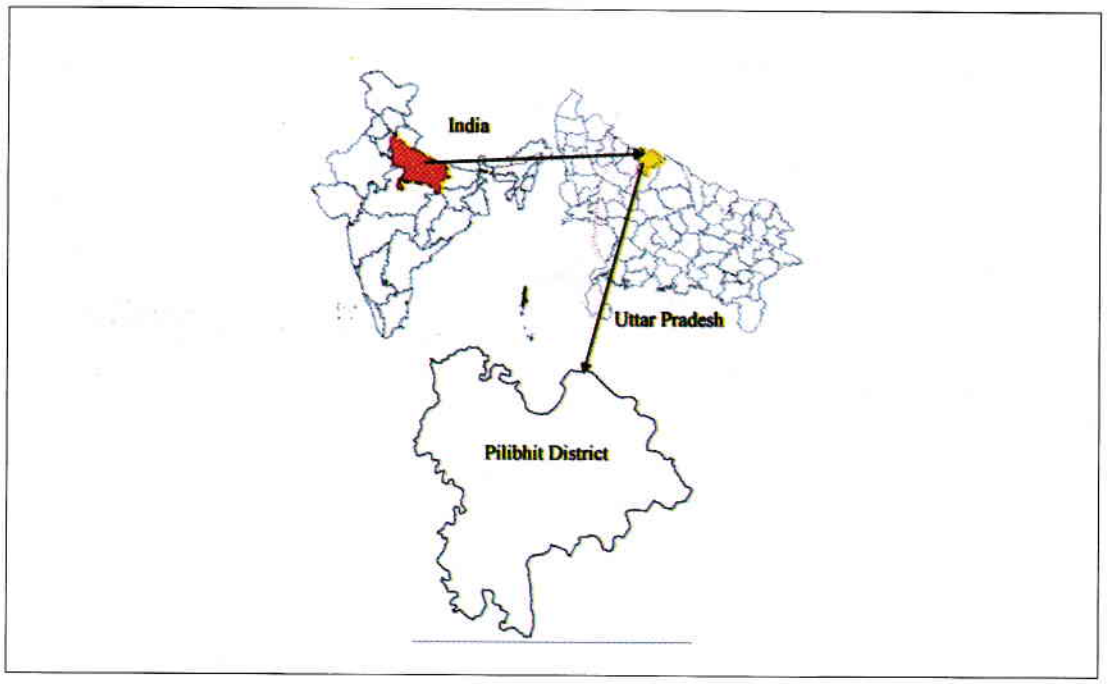

Fig. 2 Location Map

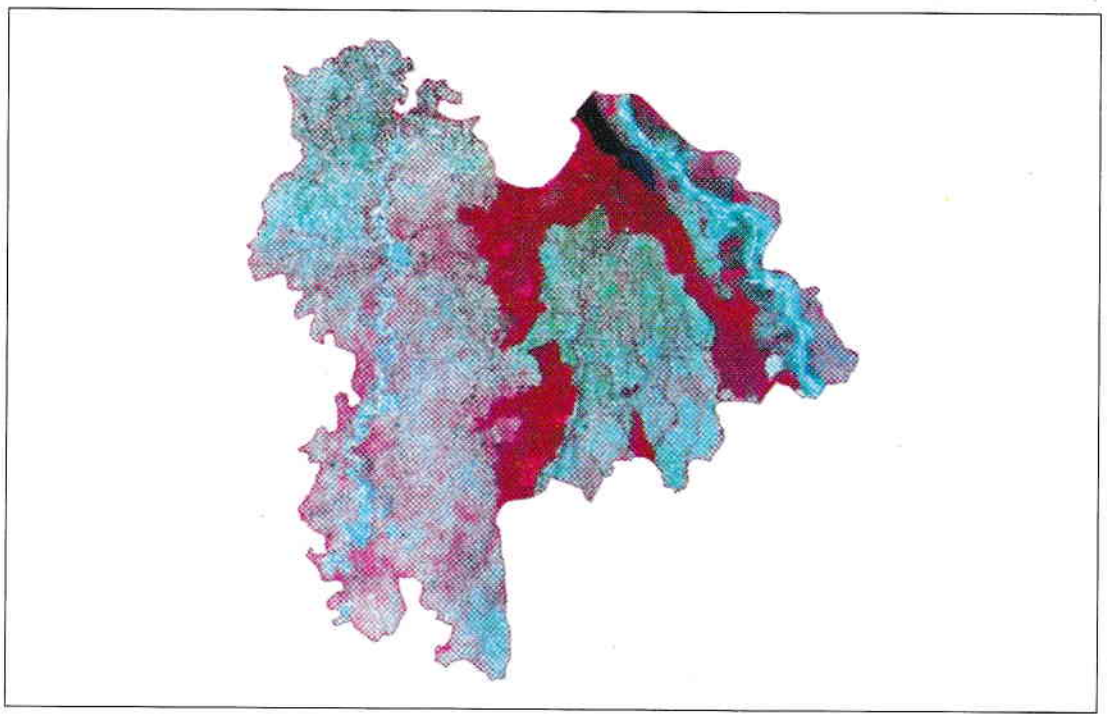

Fig. 3 Image showing Standard False Colour Composite (FCC) of the Pilibhit District extracted from the Mosaic of Two Scenes with the Time Period, 18th Nov.2005 and 13th Oct.2005.

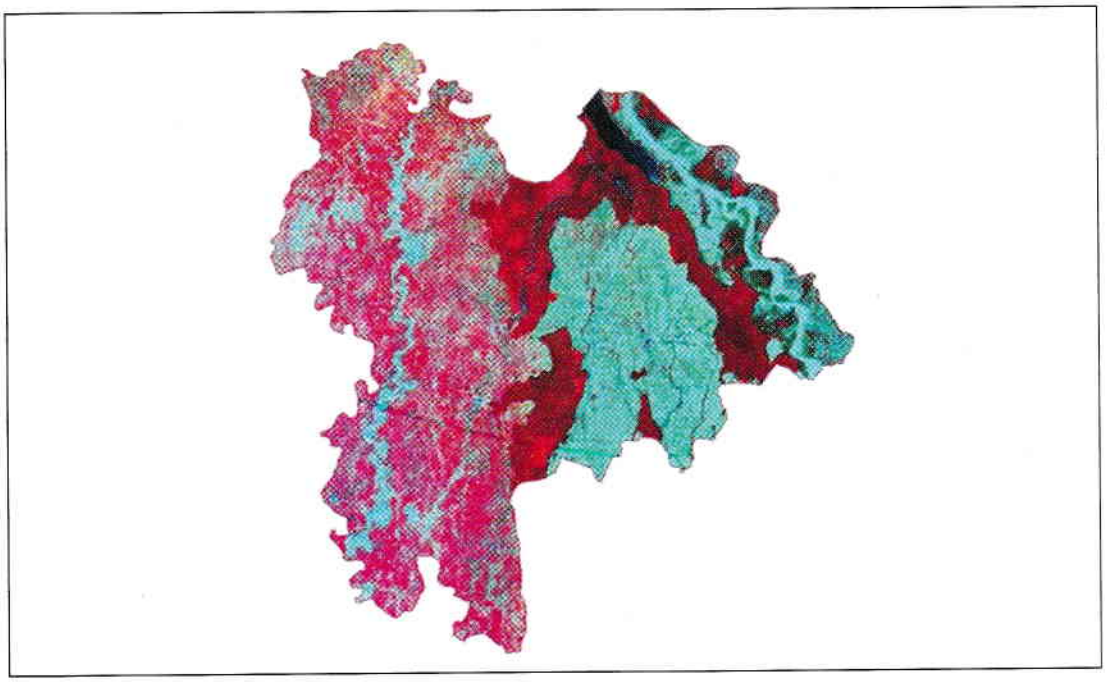

Fig. 4 Image showing the Merged Imagery of Pilibhit District extracted from the Mosaic after Data Merging of IRS P6 Data with Landsat 7 Data.

IRS P6 LISS III (MSS) [18th Nov. 2005 & 13th Oct. 2005] *Landsat 7 ETM (PAN) [9th Nov. 1999 & 15th Oct. 1999]*

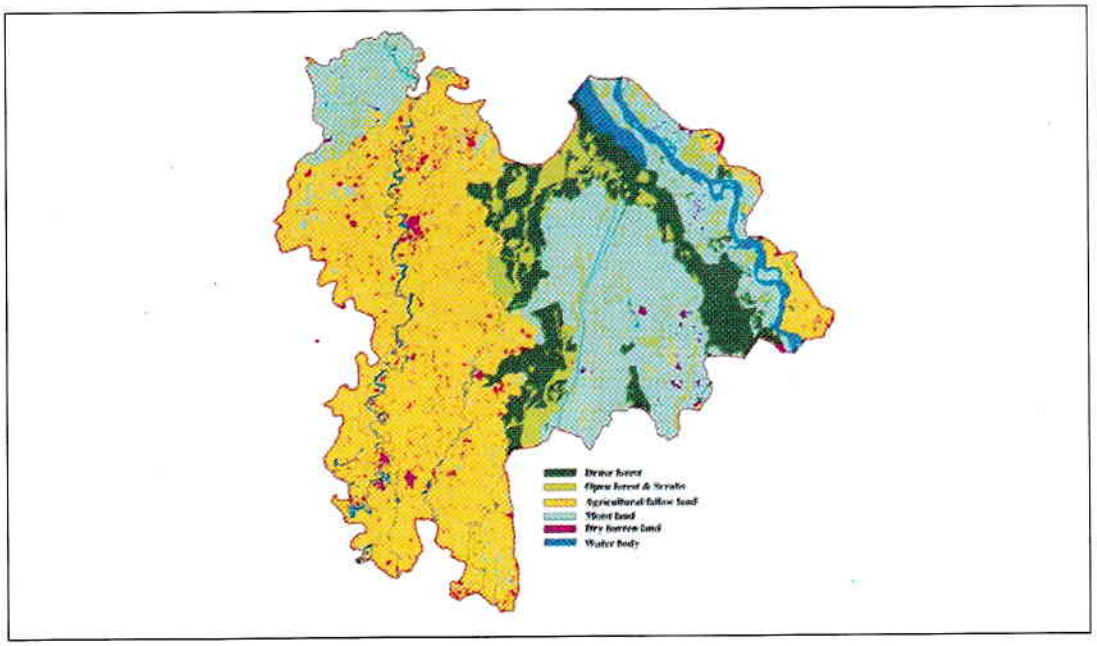

Fig. 5 Land Use/Vegetation Cover (LUVC) Map of Pilibhit District obtained by Onscreen Visual Interpretation Technique

stretched in order to adjust the mean and variance to unit intensity. The second step is the substitution of the stretched panchromatic image for the intensity component of IHS and retransformation to RGB. The merged image was shown in the Fig. 4.

Geometric Correction and Study Area Extraction

Remotely sensed data cannot be used directly for resource information due to the inherent distortion in the image data and so, the image data were georeferenced with LCC projection system and WGS 84 datum *i.e.*, map co-ordinates were assigned to the Image. Each of the two scenes was geo-referenced separately. Image enhancement techniques and proper band combination for the identification of the required features are needed to do classification of the image (4). In this study, the band combination of NIR (red), R (green), G (blue) was used for LUVC classification and mapping (Fig. 3).

Classification

The geometrically rectified and merged FCC image was subjected to the process of classification. Initially, the image was classified by onscreen visual interpretation technique, based on the available ancillary data and prior knowledge, and using ERDAS Imagine software. The multispectral characteristics of the different class types *i.e.* variation in tone, texture, shape, phenology, association, pattern of various objects within the satellite data formed the basis for classification (Table 2). Six categories were identified *viz.*, dense forest, open forest and scrubs, agricultural/fallow land, moist land, dry barren land and water body. In each class, it is natural to have a range of variations, and with this conception, land use categories are delineated. All the dense forest type land covers were put in a single class naming as dense forest class. The areas with dark red tone to dark brown to red tone, visible as smooth texture and contiguous occurrence in the merged image (Fig. 4) were considered as the dense forest. Open forest, degraded forest, forest gaps and scrubs were all placed in open forest & scrubs class. Those regions with bright red tone, visible as smooth to coarse texture, and scattered pattern in the merged image (Fig. 4) were considered as the open forest and scrubs. Similarly the entire crop lands, arable lands, plantations and permanent pastures were put in one class naming as agricultural/fallow land class. Those regions with red tone to light to bright pink tones, visible as smooth texture, regular in shape and contiguous pattern in the merged image (Fig. 4) were considered as the agricultural/fallow land. Shady areas and damp grounds were placed in moist land class. Those regions with pale green tone, visible as medium smooth texture and contiguous pattern in the merged image (Fig. 4) were considered as the moist land. Likewise sandy areas, dry lands and settlements were put in one class naming as dry barren land class. Those regions with white to whitish blue tone, visible as medium coarse texture, and scattered pattern in the merged image (Fig. 4) were considered as the dry barren land. Reservoirs, river course, channels, ponds and tanks were placed in water body class. Those regions with blue to black tones, visible as smooth texture and contiguous pattern in the merged image (Fig. 4) were considered as the water body. The merged image was displayed using bilinear interpolation method for better interpretability. Pre-defined interpretation

keys (Table 2) were used to generate the land use/ land cover map (Fig. 5).

Results and Discussion

The FCC image and the merged image are shown in Fig. 3 and Fig. 4 respectively. In the FCC image, the objects are more clearly visible. Due to the data merging of IRS-6 (LISS III) data of 23.5 m spatial resolution with Lansat-7 (ETM+PAN) data of 10 m spatial resolution, the objects in the merged image were identified more clearly, and accuracy in delineating boundaries for the regions was found to be more. For instance, red colour component in data merging gets converted to an intense one, and with this strength of red colour, lands under farming and fallow use are clearly visible. The northwestern part of the district in the FCC image (Fig. 3) appears to be with moist land, but in the merged image (Fig.4), it appears to be a different land use, and it may be because of data differences between two seasons. Period of data for ETM had the crops standing on the fields, and for LISS III, had the crops harvested. However, it does not come in the way to treat agricultural/fallow lands as a single class. The rivers in the FCC image were clearly visible along with the river line sands but in the case of merged image, rivers as well as river line sands were detectable as one category. This may be due to different satellite images captured in different time periods. Yet, it is fine when both these categories get clubbed one as water bodies. Thus, data merging helps to achieve more visibility in boundary delineation of the objects. As a result it was easier to digitize the merged image for classification and mapping as compared to FCC image.

The result of classification is shown in the Fig. 5. It provides different types of classes as given in Table 3. The colour-coded map (Fig. 5) represents different LUVC classes i.e., dense forest of 414.42 sq.km (11.56%) area, open forest and scrubs of 268.85 sq.km (7.5%) area, agricultural/fallow land of 1545.80 sq.km (43.12%) area, moist land of 1079.15 sq.km (30.10%) area, dry barren land of 82.19 sq.km (2.29%) area, and water body of 194.79 sq.km (5.43%) area of the district (Table 3). Fig. 6 illustrates the histogram of area statistics for each class obtained by the onscreen visual

Table 3
Area Estimation of LUVC Mapping following On-screen Visual Interpretation

Class Names	Unsupervised Classification (Area in Sq.km)
Dense Forest	414.42 (11.56 %)
Open Forest and Scrubs	268.85 (7.5 %)
Agricultural / Fallow Land	1545.80 (43.12 %)
Moist Land	1079.15 (30.10 %)
Dry Barren Land	82.19 (2.29 %)
Water Body	194.79 (5.43 %)

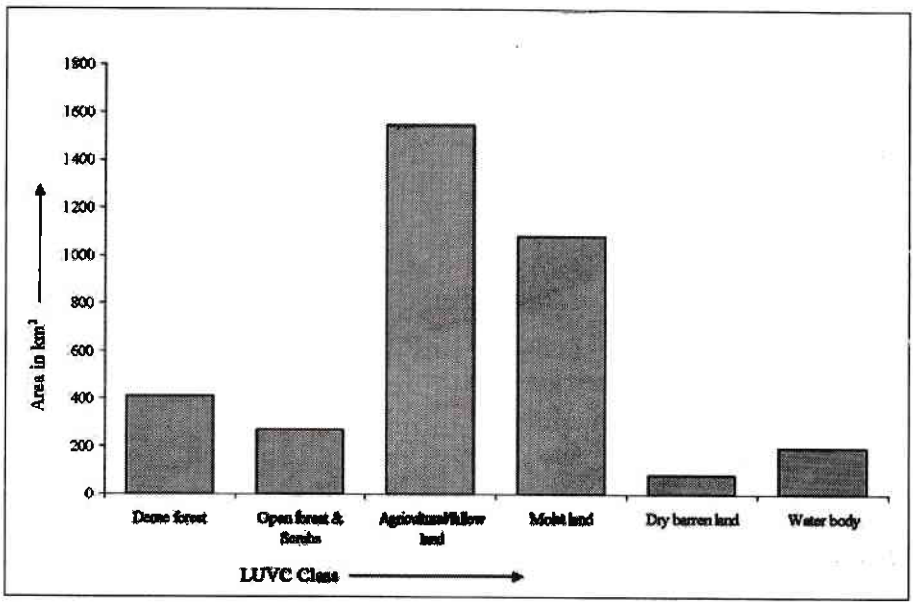

Fig. 6 Histogram showing Area Statistics of Various LUVC Classes of Pilibhit District following Onscreen Visual Interpretation Classification.

interpretation. From the LUVC map (Fig. 5) comparing with the merged image (Fig. 4) as well as FCC image (Fig. 3), it is seen that all the categories of land use are found occurring in each and every district, and they are described as follows (Table 3).Dense forests occupy about 12 per cent of the area (Table 3) of the district. Open forest, degraded forest, forest gaps and scrubs are clubbed as open forest and scrub class, and they spread over 7.5 per cent of the area. Arable land, permanent crops, plantations, and permanent pastures are included under agricultural/fallow land, and about 43 per cent of the area of the district is seen with this land use. Moist lands occupy about 30 per cent of the area. Sandy areas, dry lands and settlements are treated as barren land class, and they form about 2 per cent of the area of the district. Reservoirs, river course, canals and channels, and ponds are included under water bodies and they occupy about 5 per cent of the area.

Report of Forest Survey of India (10) finds that forests occupy about 11 per cent of the district, and scrubs account for about 7.5 per cent of the area in 2005. The estimate of the present exercise, based on visual interpretation, too is closer to the estimate of the Forest Survey of India in the spread of forests and scrubs. The over estimation of area by about 0.86% in the case of FSI estimate may be attributed to their use of the remote sensing products with lower resolution (23.5 m data). As mentioned, the present exercise used higher spatial resolution data *i.e.*, 10 m merged image. The difference may also be attributed to data of different periods and different methodology of mapping followed.

Conclusions

Data merging facilitated the mapping at higher resolution. On-screen visual interpretation resulted in the identification of six categories of land use/land cover, *viz.*, dense forest, open

forest & scrubs, agricultural/fallow land, moist land, dry barren land and water body. On-screen visual interpretation is nearly an object-based procedure of classification, and the user's expertise and field knowledge are also drawn for interpretation with image characteristics; and this enhanced interpretation capabilities. On a comparison with FSI estimates, it is brought out that the estimates of land use/land cover for the selected district are more accurate that can possibly be attributed to higher resolution satellite data.

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References

1. Bocco G and C. R. Valenzuela (1993). 'Integrating Satellite-remote Sensing and Geographic Information Systems Technologies in Gully Erosion Research', *Remote Sensing Reviews, 7*, pp. 233–240.
2. Campbell J. B (2007). *Introduction to Remote Sensing*. New York: The Guilford Press. (Fourth Edition).
3. Carper W. J, T. M. Lillesand and R. W. Kiefer (1990). 'The Use of Intensity-Hue-Saturation Transformations for merging SPOT Panchromatic and Multispectral Images Data', *Photogrammetric Engineering and Remote Sensing*, 56(4), pp. 459-467.
4. Jensen J. R (1996). *Introductory Digital Image Processing: A Remote Sensing Perspective*. New Jersey: Prentice-Hall.
5. Martinez-Casasnovas J.A (2003). 'A Spatial Information Technology Approach for the Mapping and Quantification of Gully Erosion', *Catena*, 50, pp. 293-308.
6. Myint S. W, M. Yuan, R. S. Cerveny and C. P. Giri (2008). 'Comparison of Remote Sensing Image Processing Techniques to identify Tornado Damage Areas from Landsat TM Data', *Sensors 2008*, 8, pp. 1128-1156.
7. Nasr A. H and T. M. Ramadan (2008). 'Data Fusion using IHS Transformations for exploring Ore Deposits in Northeastern Part of the Saharan Metacraton', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 37(B7), pp. 1119-1124.
8. Prasad R, A. K. Sinha and K. R. Ranjan (2002). 'Visual Interpretation of FCC Image for Land Use and Land Cover Mapping: An Expert System Approach', *IEEE, SICE* 02, (http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=01195718), Aug 5-7, pp. 2093-2098.
9. Ramani K and N.C. Gautum (1990). 'Expert System for Identification of Land Use/Land Cover Categories from Satellite Data, Proceedings of the Seminar on AI, Expert System & Knowledge Based System', Bangalore: ISRO..
10. State of Forest Report (2005). *Forest Survey of India. Dehradun:*Ministry of Environment and forests).
11. Wang Q, J. Chen and Y. Tiana (2008). 'Remote-sensing Image Interpretation Study serving Urban Planning based on GIS', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 37(B4), pp. 453-456.
12. Welch R and M. Ehlers (1987). 'Merging Multiresolution SPOT HRV and Landsat TM data'. *Photogrammetric Engineering and Remote Sensing*, 53, pp. 301-303.

Year 2005 Floods in Maharashtra

A Mirco-level study

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The present paper, bsed on the primary data collected in 2006, looks into the impact of disaster on Ambewadi and Prayag villages in Karveer taluk of Kolhapur district (Maharashtra) where heavy flood was reported in July-August 2005. It describes the causes of flood, loss of life and economy, and aid recieved by the flood-affected people from the government. It caused massive loss in both of these villages and very prominently in Marata caste. Most of the katcha *houses of weaker sections got collapsed. The damage of houses in Prayag Chikkali was much higher than in Ambedwadi. Heavy rainfall caused damage to land and standing crops.*

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Floods refer to a stage wherein the water level reaches a height above a given point such as the banks of a stream (3). They occur normally due to heavy rains or rapid thawing of snow and topographic characteristics. Topography gets very often modified by anthropogenic activities in these days of unmindful development activities, and these landscape changes may be seen causing flooding now. In the alluvial tracts, during heavy and incessant rainfall, rivers are generally incompetent to discharge the sudden surge of water, resulting in floods crossing over their banks; with heavy deposition on the alluvial tracts because of floods, stream courses may also get changed during the time of flooding (5). These floods have in many instances defined the history of human civilization that flourished in these rich alluvial tracts (2). Floods are natural and they turn out to be a human concern when economic and cultural development takes place in the flood plains where floods occur.

Flood happened in the year of 2005 in Maharashtra was one of the extreme consequences of the climate in the recent history of the State. Actually, the first six months of the year 2005 were beset with severe drought conditions in Maharashtra, particularly in Vidarbha and Marathwada; and the situation changed so dramatically in the last week of July 2005. July 26th had the highest rains in the last 100 years. Thanks to heavy rains, Koyana and Ujani dams got filled

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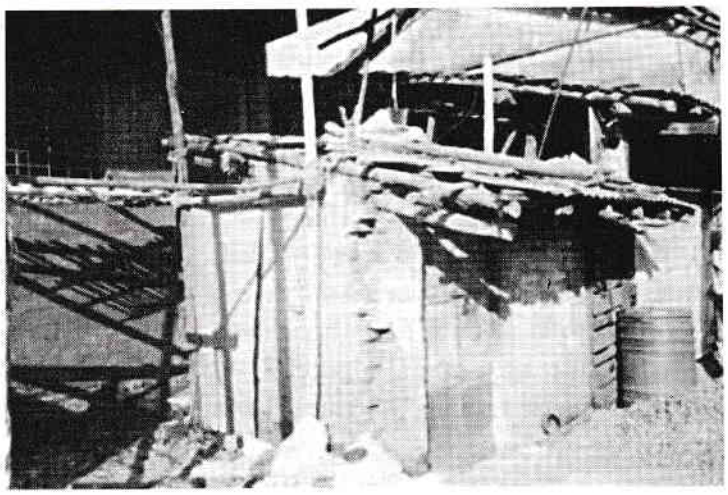
Settlements Flooded

Houses Flooded (Ambewadi Village)

Partly Collapsed House (Prayag Chakhali Village)



Totally Collapsed House (Ambewadi Village)

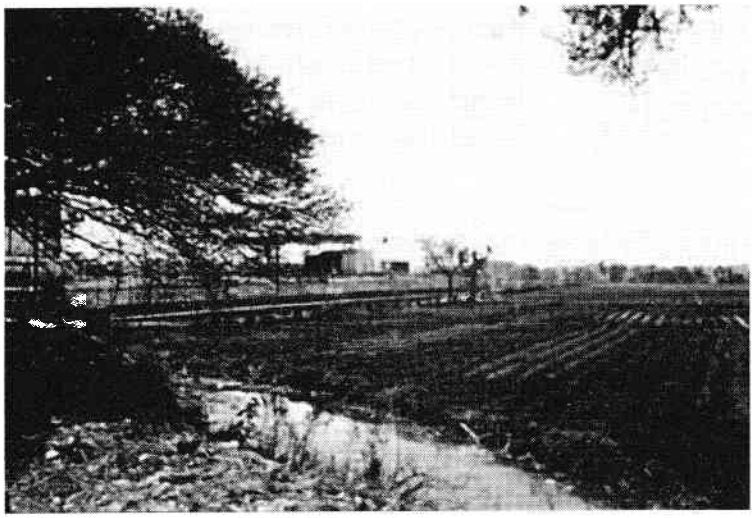
(Source: Field Survey, February 2006)

in quickly and the release of surplus waters from them flooded the districts of Sangli, Kolhapur and Solapur. About 90000 ha of farm land, including 3600 ha of area under sugarcane cultivation, in Kolhapur district got submerged during the floods (1), resulting a serious set-back to the sugarcane economy of the State. The state government released a sum of Rs.50 million immediately to attend to the damaged school buildings, hospitals, roads, bridges and drinking water lines.

Study Area and Objectives of the Study

The study looks into the impact of floods, taking a case study with two villages, Ambewadi and Prayag Chikhali, in the flood-affected area in Kolhapur district. The two villages are located in Karveer taluk to the north of the district. Ambewadi is located on

Farm Lands Flooded



Damaged Crops due to Flood (Ambewadi Village)

Heap of Flood affected; Sugarcane used as Fuel (Prayag Chikhali Village)

(Source: Field Survey, February 2006)

the SH-204 highway and Prayag Chikhali, 2 km away from the Ambewadi (7). Ambewadi occupies an area of 159.26 ha with a population of 2077 and Prayag Chikhali, of 550.15 ha with a population of 5994 (4). They are located on the flood plains of the Panchaganga river that is fed by smaller streams of Kumbhi, Kasari, Bhogavati and Tulsi rivers (Fig 1).

The study first brings out the factors that led to the floods, and then it assesses the damages caused to persons and properties. Efforts by the institutions to restore the normalcy and assist those affected are then discussed, along with relevant way-outs for minimizing the loss in the time to come.

Data and Methods

The present study is based on primary data gathered from sample households selected on a stratified sampling frame. Sample households were drawn from all economic categories of the villages. Required secondary data were collected from Census 2001 and *gramapanchayat*, taluk and *zilla parishad* offices. Newspapers, District Census Handbook and the Statistical Abstracts were consulted for rainfall data and other information. Records kept at *gramapanchayats* were consulted for locating those affected villages by floods. Ninety eight households from Ambewadi and 140 households from Prayag Chikhali were

Table 1

Rainfall in Karveer Taluk between July 24 and August 3, 2005

Date	Rainfall in mm (2004)	Rainfall in mm (2005)
24th July	326.9	359.9
25th July	331.1	359.8
26th July	333.5	359.5
27th July	338.0	359.9
28th July	343.5	359.1
29th July	344.9	498.0
30th July	362.2	498.0
31st July	378.6	498.0
1st August	395.7	690.6
2nd August	409.3	696.6
3rd August	443.9	696.0

Source : Collector's Office, Kolhapur 2005.

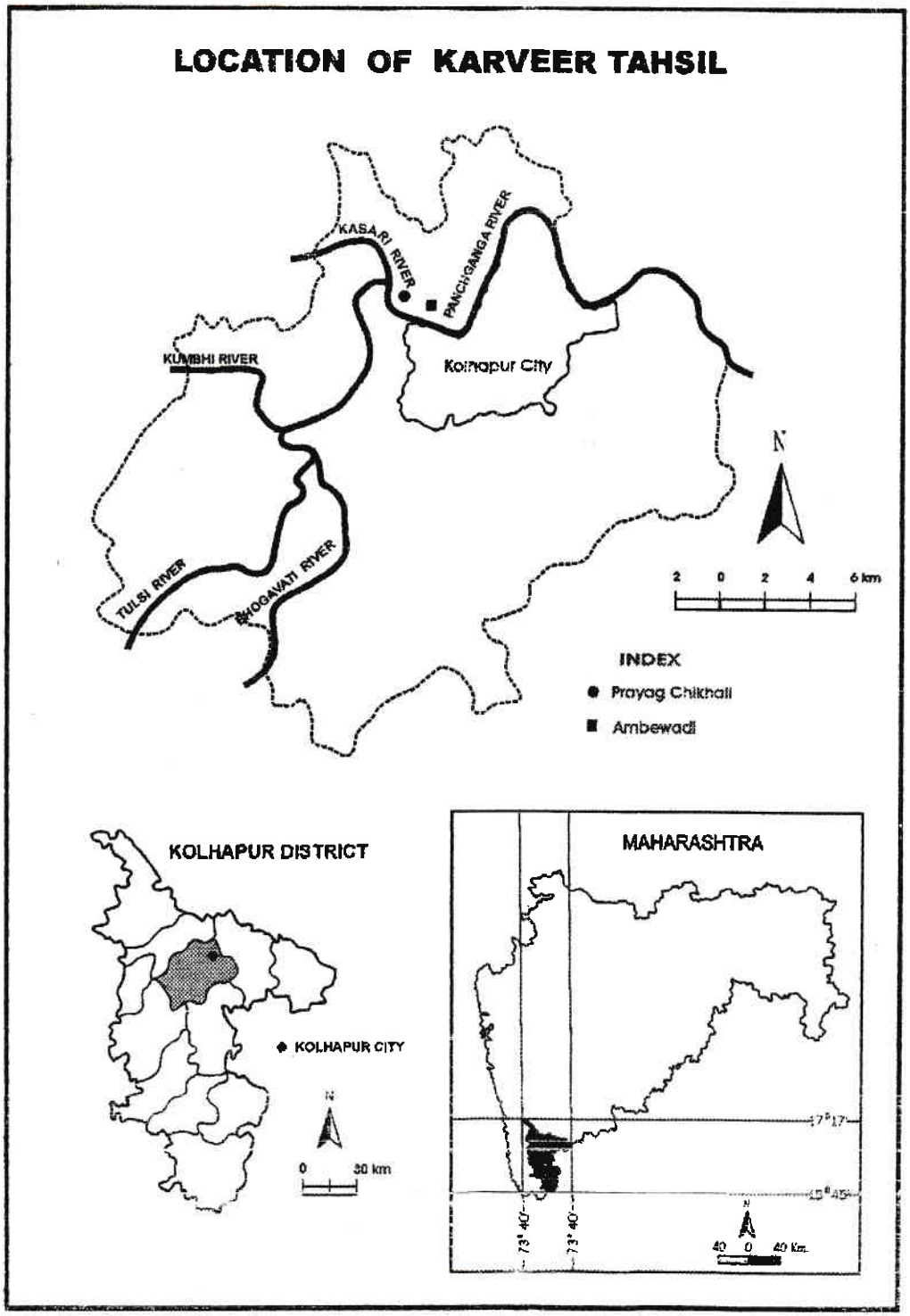

LOCATION OF KARVEER TAHSIL
KASARI RIVER
PANCHGANGA RIVER
KUMBHI RIVER
Kolhapur City
TULSI RIVER
DHOGAVATI RIVER
N
2 0 2 4 6 km
INDEX
Prayag Chikhali
Ambewadi
KOLHAPUR DISTRICT
KOLHAPUR CITY
0 30 km
MAHARASHTRA
17°17'
15°45'
73° 40'
73° 40'
40 0 40 Km

Fig. 1

Table 2a
Damage of Houses : A Case Study of Ambewadi Village, 2005

Caste	Total Households	Loss in Rs.	Per House Loss in Rs.	Aid received from Govt.	Per house Aid	Difference
Maratha	41	98500	9850	17300	1730	81200
Lingayat	16	--	--	--	--	--
Bhoi	7	--	--	--	--	--
Mahar	7	--	--	--	--	--
Mang	5	27000	13500	3400	1700	24400
Chambhar	7	50000	25000	3000	4000	4700
Muslim	8	8000	8000	5000	5000	3000
Others	7	3000	3000	2000	2000	1000
Total	**98**	**1,86,500**	**59,350**	**30700**	**22231.25**	**1,55,800**

Table 2b
Damage of Houses : A Case Study of Prayag Chikhali Village, 2005

Caste	Total Households	Partly Collapsed Houses %	Loss in Rs.	Per house Loss Rs.	Aid Recieved from Govt.	Per house Aid	Difference
Maratha	100	24.00	370000	15416	32800	1366	38200
Dhangar	06	--	50000	--	--	--	50000
Chambhar	06	66.66	84200	12500	--	--	84200
Mahar	25	60.00	3000	5613	7750	516.66	4750
Others	03	33.33	507200	3000	2000	2000	505200
Total	140	31.42	1014400	15527	42550	967.04	971850

Source : Field Survey, February 2006

Table 3a
Caste-wise Damage of Household Assets in Ambedwadi, 2005

Caste	Total Households survyed (Sample Village)	Househods affected	Caste-wise affected Hosueholds to total affected Houses	Total Loss Estimate of affected Households
Maratha	41	20	36.36	184000
Lingayat	16	10	1.81	2000
Bhoi	7	4	12.75	131000
Mahar	7	4	7.27	67000
Mang	5	4	7.27	185000
Chambhar	7	4	7.27	134000
Muslim	8	8	14.54	32500
Other	7	7	12.72	39000
Total	**98**	**55**	**56.12**	**608000**

Table 3b
Caste-wise Damage of Household Assets in Prayag Chikhali, 2005

Caste	Total Households survyed (Sample village)	Househods affected	Caste-wise affected Households to Total affected Houses	Total Loss Estimate of affected Households
Mahar	100	41	59.42	228000
Dhangar	6	1	1.45	1000
Chambhar	6	46	8.70	6000
Mahar	25	18	4.34	27100
Other	3	3	49.26	99710
Total	**140**	69	**56.12**	361810

Source : Field Survey, February 2006

Table 4a
Ambewadi : Caste-wise Damage, 2005

Caste	Cultivated Land (ha)	Land under Sugar-cane (ha)	Total Land (ha)	Affected Land (ha)	Per House-hold Land (ha)	Total Loss (Rs.)	Loss per House-hold (Rs.)	Total Aid recieved from Govt. (Rs.)	Aid recived per Hectare from Govt. (Rs.)
Maratha	20.3	20.3	20.3	20.3	0.49	1067000	52501	164000	8078
Lingayat	8.55	8.44	3.55	8.55	0.53	664000	77660	51800	6058
Bhoi	1.04	1.04	1.04	1.04	0.14	64000	61538	10000	9615
Mahar	2.00	2.00	2.00	2.00	0.28	100000	50000	20000	10000
Mang	--	--	--	--	--	--	--	--	--
Chambhar	--	--	--	--	--	--	--	--	--
Muslim	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Total	**31.89**	**31.78**	**31.89**	**31.89**	**0.32**	**1895000**	**59423**	**245500**	**7707.74**

Table 4b
Chikhali : Caste-wise Damage, 2005

Caste	Cultivated Land (ha)	Land under Sugar-cane (ha)	Total Land (ha)	Affected Land (ha)	Per House-hold land (ha)	Total Loss (Rs.)	Loss per House-hold Rs.	Total Aid recieved from Govt. (Rs.)	Aid recived per Hectare from Govt. (Rs.)
Maratha	42.86	42.86	42.86	42.86	0.42	3312700	77291	251800	5874
Dhangar	1.2	1.2	1.2	1.2	0.02	150000	125000	4000	3333
Chambhar	0.46	0.46	0.46	0.46	0.07	77000	158738	21500	46739
Mahar	1.03	1.03	1.03	1.03	0.04	163500	--	4400	42718
Other	--	--	--	--	--	--	--	--	--
Total	**45.55**	**45.55**	**45.55**	**45.55**	**0.55**	**3703200**	**528420**	**281700**	**6184.41**

Source : Field Survey, February 2006

selected for the survey. Income and literacy level were used to define the socio-economic status of the households, and farm incomes were estimated for the households from the produce obtained minus farm expenditure. Loss due to floods was computed by assessing the damages to land, crops, livestock and personal belongings.

Factors of Year 2005 Floods

Excess rains and release of water from Radhanagari dam were the main causes for floods in Kolhapur district. Kalammawadi and Bhogawati are the main dams in the catchment area of the Panchaganga basin. The release of excess water from these dams in order to secure the dams was also responsible for floods. In six days between July 24 and July 29 in 2005, there was a total rainfall of 230 cm, and in the next five days from July 30, total rainfall was 310 cm. A rain of 540 cm happened in 11 days (Table 1). A comparison between the rainfalls of 2004 and 2005 (Table 1) may also indicate the exceptional case of the year 2005. Almost a flat flood plain on both sides of the river and meandering nature of the river in Karveer taluk must have accelerated the flooding in the study area (Fig.1).

Flood Damages in Ambewadi and Prayag Chikhali Villages

Ambewadi and Prayag Chikhali villages got extensively affected by floods. The Maratha caste is the predominant one in both the villages and they were very badly affected [Table 2(a) and Table 2(b)]. There was a considerable damage to public utilities and infrastructure. About 50 *kutcha* houses made up of bricks and mud were severely damaged by flood. In Ambewadi 16 per cent of houses was partly collapsed and 3 per cent, totally collapsed. As much as 90% of the *kutcha* houses were collapsed in these villages [(Table 2(a) and Table 2(b)]. In both the villages, the houses are made of local materials available such as bricks, bamboos, dry grass, etc. The affected people were given shelter in primary school in Ambewadi and *grampanchayat* building immediately during the flood. Loss of household assets like TV, radio, clothes, two-wheelers, four-wheelers, irrigation pumps, vessels, etc. due to flood waters entered into the households was also assessed [Table 3(a) and Table 3(b)].

It was estimated that the total loss to farming sector in Ambewadi was Rs. 1.9 million and in Prayag Chikhali, Rs. 3.7 million; and however it is sad that the government was able to compensate the loss only to about 10 per cent of the total loss of the farmers [Table 4(a) and Table 4(b)]. Loss to sugarcane crops is almost total, and to other crops too was quite considerable.

Conclusion

The study assessed the damages due to floods of the year 2005 in Maharashtra, taking two sample villages, Ambewadi and Prayag Chikhali in Kolhapur district. Damages to the buildings are more found in Prayag Chikhali. In Ambewadi, 31.89 ha and in Prayag Chikhali 45.55 ha of cultivated land was affected by flood. From the views of the sample households, financial support received from the government appears to be quite insufficient to recover from the loss.

Suggestions

1) There should be a regulation on the construction of houses over flood plain of Panchaganga river.

2) Dumping of waste material along the bank of Panchaganga river should not be allowed.
3. For the construction of concrete houses, Government should provide suitable compensation and soft loans for the poor people in both villages.
4. Cleaning and deepening of river bed and removing of rubble from the bank of Panchaganga river have to be periodically carried out.
5. Disaster management, rehabilitation and relief committees should be formed in these two villages so as to ensure timely relief like water, food, etc. to the flood-affected people.
6. Wireless communication during such calamity hours should be made available in both villages.

References

1. Atre, Abhiji (2005). 'Kolhapur Flood Damage Pegged of Rs 1200 Crore'. *The Times of India*, September 6.
2. Bahadur, Nawad Ali Nawab Jung (1947). 'River Training and Protection against Floods', in K.T.Shah (ed.). *River Training and Irrigation*. Bombay: Vora and Company Publishers Ltd.
3. Botkin D.B and E.A. Keller (1998). *Environmental Science: Earth as a Living Planet*. New York: John Wiley and Sons.
4. Census of India 1991. *District Census Handbook, Kolhapur* part XII, A & B.
5. Davis, Lee (2002). *Natural Disasters*. New York: Checkmark Books.
6. Maharashtra State Gazetteer (1989). *Kolhapur District*. Mumbai: Government of Maharashtra.
7. Singh, Savinder (2001). *Physical Geography. Jaipur: Rawat Publications.*
8. *The Times of India*. August. 26, 2006.

Rainfall Variability in Doon Valley:

A Statistical Analysis

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Rainfall variability of Doon Valley is the subject matter of the paper. The study is made by analyzing daily and monthly rainfall data for four meteorological stations of the Valley. In the last 30 years, annual rainfall got declined by about 10 per cent and it is interesting to note that decline is more for monsoon months. Monsoon months recorded high variability. Variability of rainfall seems to be increasing from plains towards hills.

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Rainfall is the basic parameter to the climate of a place, and variability in this parameter is of a great concern for human and economic activities. Monsoon is known for its variable nature and so Indian agriculture is a gamble of monsoon. Variability of rainfall, both spatial and temporal, seems to be more pronounced in hills which are endowed with varied relief features, slopes and aspects. The complex relief of the Himalayas brings out the importance of micro climates, and understanding these micro climates is needed for assessing agricultural and forest potentials of this region. A long term meteorological observation may be required for this understanding.

The variability of rainfall pattern occurring in India at both macro and micro level is a well researched topic. Over most part of India, rainfall is confined to a brief period, the south-west monsoon season (June – September). This period accounts for 90 per cent of the annual rainfall in the large tract of the country. Parthasarthy and Dhar (10) analysed the seasonal and annual precipitation of India from 1901 to 1960 and found a significant increase of 5 per cent for thirty years mean in the southwest monsoon and annual precipitation while the observed increase in the winter monsoon was not statistically significant. Rupa Kumar *et al.* (15) studied the trends in rainfall during 1871 to1984, in different parts of the Indian subcontinent, and noted an increasing trend in the precipitation all along the west coast and northwest India, and a decreasing trend in eastern Madhya Pradesh. Houghton *et al.* (5) also observed an increase in Indian precipitation, particularly in the western and north eastern areas of the country during 1900 to1999.

Kothyari and Singh (7) in their study of the long term trends over the Gangetic basin found that the decreasing trend started during 1960's, and the temperature had an increasing trend. Roy and Singh (14) examined the climate variability in Kullu district of Himachal Pradesh, and noted an overall decline in the

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rainfall over a span of 50 years (1945-95). Rawat and Rawat (11) studied micro level spatial variability in air temperature in Almora region. Roy and Balling (13) analysed the trend in the pattern of extreme precipitation events from 1910 to 2000, and observed an increasing trend over western India. Analysis of diurnal characteristics of climatic parameters is another area of interest among the researchers. Some of the recent studies of micro level climatic studies with daily or weekly measures include those by Ananthakrishnan and Soman (2), Swaminathan *et al.* (17), Kumar (9), Krishnan *et al.*(8), Agashe and Padgalwar (1), and Sahu and Nandankar (16).

The Study Area

This paper takes up the analysis of daily rainfall data of four meteorological stations in Doon valley, India. Spatial and temporal patterns of rainfall and the variability are described from the data for the period of 1950-2005. Doon valley is a distinct ecological biome in the district of Dehradun, located in the Himalayan foothills of Uttarakhand. It is bounded on the north-east by the Lesser Himalayan ranges and on the eastern half of its south-west by the Shiwalik ranges. The two most important rivers of north India, the Ganga and the Yamuna demarcate its south-eastern and north-western boundaries, respectively. The fragile Doon valley has a major boundary fault passing through the northern parts of the valley and is characterized by heavy rainfall of about 2100 mm per year. The average width of the valley is about 25 km and the length is nearly 72 km. It comprises two distinct sub-catchments, one formed by the drainage basin discharging into the Ganga a little south of Rishikesh, and the other by the drainage-basin discharging into the Yamuna near Rampur.

The Lesser Himalayan range, which forms the northern boundary of the Doon valley, is part of the Great Himalayan range. The Shiwalik ranges, which form the southern boundary of the valley, are alluvial formations that are younger than the Himalaya. The Shiwalik ranges present a stiff face to the plains, while a long and gentle slope meets the foot of the Himalaya to form shallow valley. These valleys or longitudinal depressions formed between the Shiwalik and the Himalaya are generally called "Duns". The variation in the relative relief from one end of the valley to the other adds complexities in the climatic conditions over space and time, realizing a mosaic of micro climates that get fitted to altitude, relief, alignment of ranges, and slopes and aspects. In the valley mid- November to February is the winter season, and the summer that follows continues to mid-June. Rainy season extends from mid-June to mid-September, followed by post-monsoon period till mid-December.

Data and Methods

Needed data were primarily obtained from the Indian Institute of Tropical Meteorology (IITM), Pune, and India Meteorological Department, Dehradun. Data for the stations, Dehradun and Mussoorie were gathered from Pune, and for other two stations, New Forest and Selakui, the data were obtained from the Forest Research Institute, Dehradun and Centre for Soil and Water Research and Training Institute, Dehradun, respectively. Daily rainfall data were available for Dehradun for the period of 1950-2005, for Mussoorie, of 1950-1998, for Selakui of 1961-2005 and for New Forest of 1950-2005.

Any day recording rainfall greater than 0.1 mm was considered for giving the daily rainfall amount. Annual rainfall was smoothed with five-year moving averages. Annual data were analyzed with linear trend analysis. Time series analysis was done with line graph. Dispersion of actual annual, monthly and seasonal rainfall of the valley has been ascertained from co-efficient of variations. Variability refers to the mean departure from the annual mean as a percentage of that mean.

Results and Discussion

Rainfall is found to be increasing with altitude; for instance, Mussoorie located at altitude of above 2266 m receives annual mean rainfall of 2129 mm, whereas Selakui at altitude of 649 m gets an annual mean of 2017 mm. Rainfall is relatively higher over the northwestern uplands, and most of the region of Doon valley comes under the range of 1600-2000 mm of annual rainfall.

Annual Rainfall

Doon Valley gets some rains all through the year, and rainfall is relatively less during October and November. The highest mean rainfall is recorded at Mussoorie followed by Dehradun. A little over one third of annual rainfall during December and March. Winter rainfall generally occurs in association with the passage of western disturbance and sometimes in the form of snowfall in the higher reaches of the valley.

The five year moving average of annual rainfall over the area (Fig.1) shows remarkable variations. The fluctuation in rainfall is pronounced in post-1963 for most of the stations. The smoothened data series indicated a decline in the late 1970's and early 1980's. All the stations recorded a very high rainfall in 1965, 1970 and 1992.

The annual rainfall is erratic since 1960's. The year 1966, 1970, 1971, 1986, 1998, 2002,

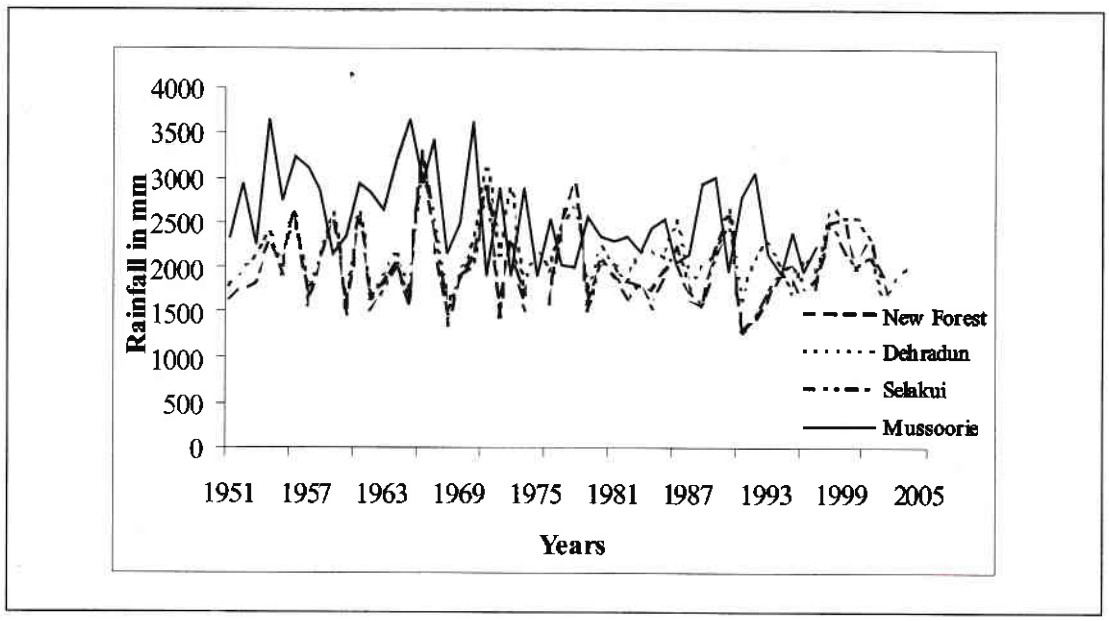


Fig. 1. Five Year Moving Average of Annual Rainfall in Doon Valley

and 2004 were heavy rainfall years interrupted by extremely low rainfall years of 1964, 1965, 1974, 1975, 1978, 1980, 1982, 1987, 1991 and 2000. The rainfall ranged between 1702 to 1900 mm in most of the consecutive dry years, whereas it ranged between 2101 to 2300 mm during high rainfall years. Few extremely high rainfall years were 1978, 1998, 2001, 2004, and 2005, with rainfall ranging between 2501 to 2900mm. 1971 recorded the highest ever rainfall of 3416.70 mm in last 50 years at Dehradun. Over the past 55 years from 1950-2005 Dehradun and New Forest showed a variability of 41.4 per cent and 42.6 per cent respectively. In the past 50 years, Mussorie had 32.7 per cent variability.

Rainfall Frequency

The amount of rain and its frequency are two important factors to which moisture availability is dependent. The most common parameter used is the number of rainy days per unit time period. In India, as per Indian Meteorological Department standard, it is defined as a rainy day of 24 hours if rainfall is 2.5 mm of rainfall or more (12). Most of the areas in Doon valley receive more than 75 rainy days. Mussoorie which receives annual rainfall above 220 cm, has 90 rainy days. South of the northern hills, the annual rainy days tend to decrease. The average annual rainy days in the valley over various time periods are shown in Table 1. Dehradun shows a swinging pattern in the average annual rainy days. The period from 1971-90 saw an increase of rainy days and in late 90's showed a marked decrease.

A similar pattern is noticed for the station New Forest and Selakui. Selakui observatory being in the valley region accounts for lesser rain when compared to other stations. New Forest station shows an increase for the later half of data set (1976-2000) to 81 days in comparison to the data set before 1976 (78 days).

Selakui station shows a gradual decrease. The altitudinal differences in the location of observatories may be the reason of differences in the number of rainy days. Mussoorie shows the highest number of average annual rainy days of 95.8, whereas Selakui records 76 days as annual average. Dehradun observatory accounts for 81.2 days and New Forest, for 79 days. The number of rainy days increased from 79.5 days during the period 1951-75 to 81.8 days during the period 1976-2005 for

Table 1
Average Number of Rainy Days

Years	Dehradun	Mussoorie	New Forest	Selakui
1951-60	79	98	77.5	75.0
1961-70	81	97	79.0	79.0
1971-80	84	96	79.0	76.0
1981-90	82	99	80.0	73.0
1991-2000	80	89	82.8	74.5

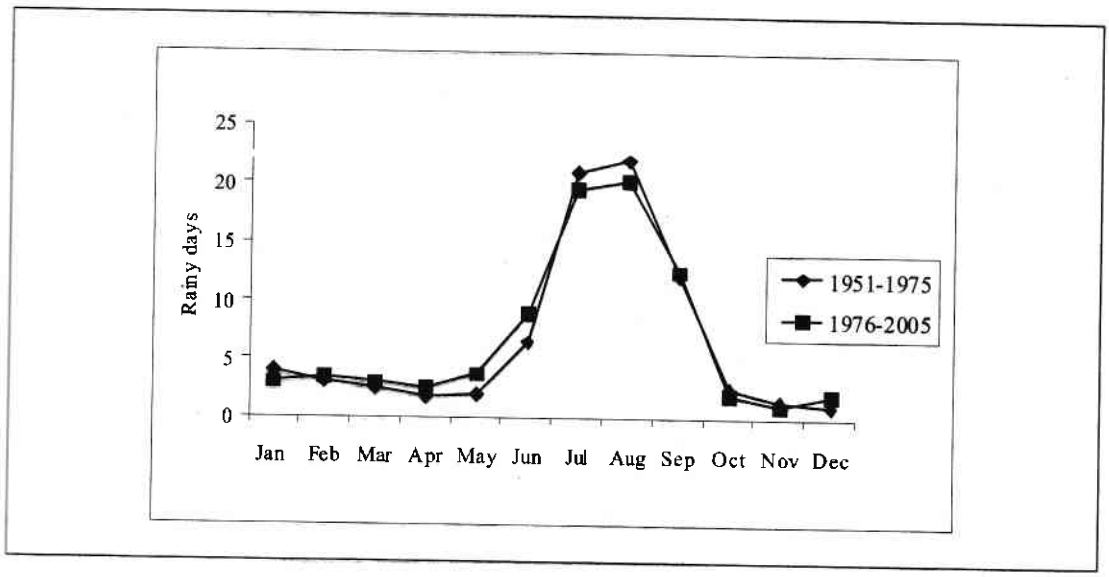


Fig. 2. Monthly Average Rainy Days, Dehradun

Dehradun station (Fig.2). A decline is noticed for Mussoorie from 95.7 days (1950-70) to 94 days (1971-97). The average monthly number of rainy days during active months of monsoon, i.e. July, August and September decreased in the latter half in New Forest station (Fig.3). Summer rainy days i.e. March, April, May and June have shown marked increase than earlier half at both the stations. Still, Mussoorie accounts for lesser number of rainy days in later half of the data set (Fig.4).

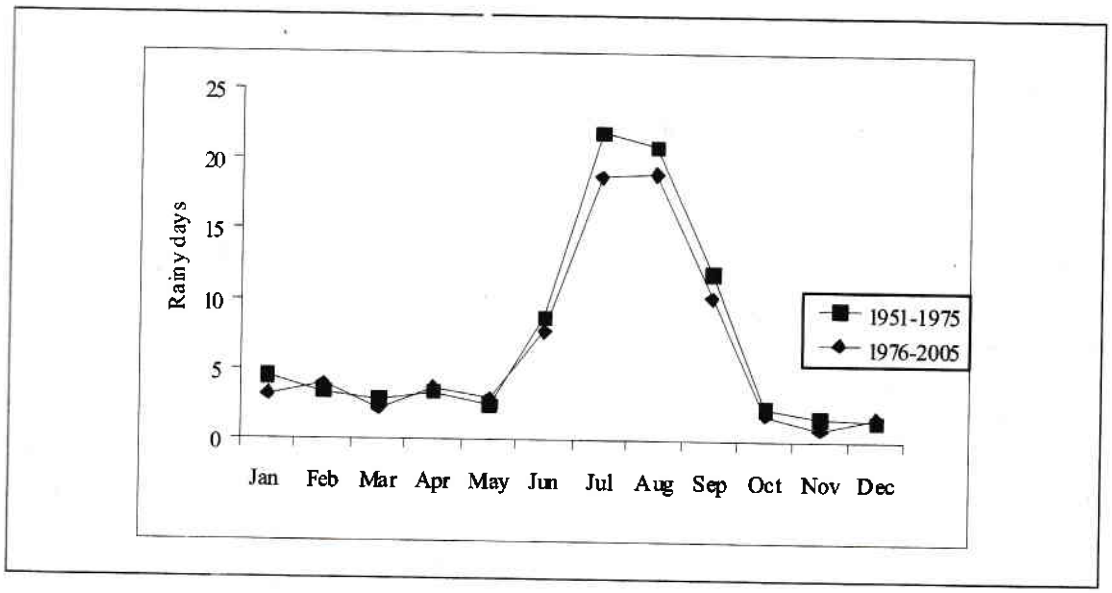


Fig. 3. Monthly Average Rainy Days, New Forest

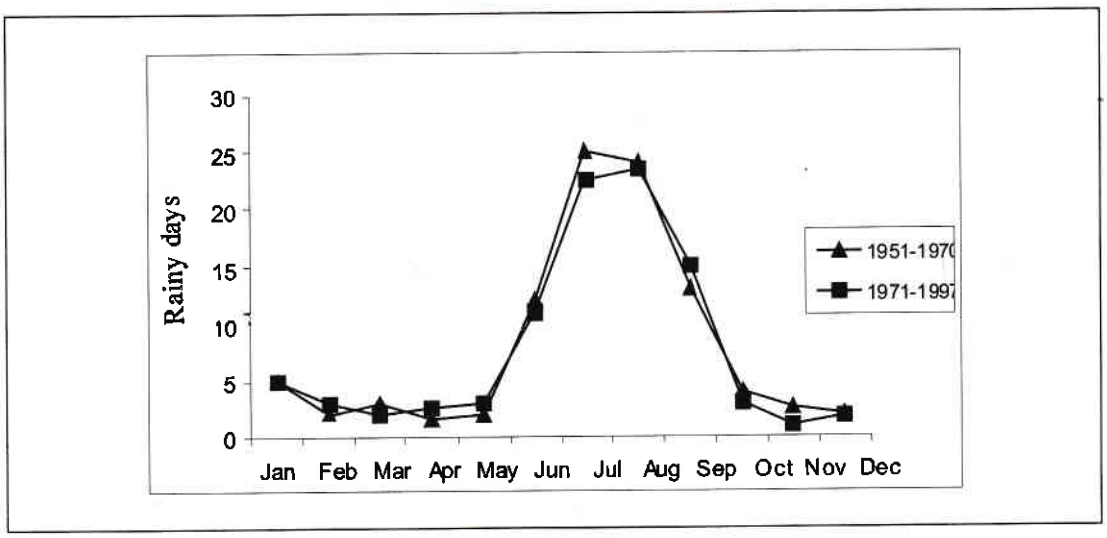


Fig. 4. Monthly Average Rainy Days, Mussoorie

Rainfall Variability

As noted earlier, rainfall in the Doon Valley recorded higher variability. The lowest rainfall was recorded in 1971-80 and 1991-2000 (Table 2). About 85 per cent of rainfall is received during the southwest monsoon season, and rest of it is of local origin. The rainiest months are July and August. On the other hand, April and November are the months of the lowest rainfall in Dehradun, whereas November and December are the lowest rainy months in Mussoorie.

The comparative assessment of monthly rainfall variability for the two periods, 1951 – 1975 and 1976 – 2005 reveals an increase in all the stations of Doon valley. In recent 30 years of observation, there is an increase in variability for the months of November, September, July, March and January as evident from Fig. 5 (a), (b), (c) and (d). Lesser amount of rainfall in the main monsoon months of July and August is of greater concern in the valley. Decline in average July rainfall is also observed (Table 3).

The annual means in the last 70 years ranged from 5426.9 mm in 1981-90 to 6981.3 mm in 1931- 40. The average for recent 5 years (2001-05) was 3495.6 mm but the percentage rainfall during July to total rainfall in the valley was 28.69 per cent due to two consecutive dry years of 2002 & 2003. The total annual rainfall was 1565.1 mm in 2002 and 1861.1 mm in 2003, the lowest in recent 35 years of observation at Dehradun observatory.

The highest variability occurs at the Mussoorie, above 48 per cent and lowest at New Forest, with 45.6 per cent. The post-monsoon season is marked by high variability in all stations. The variability at foothills accounts for 120 per cent on average and 110 per cent at Mussoorie. The summer season is with 70 per cent variability. The northern region of Doon valley shows lesser variability as seen in Mussoorie. New Forest station reported a higher post-monsoon variability of 147.9 per cent. Post-monsoon season shows highest co-efficient of variation followed by summer season. As evident from

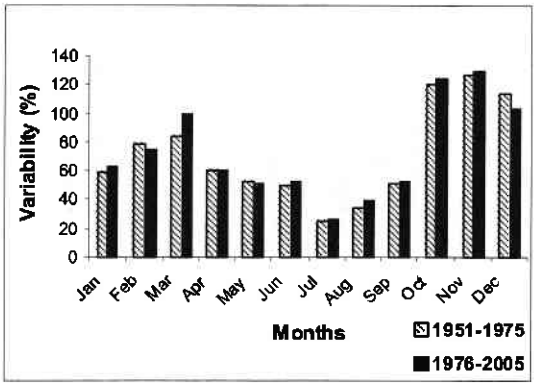


Fig. 5 (a) Dehradun

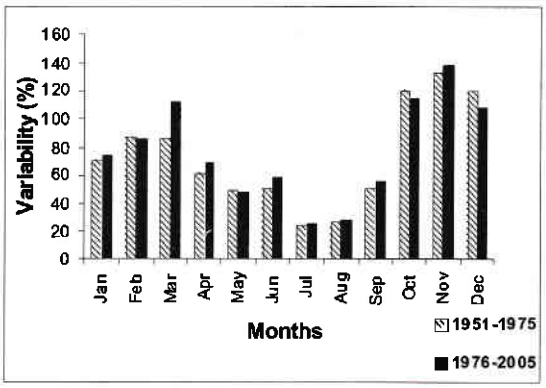


Fig. 5 (b) New Forest

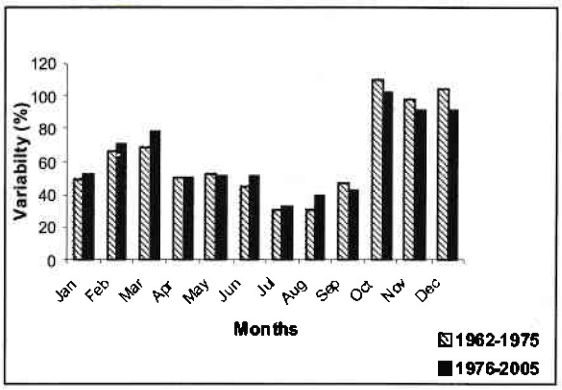


Fig. 5 (c) Selakui

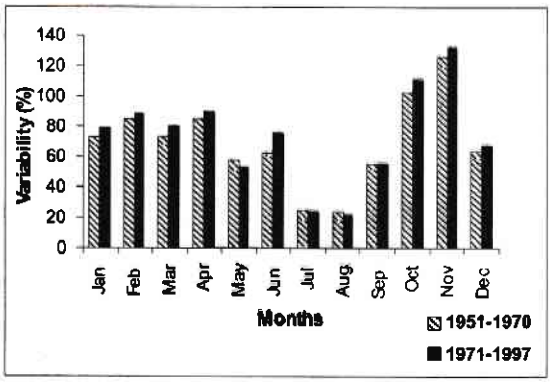


Fig. 5 (d) Mussoorie

Table 2
Inter-decadal Rainfall Variability

Years	New Forest	Dehradun	Selakui	Mussouorie
1951-60	38.93	39.25	--	29.00
1961-70	40.80	41.06	38.06	30.54
1971-80	42.12	42.87	41.48	30.62
1981-90	39.62	41.95	40.05	32.64

Table 3
Rainfall in July at Dehradun, 1931-2005

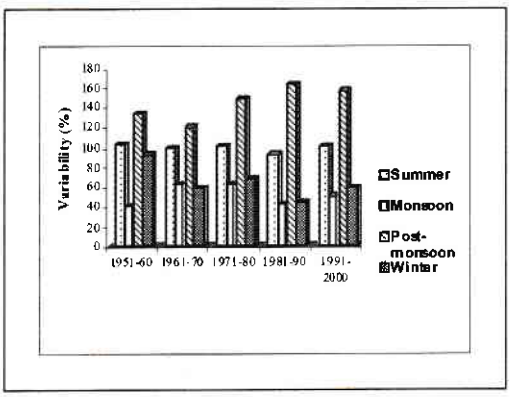
Decades	July (in mm)	July Rainfall to Total Rainfall (in per cent)
1931-40	6981.3	31.50
1941-50	6793.5	31.01
1951-60	5856.5	30.80
1961-70	6282.7	30.26
1971-80	6074.4	31.99
1981-90	5426.9	26.84
1991-2000	5539.8	28.87

Table 4, variability is seen increasing from north to south, varying from 62.8 per cent at Mussoorie to 69.2 per cent at Dehradun. The winter variability differs from 64 per cent at Mussoorie to 54.2 per cent at Dehradun.

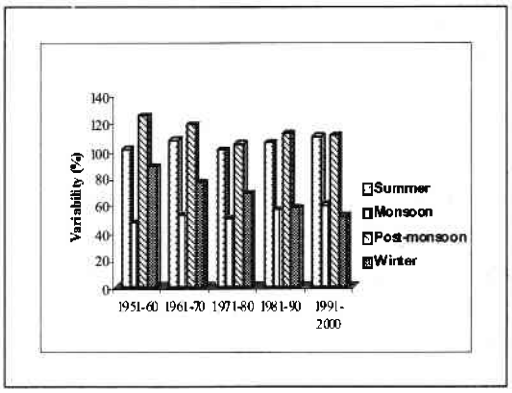
Further analysis of seasonal variation in rainfall and its variability over years is made by calculating decadal co-efficient of variability. The seasonal rainfall variability during five and half decades at Dehradun and five decades at Mussoorie are shown in Fig. 6(a) and (Fig.6 d) respectively.

Co-efficient of variation was lowest during southwest monsoon period (except during 1961-70). It varies from 39.4 per cent during 1981-90 to 62 per cent during 1961-70 at Dehradun. The variability during southwest monsoon over 50 year period from 1951-2001 was 46.5 per cent and the corresponding value for period 1961-70 was 47.5 per cent.

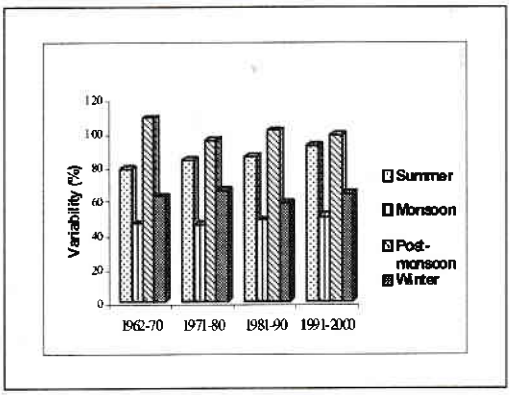
Over 50 years monsoon variability increased from 41.5 per cent during 1951-1975 to 46.8 per cent during 1976-2005 in the plain region. In Mussoorie, there was an increase of about 3.46 per cent (from 37.8 to 41.2). Post-monsoon season recorded highest coefficients of variation followed by summer



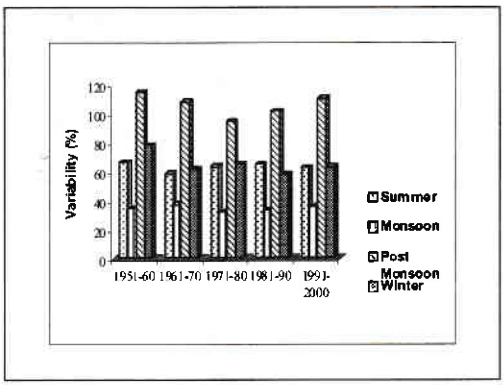
(a) Dehrahun



(b) New Forest



(c) Selakui



(d) Mussoorie

Fig. 6. Inter-decadal Seasonal Variability

Table 4
Inter-decadal Rainfall Variability

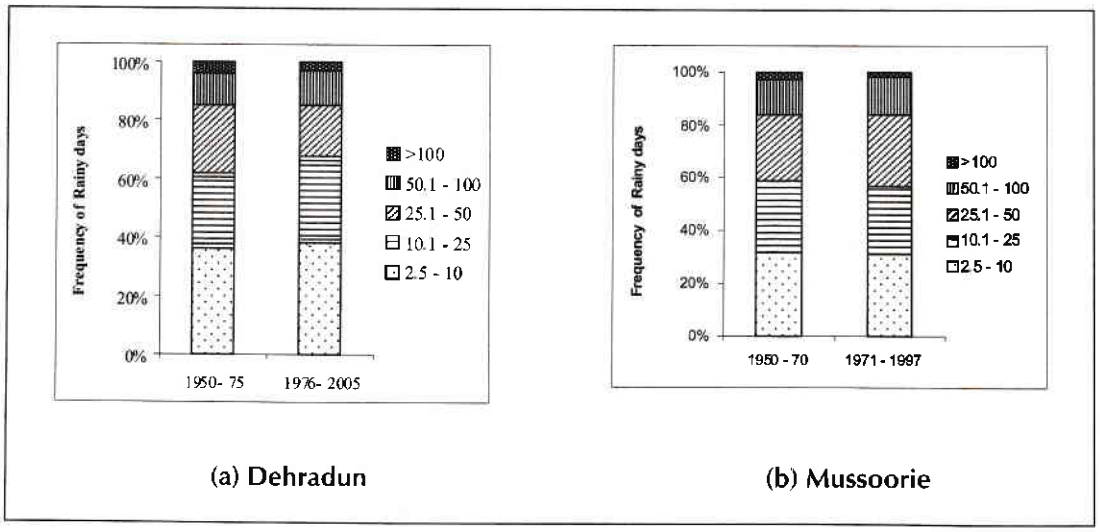
Station	SW Monsson	Post Monsoon	Summer	Winter
Dehradun (1951-05	46.8	122.4	69.2	54.2
New Forest (1951-05)	45,5	121.5	72.4	53.2
Selakui (1962 -05)	46.7	122.8	71.7	54.2
Mussoorie (1951-97)	48.4	110.8	62.8	64.0

season. On the whole, there is a declining trend in the monsoon rain since 1950 onward with an exception in 1966-70, 1978, 1990 and 1998. A substantial increase in local rainfall since 1980's is noticed in Doon Valley (12).

Rainfall Intensity

Rainfall intensity is defined as amount of rainfall per unit period of time. In the present study, unit time is taken asa rainy day. Annual and seasonal intensities have been calculated for the selected stations of the Doon Valley. Rainfall intensities are classified into five classes: 2.5 – 10.0 mm/day, 10.1 - 25 mm/day, 25.1 - 50 mm/day, 51.0 – 100 mm/day, and > 100 mm/day. The highest per cent of rainy days occurs in the class of lowest rainfall. The per cent number of rainy days decrease with the increasing rainfall intensity.

There is 13 per cent increase over the number of rainy days in rainfall class I from the annual average of 1950-1975 to that of 1976-2005 at Dehradun (Fig.7a). This increase was 12.53 per cent for 1971-1997 at Mussoorie station (Fig.7b). The per cent number of rainy days



(a) Dehradun (b) Mussoorie

Fig. 7. Frequency of Rainy Days with Rainfall Intensity Classes

with rainfall frequency in class V decreased to 5 per cent from the average of 1951-75 to 1976-2005. This change was 15.24 and 18.89 per cent respectfully for the period of 1951-75 and 1976-2005. On the decadal scale it was seen that class II, i.e. 10.1-25 m rainfall showed an increasing trend. The highest was observed during 1971-80 at 30 per cent in comparison to 25 per cent in 1950-1960. An overall increase of 3 per cent in class is attributed to the annual average in respect to 1951-1970 and 1970-1997 period.The subsequent analysis at the decadal level shows moderate increase in class III (25.1-50 mm) between 1971-80 and 1981-90, but an overall decreasing trend is observed when compared with annual average for the period 1950-1970 and 1970-1997 at Dehradun station (Fig. 8 a). This change was from 21.08 per cent to 19.5 per cent.

The lowest rainfall recorded was in 1971-80 at 18.53 per cent. Class V shows a fluctuating trend in Mussoorie (Fig 8 b). Here rainfall intensity reaches as high as 43.1 mm/day at Mussoorie.

The picture would be much clear when the monthly percentage frequency of rainy days with specified amount of rainfall is depicted. An analysis could be easily made comparing the monthly analysis for the period 1951-75 and 1976-2005. The rainfall class would be the same as taken for rainfall intensity classification. Increase in less intensity rainy days for month of March, April and May is evident. A decrease in the month of June in moderate intensity class (25.1-50mm) from 1951-1975 to 1976-2005 is seen. The monsoon months of June, July, August and September account for higher number of rainy days along with greater rainfall intensity.

The per cent frequency of days with low rainfall amount is increasing with time and reverse is true for days with high rainfall intensity. Thus during monsoon months as well the average number of rainy days with higher amount of rainfall (class IV and V) was greater in the decade 1951-60 and decreased during 1971-80 and 1990-2001 for Dehradun (Fig.9a and 9b). In Mussoorie both monsoon and post-monsoon seasons show a declining

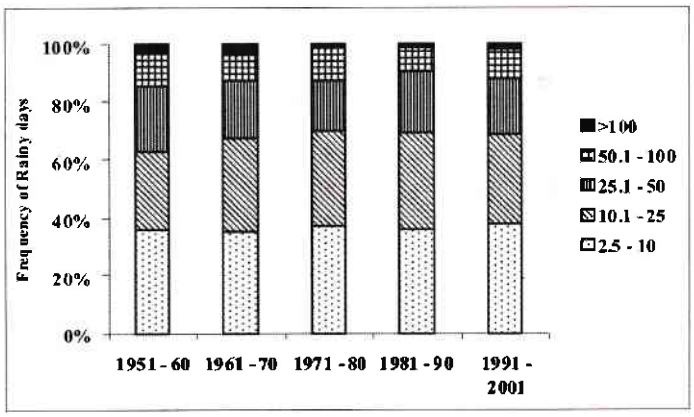


Fig. 8 (a) Dehradun

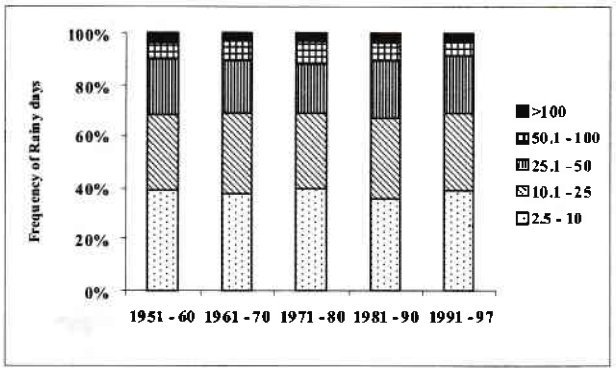


Fig. 8 (b) Mussoorie

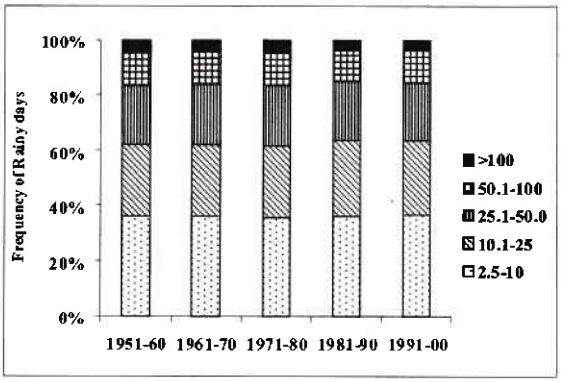


Fig. 8 (c) New Forest

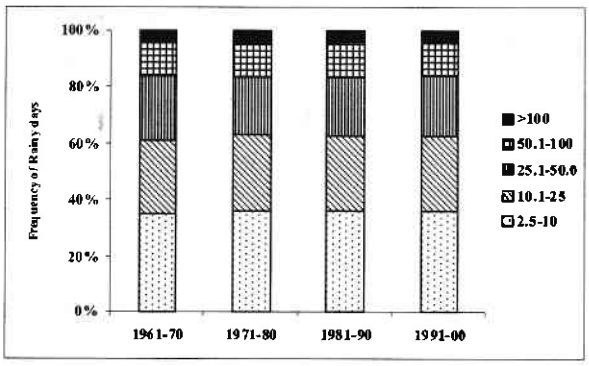


Fig. 8 (d) Selakui

Fig. 8. Decadal Frequency of Rainy Days with Rainfall Intensity Classes

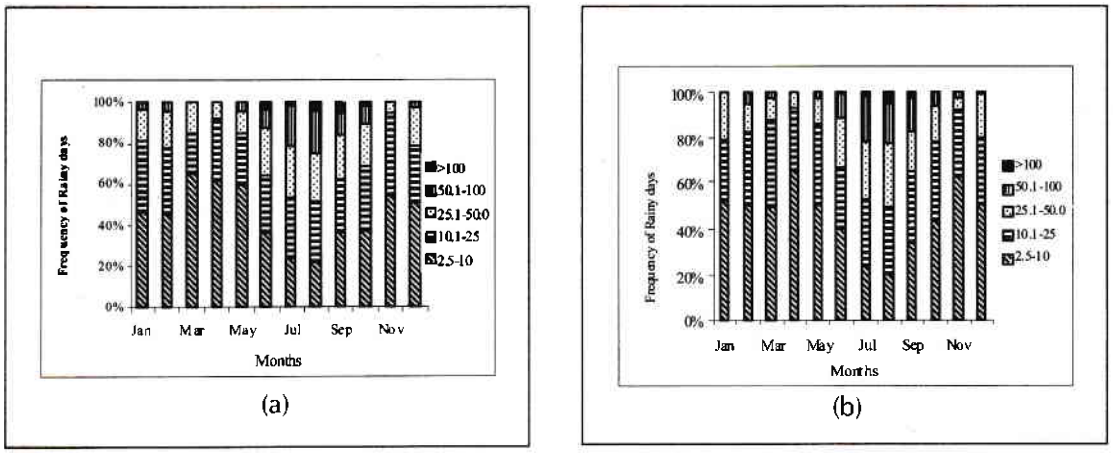


Fig. 9. Monthly Average Frequency of Rainy Days with Rainfall Intensity Classes (mm) at Dehradun (a) 1950-1975 (b) 1976-2005.

trend (Fig.10a and 10b), and decline is more evident in classes of III and IV of intensity.

Percentage Departure from Mean

The time series analysis of the observed data for the two stations Dehradun and Mussoorie reveals the sign of significant change in mean annual rainfall. The percentage departure from normal annual rainfall over Doon valley may be seen in Figs. 11a and 11b respectively. The anomalies are much of negative with longer number of peaks below normal. Till 1970 there are lesser pillars below normal for both the stations. Mussoorie station showed more below normal period during 1978-1989. The closer bars indicate maximum concentration of below normal years. The deviation ranged from 1.93 to 22.5 per cent. The recent years showed more fluctuations in both high and lows from normal. Year 1993-1994 remained

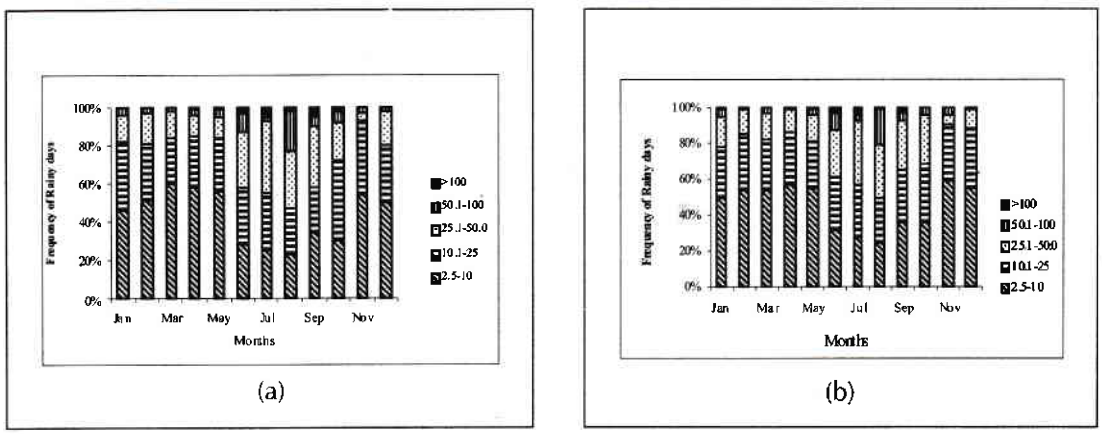
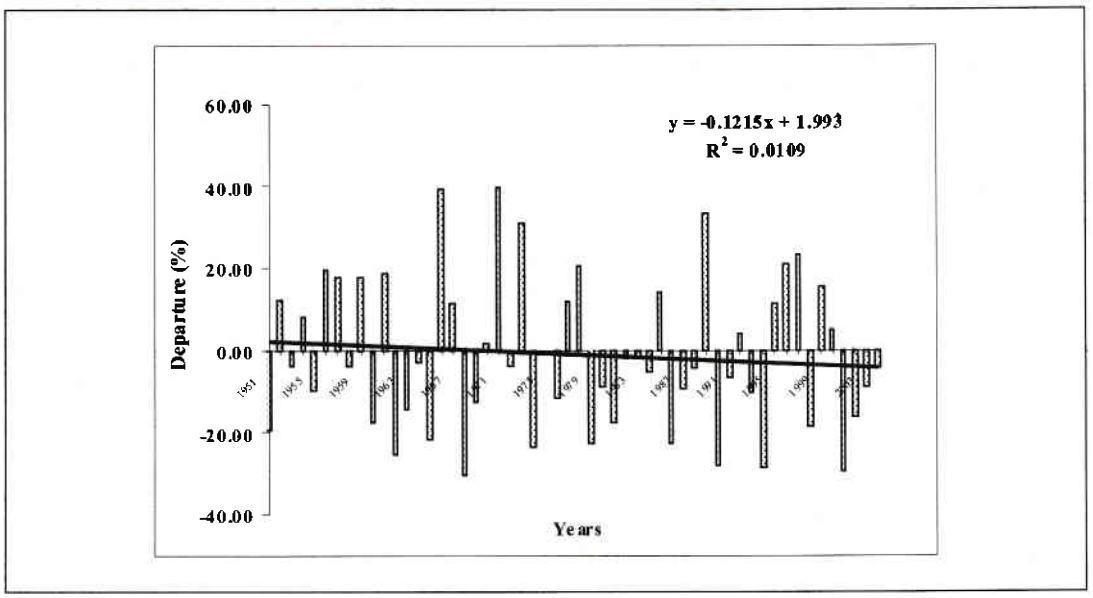


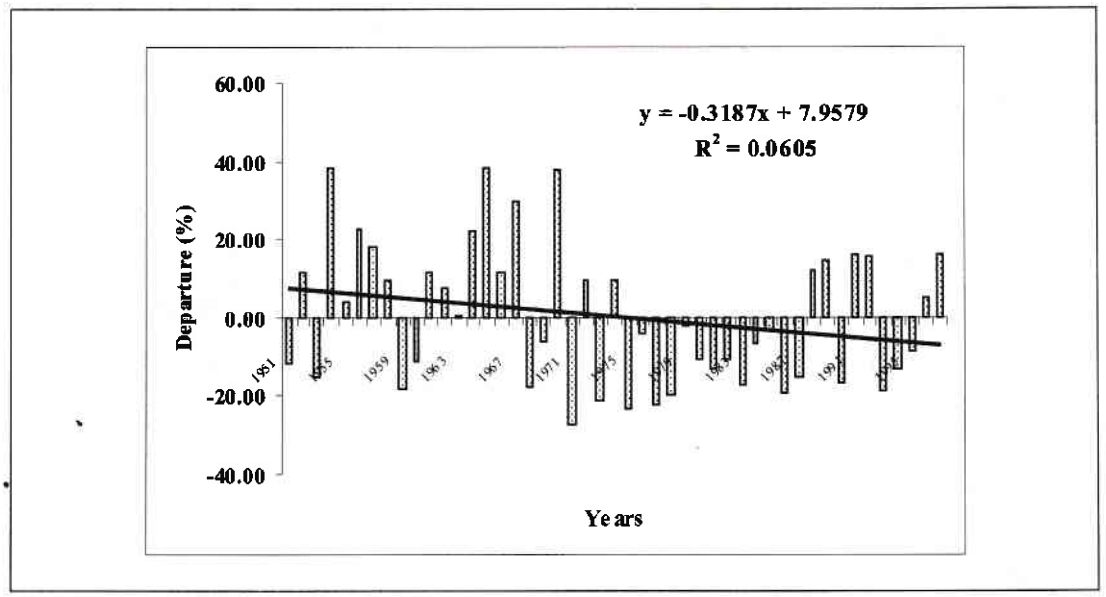
Fig.10 Monthly Average Frequency of Rainy Days with Rainfall Intensity Classes (mm) at Mussoorie (a) 1950-1970 (b) 1971-1997.

with bars below normal where as 1996-1997 had positive high deviation rainfall ranging from 47-50 per cent of normal.

It is thus seen that both the stations had larger fluctuations. The period till 1970 saw less deviation from means, and from 1971



(a) Dehradun (1950-2005)



(b) Mussoorie (1950-1997)

Fig. 11. Percentage Departure from Mean Annual Rainfall

onwards, deviations got increased. The period 1980-1990 saw maximum deviation below normal. Deviations seem to be more marked in summer.

Conclusions

Meteorological data analysed in this study show large inter-annual variability in rainfall in the micro region of Doon Valley. During the last 30 years (1975-2005), annual rainfall decreased by 10 per cent on an average; and this decline was 12 per cent during monsoon months and 9.8 per cent in winter months. The annual variability is well-marked during the study period of 1950-2005. When considering the seasonal variability, monsoon rainfall is highly variable in all the stations with 46.8 per cent in Dehradun, 45.5 per cent in New Forest, 46.7 per cent in Selakui and 48.4 per cent in Mussoorie. During post-monsoon months, variability in Mussoorie is 111 per cent and 122 per cent at Dehradun. It appears that variability is increasing from the plains to the hills. In July, the core month of the monsoon for the study area, rainfall seems to be declining. Also number of rainy days during monsoon months seem to be decreasing.

Acknowledgements

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References

1. Agashe P.S and K.V.Padgalwar (2005). "On Some Characteristic Features of Daily Rainfall over Madhya Maharashtra", *Climate Change*, 56(3), pp.571-580.
2. Anantha Krishnan A and M.K.Soman (1989). "Statistical Distribution of Daily Rainfall and its Association with Coefficient of Variation of Rainfall Series", *International Journal of Climate*, 9, pp.485-500.
3. Dhruva V.V and G.Shastry (1983). "Runoff Characteristics of Small Watersheds in the Outer Himalayas of Doon Valley". Dehra Dun:CSWERTI (Annual Report).
4. Domroes M (1987). "Temporal and Spatial Variations of Rainfall in the Himalayan with Particular Reference to Mountain Ecosystem", Journal of Nepal Research Centre, 2(3), pp.41-48.
5. Houghton J.T, Y.Ding, D.J.Griggs, M.Noguer, P.J.Vander Linden, X.Dai, K.Maskell and C.A.Johnson (ed.)(2001). *Climate Change: The Scientific Basis*. London: Cambridge University Press, Cambridge.
6. Jackson I. J (1986). "Relationship between Rainy Days, Mean Daily Intensity and Monthly Rainfall in the Tropics", *International Journal of climate*, 6, pp.117-134.
7. Kothyari U.C and V.P.Singh (1996). "Rainfall and Temperature Trends in India", *Hydrological Processes*, 10, pp.357-372.
8. Krishnan R, N.Gopalaswamy, S.Natrajan and T.N.Balasubramaniam (1995). "Analysis of Daily Rainfall of Coimbatore", *Mausam*, 46 (1), pp. 89-92.
9. Kumar A (1993). "Rainfall Characteristics over Gorakhpur", *Mausam*, 44 (2), pp.209-210.
10. Parthasarathy B and O.N.Dhar(1976). "A Study of Trends and Periodicities in the Seasonal and Annual Rainfall of India", *Indian Journal Metrological Hydrology and Geophysics*, 27, pp.23-28.

11. Rawat J.S and G.Rawat(2003). "Micro-Level Spatial Variability and Human Impact in Air Temperature : A Study from the Almora Region, Uttaranchal Lesser Himalaya, India," in C.M. Agrawal (eds.). *Dimension of Uttarancha*. Delhi: India Publishers Distributors, pp. 393-416.

12. Rawat (2006). "Changing Trends of Climate of Doon Valley", *Indian Forester*, 132 (5), pp.615-622.

13. Roy S and R.C.Balling Jr. (2004). "Trends in Extreme Daily Precipitation Indices in India", *International Journal of Climatology*, 24, pp.457- 466.

14. Roy S.S and R.B.Singh (2002). *Climate Variability, Extreme Events and Agricultural Productivity in Mountain Region*. New Delhi: Oxford and IBH Publishing Co. Ltd.

15. Rupa Kumar K, C.B.Pant, B. Parthasarathy and N.Sontakke (1992). "Spatial and Sub-seasonal Pattern of the Long-term Trends of Indian Summer Monsoon Rainfall", *International Journal of Climatology*, 12, pp.257-268.

16. Sahu M and P.K.Nandankar (2006). " Spatial and Temporal Variation of Summer Monsoon Rainfall over Chhattisgarh during the Period, 1901-2000", *Mausam* , 57 (4), pp.679-683.

17. Swaminathan C, K.K.Suresh and C.Surendran (1991). "Rainfall Pattern at Forest Research Station, Mettupalayam", *Madras Agriculture Journal*, 78, pp.506-510.

Irrigation Suitability of Water in Cuddalore Area, Tamil Nadu

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Hydrochemistry of surface water (pH, EC, TDS, Salinity, Cl, TH, Ca, Mg, Na, K and PO4) in the Uppanar river, and Gadilam and Ponnayar estuarines of Cuddalore district is assessed for irrigation suitability. Water samples were collected from 27 locations during the pre-monsoon season (July) of 2008. SAR and Na were also calculated for a better understanding of the river water quality for agricultural purposes. Analysis of river water samples indicates deterioration of water quality, and of estuarine samples, a larger degradation. Urbanization and industrial development appear to have adversely affected the waters of the Uppanar River, Gadilam and Ponnayar estuarines.

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Indian farming is largely dependent on irrigation, and water quality matters much for achieving the required crop yield. In irrigated agriculture, the hazard of salt water intrusion in the soil is a constant threat, and it is more so in arid climatic conditions and areas under constant irrigation (2). The surface water quality gets changed both by natural processes and anthropogenic ones. Weathering, erosion, rains and sediment transportation affect the quality of surface water. Water quality gets degraded with the abuse of water resources by growing human population (5, 12, 13, 18). Ansari *et al.* (1) studied the impact of the industrial effluents, runoff from farms and domestic sewage on water quality in the river Ganga. Seasonal variations in precipitation, surface runoff, interflow and groundwater flow have a strong effect on river/stream discharge and subsequently on the concentration of pollutants in surface water (18). Singh *et al.* (18) reported the spatial and temporal variations and sources of contaminants in Gomuti river, a tributary of the Ganges. M.P.Jonathan *et al.* (9) reported the contamination of Uppanar river and coastal waters of Cuddalore in Tamil Nadu, India.

Cities, growth of industries and increasing population add a greater contamination to surface and ground water resources, and streams flowing through urban centres get alarmingly polluted (10, 16). Ayyamperumal *et al.* (3) studied the aquatic regions of industrial zones of Tamil Nadu, indicating an enrichment of trace metals in sediments all along the Uppanar River. Effluents and sewage systems discharge directly into the Uppanar river, and they in turn enter the coastal water in Cuddalore area. The northeast monsoon season brings heavy rains in this region, leading to a heavy inflow into the coastal zone during the rainy season. During the summer season the flow is very low. About 90 to 95% of all domestic sewage and 75% of all industrial effluent usually from urban areas are

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discharged into surface waters without any treatment (7, 15). Improper landuse practices, urban runoff with all kinds of waste materials, and industrial and construction activities thus potentially contribute to pollutants flowing into aquatic ecosystem. Thus surface water quality management efforts should be mainly focused on controlling sources of pollution.

The present study focuses on the physico-chemical condition of the river in Cuddalore area of Tamil Nadu coast. The hydro-chemical characteristics of water determine its usefulness for agricultural, municipal, industrial and domestic uses. The suitability of river water for agricultural purposes may be determined by evaluating the physico-chemical parameters along with hydro-geochemical parameters and graphical representation. In the study area, municipal sewages and untreated effluents from industries have been directly discharged into the river before the confluence point in the coast of Cuddalore. It is reported that SIPCOT industries drain out about 17.7 million litres of effluents per day. A Common Effluent Treatment Plant (CETP) proposed, when runs for 24 hours a day, has a capacity of treating 12 million litres only. Tamil Nadu Pollution Control Board estimates that there is a release of 9.6 million litres of effluents per day in this area.

Study Area

Cuddalore is in the heartland of Tamil Nadu, located 200 km south of Chennai. The district of Cuddalore spreads over an area of 27 sq.km and is divided into six taluks and 136 *panchayat* villages. It has a good wealth of surface and ground water. It is drained by

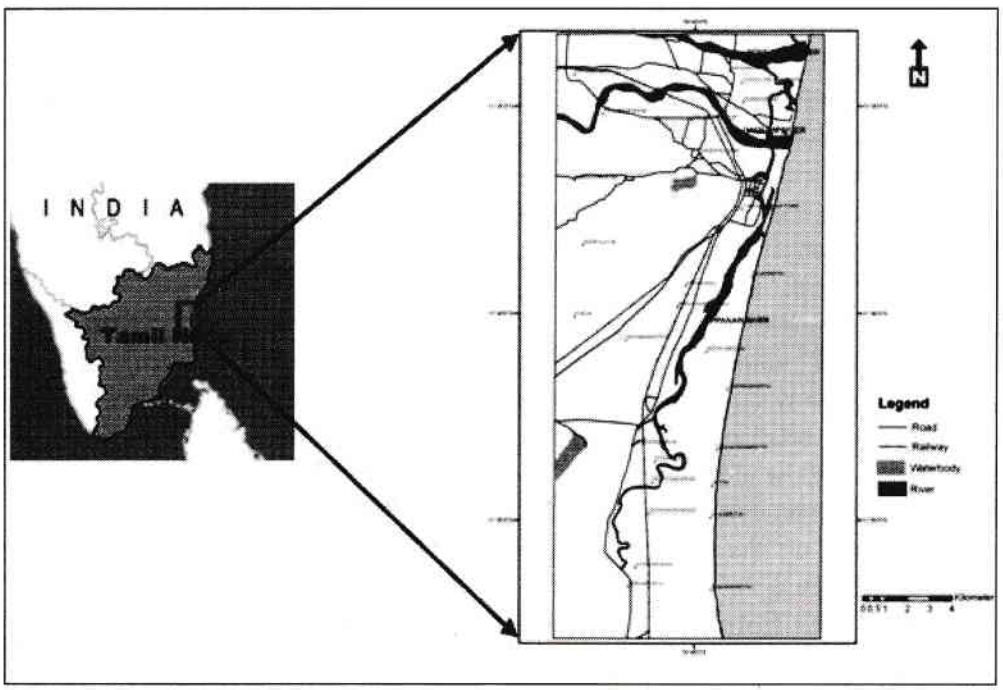

Fig. 1 Study Area Location

Uppanar in the south and Gadilam and Ponnayar in the north, and they enter into Bay of Bengal in the vicinity of Cuddalore town (Fig 1). Agriculture is the mainstay of the district and is dependent on irrigation; and water quality is an important parameter for the success of farming.

The primary crops are paddy, sugarcane, groundnut, gingelly, coconut and millets, pulses like red and black grams, bananas, cashew, mango and jackfruits. Being a coastal district, fishing activities are also important here. Marine fishing is well developed in the Uppanar mouth area, and State Industries Promotion Corporation of Tamil Nadu (SIPCOT) put up an industrial estate on the bank of Uppanar. Cuddalore harbour is located in the estuarine region of Uppanar river. A number of irrigation tanks along with their *ayacuts* are seen around the town of Cuddalore. The Uppanar river runs parallel to the coast, south of Cuddalore town and a number of small streams carrys domestic and industrial waste water and effluents to this river that takes them to the sea, affecting the fisheries. The major industries along the western bank of Uppanar river include chemicals, tanneries, paper, beverage, oil, paint and metal processing.

Till date, no site has been developed for secured storage of hazardous wastes being released by the industries. In the absence of such facilities, factories have dumped these wastes on neighboring lands and in open pits within their factory site. These poisons leach into the groundwater and contaminated the water resources of communities living around the factory. Foul smelling sludge from chemical and pharmaceutical units is dumped in a pit lined with HDPE plastic on the bank of Uppanar. Ash water discharged from the thermal power plant nearby also pollutes the river in the southern region through Perumal Eri and small streams.

Material and Methods

Remote sensing technology is an effective tool to study water quality. Land use studies are pre-requisite for locating the factors that determine water quality, and remote sensing and GIS are widely used nowadays for describing land uses (4). Coastal landuse/wetland mapping using IRS-LISS and SPOT data helps in extracting detailed information of coastal zone (14). Survey of India toposheets (1:50000) of 58 M 9, 14 and 15 were consulted to prepare the base map. Geometrically-corrected satellite imagery data of IRS P6 LISS III (at the scale of 1:10000) were used to make land use/land cover maps for the year 2007. Visual interpretation was adopted to get the data from imageries, and ArcMap 9.1 was used to draw maps and carry out spatial analysis

Water samples were collected from 27 locations along coastal zone of Cuddalore during the pre-monsoon season (July) in 2008 (Fig 2). Samples of one litre of water were collected in pre-cleaned bottles following standard methods and preserved till all analyses were completed. Fourteen samples from the Uppanar River (river water, RW) were collected in the river upto Gadilam and Ponnayar estuarine. Seven samples from coastal surface water (CSW) were taken from the coastal region. Six samples from land surface water (LSW) were collected from the coastal zone of Cuddalore. pH, Conductivity (EC), Total Dissolved Solids (TDS) and Salinity

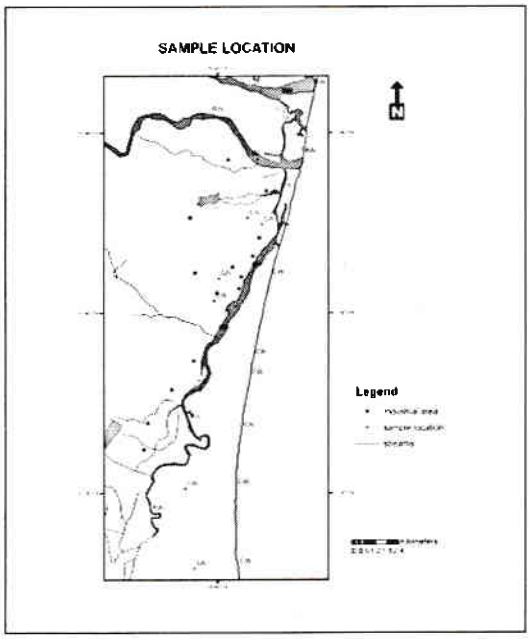

Fig. 2 Sample Location

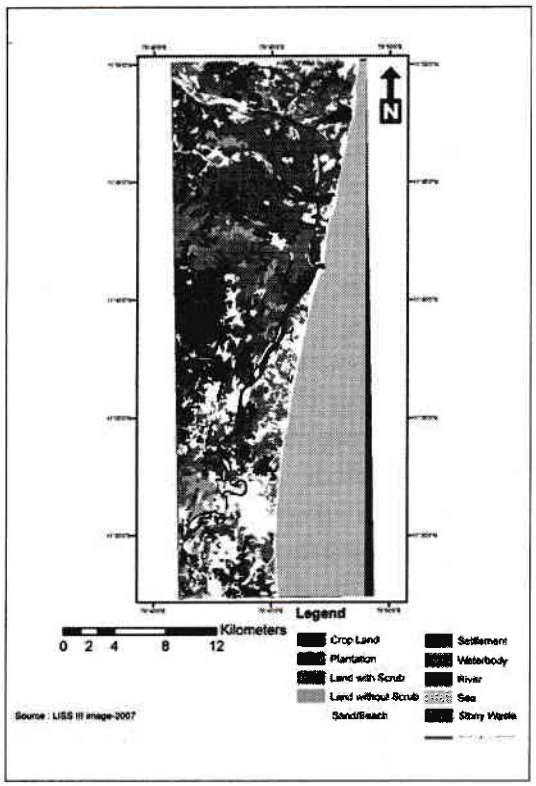

Fig. 3 Coastal Landuse

were measured using digital water analyzer (Deep Vision –model 191) soon after the collection of samples. Hardness was determined by EDTA titrimetric method (APHA, 1992). Concentration of chloride was determined by titration with 0.02N $AgNO_3$ using potassium chromate as indicator. Calcium was determined by titration method. Total Phosphate was determined by Spectophotometric method. Concentrations of sodium and potassium were determined by flame photometer.

Result and Discussion

Landuse /Land Cover

Landuse / land cover describes the earth surface for its pattern of use by nature and human beings. Landuse / land cover mapping of the study area was done with satellite data IRS-LISS III for the year of 2007 (Fig 3). About one fourth of the geographical area is under crops (Fig 4). Plantation crops include cashew, coconut and casuarinas and they occur on both upland and coastal areas. They appear in red to dark red tone and have smooth texture in the satellite imagery. They occupy an area of about 13% of the study area. The settlement covers of about 21%. Uncultivated land is found more significantly in upland area,

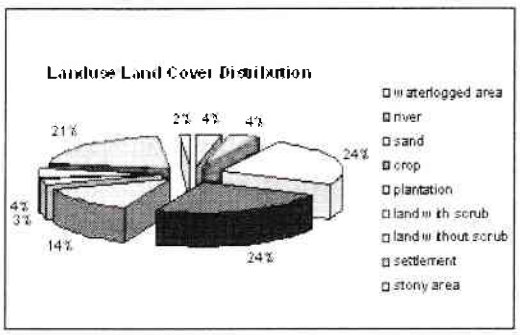

Fig. 4 Landuse / Land Cover Distribution

and appears in greenish blue and brown tone in the imagery. Coastal area such as beach, sand bars & river sand occupy about 24 per cent.

Water Quality for Irrigation

The suitability of river water for irrigation is dependent on the minerals present in the water. The major physio-chemical parameters, which decide the suitability of river water for irrigation are pH, EC, TDS, Total Hardness, chloride, calcium, magnesium, sodium and potassium. The physio-chemical parameters of the Uppanar, Gadilam and Ponnayar river estuarine system with minimum, maximum, mean and standard deviation value in 20 different locations during pre-monsoon season of 2008 are given in Table 1.

pH

pH values for all samples lie within the permissible range of 6.5 to 9.2 (WHO, 1997). The water samples were found to be alkaline in nature with pH ranging from 7.46 to 8.3 in river water (RW), and it may be because of draining of industrial effluents to the streams. In the coastal sample location (CSW) of 9, 14, 16,20,21,24, and 26, pH values vary from 7.1 to 7.6. pH values of land surface water (LSW) ranges between 7.38 and 8.75.

EC and TDS

Electrical conductivity is the most important parameters in determining the suitability of water for irrigation use. Salt concentration in the soils is harmful to crop growth. Salinity of river water that is used for irrigation is determined by EC, which is used as a surrogate measure of TDS concentration in water. The EC for water is expressed as mille Siemens per centimeter (ms/cm) and salt concentration is reported as TDS in ppt. In the river water zone the EC range was 1.45 to 16.38 ms/cm, whereas in estuarine region water it ranged from 16.23 to 17.22 ms/cm. EC values were observed from 16.97 to 17.36 ms/cm in CSW and 0.36 to 9.94 ms/cm in LSW during the pre-monsoon season of 2008. In river water zones TDS concentration ranged from 15.8 to 15.55 ppt, and estuarine region, from 0.95 to 15.82 ppt during the study period. In CSW, it ranged from 15.9 to 15.55 ppt, and in LSW, it ranged from 0.22 to 6.48 ppt. Based on the EC and TDS values, RW and LSW appear to be good for crop growth.

Chloride

The most common toxicity is from chloride in the irrigation water. Chloride is not adsorbed or held back by soil, therefore it moves readily with the soil water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tips and progresses from the tip back along the edges as severity increases. Excessive necrosis is often accompanied by early leaf drop or defoliation (2).

The concentration of chloride of the Uppanar, Gadilam and Ponnayar rivers ranged from 283.6 to 8578.9 mg/l in case of river water samples and from 9004.3 to 12478.4 mg/l in case of estuarine water samples. The concentration of chloride of coastal surface water ranged from 11202.2 to 15598 mg/l, and from 212.7 to 2765.1 mg/l in case of land surface water during pre-monsoon season (July) of 2008. The chloride content in the

Table 1
Average Values of Water Quality Parameters of Cuddalore during Pre-Monsoon Season

	River Water				Land Surface water				Coastal Surface Water			
Parameters	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.	Mean	Std. Dev.
pH	7.35	8.3	7.9	0.24	7.38	8.75	8.1	0.5	7.1	7.6	7.5	0.17
EC	1.45	17.24	6.71	5.42	0.36	9.94	2.74	3.6	16.97	17.36	17.3	0.14
TDS	0.95	15.8	5.9	5.33	0.22	6.48	1.74	2.4	15.55	15.9	15.83	0.13
Salinity	1	29.7	10.6	10.22	0.2	6.8	1.81	2.5	27.8	31.9	31.04	1.45
Na^+	160	850	390	250.4	160	530	225	149.6	320	900	530	181.2
K^+	0.5	14	5	5.34	0.5	7	1.7	2.6	2	7	5.07	1.6
Cl	283.6	12478.4	4372.2	4977.7	212.7	2765.1	1122.6	1248.7	11202.2	15598	13592.5	1367.9
Hardness	500	5700	2233.3	1945.8	400	1400	850	423.1	5200	7000	6228.6	675.1
Po_4^{2-}	0.025	4.5	1.7	1.74	0.25	5.25	2.1	2.02	0.25	3.5	2.25	1.5
Ca^{2+}	2.1	10.6	5.03	2.53	0.4	2.2	1.45	0.68	8.1	10	9.5	0.6
Mg^{3+}	9.2	112.6	43.7	38.6	7.96	27.8	16.7	8.4	101.7	138.3	122.8	13.9
SAR	5.8	180.8	95.7	44.2	--	--	--	--	--	--	--	--
Na%	7.4	857.5	122.4	213.6	--	--	--	--	--	--	--	--

** Significant at 0.01 level

* Significant at 0.05 level

southern part of Uppanar is within the tolerance limit for irrigation. In the estuarine water and coastal water zones the concentration of chloride is directly proportional to salinity, and hence these zones get ranked as 'severe' for irrigation purpose.

Hardness

Hardness is due to the presence of divalent metallic cations like Ca^{2+}, Mg^{2+}, strontium and manganese ions. It is the property of water which prevents the lather formation with soap and increases the boiling point of water. Hardness in water is also derived from the solution of CO_2 released from the bacterial action in soil in percolating water (17).

The hardness is commonly classified in terms of degree of hardness as soft (0 to 60 mg/l), moderately hard(60 to 120 mg/l), hard(120 to 180 mg/l) and very hard(>180 mg/l) (6). The Uppanar, Gadilam and Ponnayar river water, estuarine region, coastal surface water and land surface water samples contain very high value of hardness (400 to 6800 mg/l) during the study period.

Phosphate (Po_4^{3-})

Phosphate is present in natural waters as soluble phosphate and organic phosphate. It is derived from decomposing organic matter and additionally from human, animal, industrial wastes, and human disturbance of the land and vegetation. Analysis showed higher value of Po_4^{3-} in the Uppanar river (4.5 mg/l) near the industrial area. The Po_4^{3-} concentration of the rivers Gadilam and Ponnaiyar near the urban area ranged from 1.75 to 3.5 mg/l, obviously due to contamination by the large number of sewage discharge, particularly from the domestic sector. Another increase was observed at southern part of Uppanar (site 22), indicating the impact of a runoff from farms and industrial discharge. Increasing phosphate nutrient may encourage the growth of nuisance aquatic plants and may cause eutrophication.

Sodium

Sodium toxicity symptoms are leaf burn and many of the crops are sensitive to this (2). The sodium hazard of irrigation water (RW) is usually specified as Sodium Adsorption Ratio (SAR) and Sodium percentage (Na %). The sodium in the case of irrigation water is determined by the absolute and relative concentration of cations, and is expressed in

Table 2
Water Quality of Uppanar Area

Parameters	Rate of Hazard	Water Class	River Water
SAR	<10 10 - 18 18 - 26 >26	Excellent Good Fair Poor	All Samples
Na%	<20 20 - 40 40 - 60 60 - 80 >80	Excellent Good Permissible Doubtful Unsuitable / Poor	 10,15 1,2,3,4,5,6,7,8,17,19,22,23

terms of Sodium Adsorption Ratio (SAR). High sodium hazard in water changes soil properties and reduce soil permeability (11). The SAR value in the Uppanar, Gadilam and Ponnayar river estuarine systems ranges from 28.4 to 88.3. According to Richard's classification all the samples in the Uppanar river and surrounding estuarine system of Cuddalore coastal zone have been classified as poor for irrigation purposes with respect to SAR values (Table 2). The percentage of sodium values of the Uppanar river and its surrounding estuarine systems varied from 77.9 to 93.3 during the pre-monsoon season (July) of 2008. All water samples with exception to locations of 10 and 15 were categorized as 'Unsuitable' class with respect to Na % values. The locations of 10 and 15 were categorized as 'Doubtful' with respect to Na % values (Table 2). As per ISI (1974) guidelines, the maximum tolerance limit of Na % for surface water used for irrigation is 60. This higher value of Na % was due to contribution of sewage discharge from the Cuddalore township and untreated industrial effluent discharges of Cuddalore industrial zone.

Correlation between Water Quality Parameters

River Water

Table 3 presents the correlation matrix between various parameters of the river samples. Most of the parameters were found to

Table 3
Correlation Coefficients of River Water Samples

	pH	EC	TDS	Salinity	Na	K	Cl	TH	PO_4	Ca	Mg
pH	1										
EC	0.0692**	1									
TDS	0.645*	0.988**	1								
Salinity	0.571*	0.909**	0.947**	1							
Na	0.386	0.677**	0.730**	0.856**	1						
K	-0.359	0.633*	0.686**	0.832**	0.992**	1					
Cl	-0.538*	0.782**	0.828**	0.944**	0.860**	0.856**	1				
TH	-0.489	0.836**	0.894**	0.981**	0.855**	0.837**	0.957**	1			
PO_4	0.417	-0.043	-0.028	-0.114	-0.057	-0.076	-0.185	-0.085	1		
Ca	-0.373	0.721**	0.775**	0.911**	0.853**	0.853**	0.898**	0.922**	-0.186	1	
Mg	-0.491	0.838**	0.895**	0.981**	0.854**	0.835**	0.957**	1.000**	-0.082	0.918**	1

** Significant at 0.01 level

* Significant at 0.05 level

be significantly inter-related. The EC and TDS of the river water showed a highly positive correlation. Both the parameters are indicators of good quality of water. TDS is strongly correlated with salinity, Na^+, K^+, Cl^-, hardness, Ca^{2+} and Mg^{2+}. EC is well correlated with salinity, Na^+, K^+, Cl^-, hardness , $Ca^{2+}$and Mg^{2+}. However Po_4^{3-} has a negative correlation with all the parameters, and hardness, positively associated with all except pH and Po_4^{3-}.

Coastal Surface Water

The correlation coefficients of the water quality parameters of the CSW are given in Table 4. The correlation between pH and other parameters except Po_4^{3-} is slightly positive. Mg^{2+} is positively correlated with hardness and moderately correlated with EC, TDS, Salinity, Na^+, K^+, Cl^-, TDS and EC.

Conclusion

Present study describes the physico-chemical variations in surface water quality of Uppanar river and surrounding estuarine system in Cuddalore coast of India. The surface water contamination near SIPCOT industrial zone is more because of discharges of industrial wastes. The Uppanar river is in the severe water class and unsuitable for irrigation. The southern part of Uppanar river and some of the land surface water region of Cuddalore coastal zone is 'moderate' water class. All the water samples of the study area contain very high value of hardness, and so are unfit for irrigation and other domestic purposes. SAR and Na% values too indicate a poor quality of water for irrigation purpose. The result suggests that the

Table 4
Correlation Coefficients of Coastal Surface Water Samples

	pH	EC	TDS	Salinity	Na	K	Cl	TH	PO_4	Ca	Mg
pH	1										
EC	-0.246	1									
TDS	0-0.168	0.990**	1								
Salinity	-0.218	0.979**	0.983**	1							
Na	-0.213	0.168	0.196	0.317	1						
K	-0.285	0.130	0.084	0.258	0.650	1					
Cl	0.004	0.787*	0.795*	0.812*	-0.036	0.164	1				
TH	-0.319	0.651	0.651	0.753	0.685	0.587	0.606	1			
PO_4	0.451	-0.368	-0.316	-0.427	-0.377	-0.526	-0.542	-0.550	1		
Ca	-0.085	-0.159	-0.235	0.242	0.161	0.012	-0.524	-0.464	-0.004	1	
Mg	--0.315	0.613	0.650	0.751	0.676	0.582	0.611	1.000**	--0.545	-0.478	1

** Significant at 0.01 level
* Significant at 0.05 level

Uppanar river, Gadilam and Ponnayar estuarines are polluted, indicating an immediate need for protection measures. Treating the domestic waste water and industrial effluents before letting into the streams is an urgent requirement for the study area. A continuous monitoring system for keeping track of water pollution may be essential for the study area.

References

1. Ansari A.A, I. B. Singh and H. J. Tobschall (1999). 'Status of Anthropogenically-induced Metal Pollution in the Kanpur- Unnao Industrial Region of the Ganga Plain, India', *Environmental Geology*, 38, pp. 25–33.
2. Ayers R. S and D. W. Westcot (1994). 'Water Quality for Agriculture', *FAO Irrigation and Drainage Paper*, 29, pp. 1–130.
3. Ayyamperumal T, M.P. Jonathan, S. Srinivasalu, J.S. Armstrong-Altrin and V.Ram Mohan (2006). 'Assessment of Acid Leachable Trace Metals in Sediment Cores from River Uppanar, Cuddalore, Southeast Coast of India', *Environmental Pollution*, 143, pp.34–45.
4. Balak Ram and A.S. Kolarkar (1993). 'Remote Sensing Application in monitoring Landuse Changes in Arid Rajasthan', *International Journal of Remote Sensing*, 14, pp. 3191-3200.
5. Carpenter S. R, N. F. Caraco, D. L. Correll, R. W. Howarth, A. N. Sharpley and V. H. Smith (1998). 'Non-point Pollution of Surface Waters with Phosphorus and Nitrogen', *Ecological Applications*, 83, pp. 559–568.
6. Durfer C.M and E. Backer (1964). 'Public Water Supplies of the Three Largest Cities in the U.S', *US Geological Survey Water Supply*, 1812, pp. 364.
7. Hinrichsen D, B. Robey and U. D. Upadhyay (1997). 'Solutions for a Water-short World', *Population Reports*. Baltimore: Johns Hopkins School of Public Health, Population Information Program. (Series M, No. 14).
8. ISI (1974). 'Indian Standard Tolerance Limits for Surface Waters subject to Pollution', *Indian Standard 2296*. New Delhi: ISI.
9. Jonathan M. P, S. Srinivasalu, N. Thangadurai, T. Ayyamperumal, J. S. Armstrong-Altrin, V. Ram Mohan (2007). 'Contamination of Uppanar River and Coastal Waters off Cuddalore, Southeast Coast of India', *Environmental Geology*, 53, pp. 1391-1404.
10. Kambole M. S (2003). 'Managing the Water Quality of the Kafue River', *Physics and Chemistry of the Earth*, 28, pp. 1105–1109.
11. Kelly W. P (1951). *Alkali Soils – their Formation, Properties and Reclamation*. New York: Reinhold.
12. Melina E. K, A. G. Vlessidis, N. C. Thanasoulias and N. P. Evmiridis (2005). 'Assessment of River Water Quality in Northwestern Greece', *Water Resources Management*, 19, pp. 77–94.
13. Mokaya S. K, J. M. Mathooko and M. Leichtfried (2004). 'Influence of Anthropogenic Activities on Water Quality of a Tropical Stream Ecosystem', *African Journal of Ecology*, 42, pp. 281–288.
14. Nayak S, A. Bahuguna, P. Chauhan, H. B. Chauhan and R. S. Rao (1997). 'Remote sensing Applications for Coastal Environmental Management in India', *Maeer's MIT Pune Journal*, 4 (15 & 16), pp. 113 - 125.
15. Pandey S (2006). 'Water Pollution and Health' *Kathmandu University Medical Journal*, 4, pp. 128–134.
16. Pekey H, D.Karaka and M. Bakolu (2004). 'Source Apportionment of Trace Metals in Surface Waters of a Polluted Stream using Multivariate Statistical Analyses', *Marine Pollution Bulletin*, 49, pp. 809–818.
17. Sawyer C. N and P. I. McCarty (1967). *Chemistry of Sanitary Engineers*. New York: McGraw- Hill.
18. Singh K. P, A. Malik and S. Sinha (2005). 'Water Quality Assessment and Apportionment of Pollution Sources of Gomti River (India) using Multivariate Statistical Techniques – A Case Study', *Analytica Chimica Acta*, 538, pp. 355–374.

Microgeomorphic Forms:
An Experiment on an Artificial Cut-Slope

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This paper deals with the microgeomorphic forms of an artificial cut slope on which no human intervention occurred after its formation. This small slope is only 50.65 m long and located on a highland of Suryamaninagar of Tripura under tropical-monsoon type of climatic condition. Six serial profiles are first constructed to study micro-angles and micro-relief, and though for a naked eye, the slope may appear to be uniform but it has diversity of forms due to weathering, water flow and biotic activities. Though the small sculptures or designs are the integral parts of landforms, most of them have no terminological identity in Geomorphology. The study of overhang angles (>90°) of the surface from the six serial profiles indicates an instability of the surface. Micro-relief changes observed are due to combination of different environmental processes, and also their efficiencies at micro level. A study of microgeomorphology helps to understand the major landform features.

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Geomorphic agents sculpture several small forms and designs on the surface of the earth, and these microgeomorphic features may range from a few centimetres to a few metres in size. Micro-features have wider variations depending on time too, from a few hours to years. Short and small run-off channels, brief vertical flow channels, ripple marks on the floor, and the like may be some of the examples for the mircrogeomorphic landforms (2). They are very much the integral parts of general landforms that are normally recognized. The study of the process by which these tiny forms get developed is termed as microgeomorphology which is yet to draw the larger attention of the practicing geomorphologists. It is a fact that influences of environmental changes on geomorphic processes may first be seen in the small sculptures and designs on the surface (Fig.1). Sea level fluctuations may be identified by observing rip channels and wave ripples (3, 4). Bloom (1) observed that smaller features of landforms may be created and destroyed more rapidly than the larger ones with the changing geomorphic processes.

Considering the significance of the microgeomorphic features, it is planned to carry out a study on an artificially-cut slope located on a highland in Suryamaninagar village, Tripura. This highland (locally known as *tilla* land) has a specific environmental significance, with its elevation, slope, soil condition, ground water conditions etc.,. Geologically this highland is formed by *"Dupitilla"* type of sediments which were formed during Late Tertiary to Early Quaternary period, and the sediments consist of estuarine brown clay sand, silty clay, white to grey sand-rock with silt band, white clay (8). It proves that during the Late Tertiary and Early

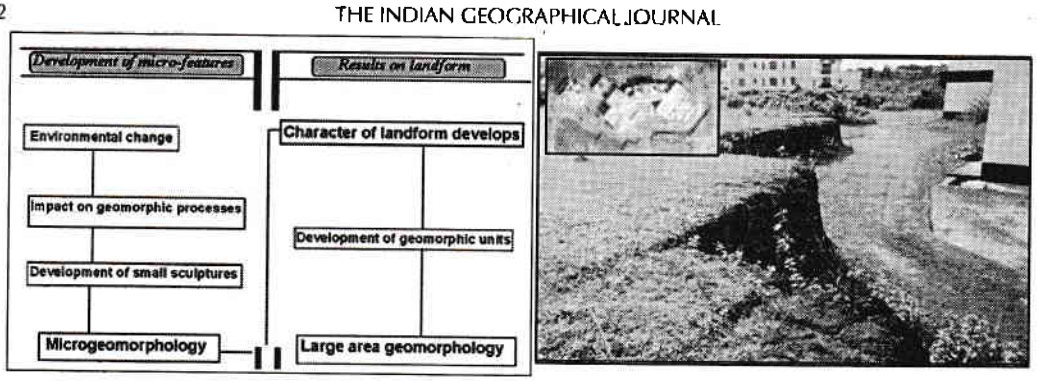

Fig. 1: Significance of Microgeomorphology and the Selected Artificial Cut-slope

Quaternary, this area was nourished by shallow marine-coastal / estuarine process under different environmental conditions (9). Menon (7) noted that the name "Tripura" originally came from Tripuri tribal word, "*Tuepra*", which means "near water land" (*Tue*=water and *Pra*=near). Geo-tectonic changes in the Quaternary period played vital role for the development of present environmental condition in the study area (6). There are enough evidences to assess that all the highlands of Tripura were covered by dense forest and very rich in ecological resources before human occupations (5).

The basic objectives of the study are (i) to identify the types and forms of microgeomorphic features on a slope of *Dupitilla* formation in a very small area and (ii) to understand the nature of micro-level variation of environmental processes. The slope selected had a smooth surface when it was made, and then processes started to act which developed many first order micro-level features on it; and this slope has not had any human interventions in the last five years or so.

Physical Set-up of the Selected Slope

The cut-slope located for the study experiences tropical monsoon climate with observable four seasons, summer, rainy, winter and autumn. Summer lasts from March to May .The temperature starts rising with the beginning of the season but monsoon showers prevents the further rising of the temperature. The average summer temperature usually varies from 25°c to 28°c. The maximum & minimum temperatures of the season are 33.93 °C & 18.02°c respectively. The annual rainfall is unevenly distributed. Maximum rainfall occurs between May to October. Rainfall is totally nil in the months of February and December, and a negligible amount is recorded in the month of January (0.85cm). The winter lasts from the second half of December to February where January is the coldest month. The average winter temperature varies between 19.21°c to 23.76°c.

The general angle of the slope selected varies from 42° to 89°. Maximum length of the vertical slope is about 400 cm but in most of the parts the vertical length of the slope extends for about 300 cm. The soil of this area is sandy and sandy loam, and poor in organic carbons (0.5).

Though the slope is very steep, it is richly covered with dense vegetation (Table 1). On upper and lower parts of the slope, plants from Gramineae family (*Cynodon dactylon* and

Andropogon aciculaths) are very commonly found. The other important plants are *Leucas easpera* (Labiatae or Lamiaceae family), *Lantana camara* (Verbenaceae family), *Pteris vittata* (Polypodiaceae), and *Crotalaria junacea* (Fabaceae or Lequminosae). Highly important medicinal plant like *Centella asiatici* (Umbelliferae (Apiaceae)) is also found on the slope.

Methodology

The selected artificial cut profile for this research was created five years ago for the construction of a concrete road. Some interesting points play important role to attract these authors towards the microgeomorphic development of this artificial cut slope. The points are as follows:

1. Since this slope is completely man-made, initially the surface of the slope was very smooth and then the natural processes started to act on it freely without any further human intervention.
2. Now the surface of the slope has remarkably changed by natural processes.
3. Since this slope is untouched by any of the human activities for last 5 years (only a concrete steer was constructed 5 years back) the natural processes got sufficient time to work on it.

Detailed field observations and data collection on forms and the process were first carried out by a meticulous field visit and survey in the study area. Instruments like Dumpy Level and clinometers were used to collect data. Six serial profiles (Fig.2) of the slope were constructed (distance between each profiles: 8.44 m) to measure variation in slope and elevation for understanding the characteristics of general micro-level morphology. Slope and elevation were measured for every 10 cm along these profiles. A systematic identification of micro-landforms was then

Table1

Types of Plants and their Families observed on the Slope

S.No.	Local Names	Scientific Names	Name of Family	Name of Plant
1.	Durba	*Andropogon aciculaths*	Gramineae	Uncountable
2.	Chorkanta	*Cynodon dactylon*	Gramineae	265
3.	Seto drun	*Leucas easpera*	Labiatae or Lamiaceae	25
4.	Chudhara	*Lantana camara*	Verbenaceae	23
5.	Teris	*Pteris vittata*	Polypodiaceae	29
6.	Lajjabati	*Mimosa pudica*	Fabaceae or Lequminosae	8
7.	Thankuni	*Centella asiatici*	Umbelliferae (Apiaceae)	23
8.	Shan	*Crotalaria junacea*	Fabaceae or Lequminosae	15

carried out, along with an understanding of plant ecology. Statistical testing was conducted with the data collected in the field, to understand the variations in slope angles, elevations, runoff tunnels at different points on the slope studied, and to indicate the relation between vertical length of the slope and the length of the runoff tunnels. Mapping of the features was done, using ET 7.95 Pro, and photographs were also taken to supplement the data analysis and mapping.

Results and Discussion

General Microgeomorphic Characters

The micro-level angles are strong evidence of the ruggedness or smoothness of landform slope since the slopes change with the change of elevation. It is found from the analysis that maximum micro-level angle of the slope is 129° and minimum slope is 1° in the study area (Table-2). Sediment wash is a very common feature that initiates the changes in the slope angle (Fig-2). The wash is very active during monsoon rains. Another characteristic feature seen is the development of several overhang micro-level slopes (>90°) which indicates the instability condition of the slope (Table-3). Those overhang slopes are the result of vertical tunnels erosion during the wet season and weathering during dry seasons. Biotic actions also may accelerate the development of overhang slopes. During the dry season hair line cracks develop on the slope which makes the upper layer very loose. On the overhang spots of the slope, the upper sediment layer collapses regularly which can be defined as sediment fall. Sometimes slaking also takes place to cause sediment fall. Soil wash and sediment fall occur at micro level, causing surface change continuously on, and leading to a big collapse of the surface in a few years time.

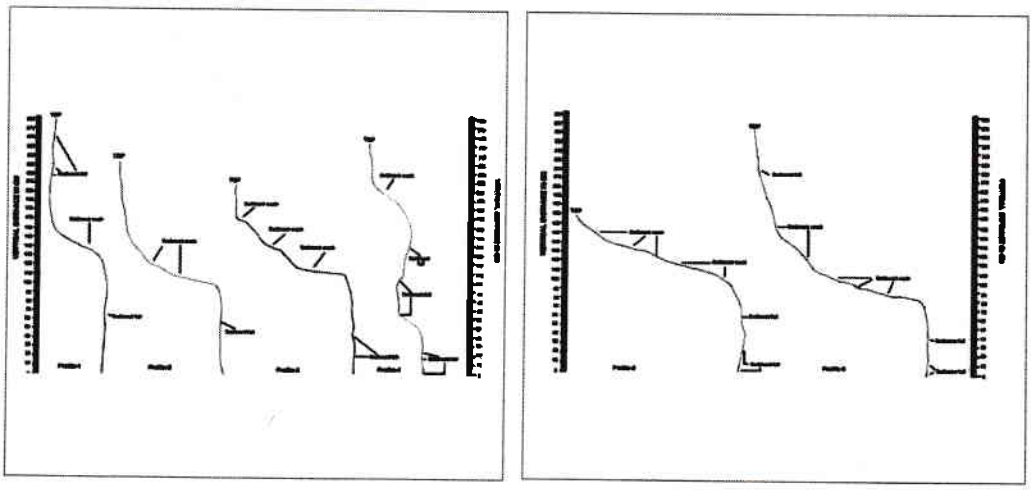

Fig. 2
General Morphology of Six Selected Serial Profiles

Table 2
Micro-level Angles of Six Serial Profiles

Vertical Distance in cm	Angles of the Slopes (in°)					
	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
0	95 (overhang)	14	91 (overhang)	1	99 (overhang)	99 (overhang)
10	97 (overhang)	6	93 (overhang)	10	94 (overhang)	98 (overhang)
20	99 (overhang)	3	94 (overhang)	99 (overhang)	1	99 (overhang)
30	94 (overhang)	2	12	6	1	3
40	91 (overhang)	94 (overhang)	95 (overhang)	17	4	10
50	4	95 (overhang)	13	56	1	11
60	96 (overhang)	91 (overhang)	92 (overhang)	49	6	1
70	98 (overhang)	97 (overhang)	92 (overhang)	64	24	14
80	1	9	12	1	11	27
90	4	15	26	94 (overhang)	54	33
100	15	56	7	14	86	46
110	19	76	83	98 (overhang)	86	64
120	31	73	84	129 (overhang)	92 (overhang)	67
130	64	94 (overhang)	67	95 (overhang)	77	75
140	69	83	86	99 (overhang)	79	82
150	61	72	86	114 (overhang)	75	79
160	60	60	76	94 (overhang)	80	71
170	48	70	59	98 (overhang)	58	74
180	5	41	35	18	87	70
190	10	33	47	17	64	76
200	3	41	73	34	72	72
210	4	25	58	41	65	81
220	94 (overhang)	11	40	64	41	74
230	98 (overhang)	4	44	49	44	83
240	100 (overhang)	10	54	53	39	70
250	94 (overhang)	10	63	15	56	79
260	95 (overhang)	94 (overhang)	5	92 (overhang)	64	50
270	95 (overhang)	9	6	94 (overhang)	30	64
280	95 (overhang)	93 (overhang)	94 (overhang)	14	33	55
290	94 (overhang)	92 (overhang)	91 (overhang)	21	13	35
300	--	--	--	--	19	--
310	--	--	--	--	25	--
320	--	--	--	--	24	--
330	--	--	--	--	15	--
340	--	--	--	--	15	--
350	--	--	--	--	6	--
360	--	--	--	--	1	--
370	--	--	--	--	16	--
380	--	--	--	--	7	--
390	--	--	--	--	4	--

Source : Field Data

Table 3
Number of Overhang Slopes on the Six Serial Profiles

Name of the Profiles	No. of Overhang Slope
Profile 1	15
Profile 2	8
Profile 3	8
Profile 4	11
Profile 5	3
Profile 6	3

Micro-relief Formations

This is a very steep slope with uneven morphology. Several runoff tunnels have been developed on the slope, which are responsible for sediment transfer and modification of morphology. Micro-relief is also modified by weathering sediment transfer during the monsoon seasons. According to Zonn (10), variation of elevation within 0.2 m to 1 m is called micro-relief. Table 4 shows the micro-relief changes of six serial profiles.

Though by naked eye the selected artificial cut slope is marked by almost uniform morphology, there are several micro-level variations on the slope. Some of the interesting features observed from the six profiles are listed below:

1. Micro-slope angle variations and micro-relief changes on the six serial profile show that this slope even at micro-scale is very uneven and rugged.
2. Among the six profiles, profiles 1 and 2 (western part) are relatively smooth and they show almost similar pattern of micro-relief condition, e.g. the values of micro-relief of upper and lower parts are higher then the middle part. On those profiles, the middle parts are comparatively less rugged. Profile 4 shows the maximum ruggedness as the micro-relief changes are very frequent on the vertical distance of the slope. In case of profiles 4 and 5, all parts of these profiles are marked by higher micro-relief changes in small areas.
3. To the east, on profile 6, the micro-relief value of the upper part is comparatively low and it is smoother than the profiles of 4 and 5.

Some Observed Micro-features and their Significance

The vertical runoff tunnels are very common feature of this slope (Fig.3). They are non-perennial flow tunnels through which water flows only during the monsoon seasons and during the other seasons they remained totally dry. Observations show that the tunnels are created by the influences of three processes, mechanical weathering, direct erosion by water flow, and extension of roots of vegetation or removal of vegetation (biological weathering). These processes are complementary to each other. There are three types of tunnels identified in the slope studies.

1. Some tunnels are created both by mechanical weathering and water flow. Vitiation of temperature through the seasons initially creates some micro-level cracks on the surface of the slope, where vegetation cover has been removed. During the monsoon rain water flows through those cracks and the length and

Table 4

Micro-relief of the Six Serial Profiles

Distance from Bottom to Top (in cm)	Micro-relief (in cm)					
	Profile 1	**Profile 2**	**Profile 3**	**Profile 4**	**Profile 5**	**Profile 6**
0 - 10	10.5	9.5	10	10	10	10
10 - 20	10	9.8	9.9	9.9	10.5	9.8
20 - 30	9.5	9.9	9.8	10.2	10.1	9.5
30 - 40	10	9.5	10.1	10.4	10.3	9.9
40 - 50	9.2	9.5	10.3	9	9.9	9.2
50 - 60	9	10.2	9.5	6	10.2	9.8
60 - 70	9.3	9.8	10.7	6.5	10.1	9.9
70 - 80	9.8	9.7	10	5	9	10
80 - 90	9.2	10	9.8	10	10	8
90 - 100	9.5	10	9.5	10	6	7
100 - 110	9	5.2	9.9	9.8	1	5
110 - 120	9.1	2.1	1	9	10	4
120 - 130	9	2	1.2	7.9	1	2
130 - 140	4	1	4	9	3	1
140 - 150	4	1.5	1.9	10	2	1
150 - 160	5	3	1.5	9	3	1
160 - 170	5	5	2.9	10	3	2
170 - 180	7	3	6	10	6	2.5
180 - 190	9.9	7	9	9	1	3
190 - 200	9.5	8	7	9	4	1
200 - 210	10	8	3	8.9	3	2
210 - 220	10	9	6	7.9	4	1
220 - 230	10.2	10	8	5	7	2
230 - 240	9.8	10.1	7	7	7	1
240 - 250	10	9.9	6	6	8	3
250 - 260	10.1	9.5	4	10.6	5	3
260 - 270	10	9.8	10	10.3	4	6
270 - 280	10	9.8	9.8	10.1	8	4
280 - 290	9.5	11	10.5	9.8	8	6
290 - 300	10.1	10.2	10.9	10	10.2	8
300 - 310	--	--	--	--	9.8	--
310 - 320	--	--	--	--	8	--
320 - 330	--	--	--	--	9	--
330 - 340	--	--	--	--	9.1	--
340 - 350	--	--	--	--	9.5	--
350 - 360	--	--	--	--	9.2	--
360 - 370	--	--	--	--	10.2	--
370 - 380	--	--	--	--	9.8	--
380 - 390	--	--	--	--	9.5	--
390 - 400	--	--	--	--	10.5	--

Source : Field data

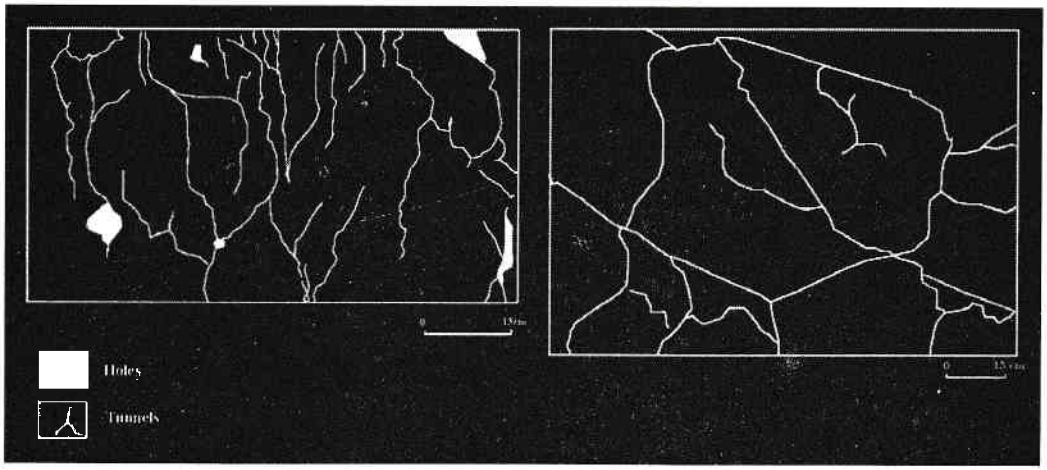

Fig. 3 Vertical Tunnels during Monsoon Season (left) and Scale-shaped Blocks by Weathering during Dry Season

width of the tunnels are increased. These types of tunnels have many turnings and micro-meanders as their initial forms are the weathering cracks.

2. Extension of roots or removal of roots on the subsurface of the slope creates many veridical tunnels which are further enlarged by runoff during the monsoon. Normally these tunnels are small in length but relatively wider than the first type of tunnels.

3. Direct erosion by water flow creates some vertical tunnels. These tunnels are comparatively straight and prominent due to their greater length and width.

According to the lengths, the tunnels may be defined into five groups. Table 5 shows the length groups and number of tunnels in different groups, and it is noted that more than 50 % of the total tunnels on the slope ranges between 41 cm to 80 cm in length. Only seven tunnels run for 80-100 cm, and tunnels running for more than 100 cm are only five. Most of the prominent runoff tunnels got formed where the vertical extension of the slope is greater. It clearly shows that influence of environmental factors increases with the increase of space of the surface (Table 6 and Fig.4).

Between the places of the tunnels remained sediments which have not been eroded by water flow, and they stand on the slope like statues. The length of the sculptures depends on the length of the associated tunnels, and their width is related to their distance. It has been observed that sometimes the tunnels shift towards each others due the presence of soluble matters in the sediment which

Table 5
Classification of the Vertical Flow Tunnels

Length of the Tunnels (in cm)	Number of Tunnels
< 40	11
41 - 60	22
61 - 80	17
81 - 100	7
> 100	5

accelerate erosion during the wet season. As a result of that the shape and size gets changed. If the tunnels are merged together, inter tunnel sculptures may get vanished. Sometimes weathering or slaking during the dry seasons accelerates the sculptures to disintegrate from the slope and by this way they lose their existence.

Scale-shaped sediment blocks are created by mechanical weathering and on the slope studied for the present exercise, both the horizontal scale-shaped sediment blocks (on the top of the slope) and vertical scale-shaped sediment blocks (on the middle part of the slope) are found. It was observed that scale-shaped micro-features have a clear seasonal character. During the summer with the increase of thermal weathering the features become very prominent and during monsoon, the details of micro-features normally get lost by sediment removal.. Also, blocks are disintegrated by the extension of thermal weathering and then are removed by water flow during the wet season. As a result of removal of sediment, small caves and holes are created.

Weathering during dry seasons and removal of soils during monsoon creates the sediment ladders on the slopes, and three sediment stairs are found formed. Grazing animals like cows, sheep and goats may also leave their foot-prints as stairs where height of the slope is less than 1 m and slope angle is less than 30°. Upper layer is removed, thereby creating a bottom layer of very small horizontal platforms, and with this process, thirty six platforms are counted, and their length ranges from 5 cm to 56 cm. Small caves and holes are

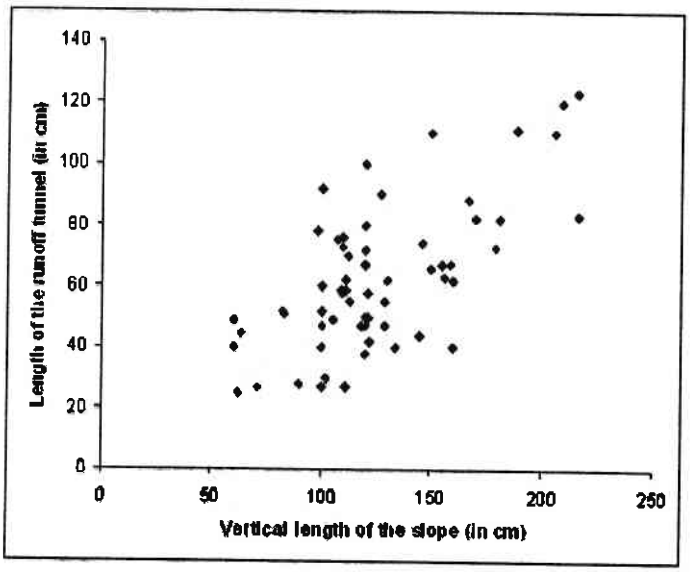

Fig. 4: Vertical Length of the Slope and Extension of the Runoff Tunnels Mapping of extension of vertical tunnels on a part of the slope during monsoon season (left) and development of scale shaped blocks by weathering during dry season in parts of the studied slope (maps prepared by ET-PRO9.5 GIS based software)

Table 6

Vertical Lengths of the Slope and Lengths of Tunnels

Vertical Length of the Slope (in cm)	Length of the Tunnel	Vertical Length of the Slope (in cm)	Length of the Tunnel
63	45	120	50
60	49	120	67
90	28	120	38
60	40	120	47
71	27	120	100
82	52	121	50
83	51	121	58
62	25	122	42
98	78	127	90
100	27	129	55
100	52	129	47
100	47	130	62
100	40	134	40
100	60	145	44
100	60	146	74
100	92	150	66
102	30	150	110
105	49	155	67
107	75	156	63
109	58	159	67
109	59	160	40
110	76	160	62
110	73	167	88
111	27	170	82
111	59	179	73
111	62	181	82
112	70	189	111
113	55	206	110
118	47	209	120
120	72	216	123
120	80	217	83

Source : Field data

also very common micro-features in the cut-slope studies, and there found are about 1000 small caves and holes On the basis of the origins, there are three types of small caves and holes: caves and holes created by mechanical weathering and disintegration of the sediment blocks; caves and holes formed at the root zone by the removal of vegetation; and holes created by living organisms. Caves and holes vary in size and shapes on this platform. The maximum radius of the holes is recorded as 9 cm. It is also seen that number of small caves and holes increase with the increase of the vertical length of the studied slope and it may indicate that that mechanical and biological activities increase with the increase of space.

Uneven erosion, variation of micro-level solubility, and presence of comparatively solid sediment grains create the micro-features like grains or pimples on the surface of the slope, and they are found all through the slope. During the monsoon the pimples do not develop well but during dry seasons they are very prominent. Another micro-feature formed at the corner of the slope looks like the nose of an alligator and it is known as alligator's nose. These micro-features become prominent and sharper, when sediments on the upper surface get removed by water flow. Micro-features are formed by the combined works of different environmental processes (Table 7). Weathering (thermal and chemical) and seasonal water flow are the major processes. Biotic processes also play an important role for

Table 7

Forms of Micro-features and Responsible Processes for Formation of the Features

Forms of the Micro-feature	Environmental Processes responsible for the Formation of the Micro-features	
	Dominating Processes	Supporting Processes
Vertical flow tunnels	Seasonal water flow	Weathering, biotic process (mainly extension of roots of the plants)
Sediment statue	Seasonal water flow	Weathering, biotic process (mainly extension of roots of the plants)
Scale shaped sediment blocks	Weathering,	Seasonal water flow
Sediment ladders	Weathering,	Seasonal water flow, biotic process (walking of the animals like cows, goats, sheeps etc)
Horizontal micro-platform	Weathering,	Seasonal water flow
Small caves and holes	Weathering,	Biotic process (mainly microbial activity)
Pimples or grains	Seasonal water flow	Weathering, biotic process (mainly microbial activity)

the formation of the micro-features. Size and shape of the micro-features are defined by these processes and their efficiency. For example the vertical runoff tunnels are very prominent during the monsoon season (Fig.5) and remained as dead features during the dry season. On the other hand the sediment statue, ladder, caves and hole, and platforms are very prominent during the dry seasons and during the wet season they disappear due to water wash.

Conclusion

Microgeomorphology is the result of combined works of different environmental processes in a very small area of the earth's surface under specific environmental condition. This study shows that landform is more complex than it appears. Small features and sculptures of landform are required to be understood for understanding general geomorphology. They are the result of geomorphic processes, including biological process. The micro-angle variations and micro-relief changes noted on the small artificial cut-slope indicates that stability and shape of landform may vary even at micro-level. These changes thus influence the shape of large scale geomorphology. Even in the small study area, several types of micro-features like vertical tunnels, scale-shaped sediment blocks, sediment ladders, horizontal micro-platforms, caves, and holes are found developed. They occur in different sizes and shapes, and different environmental processes are found involved in defining these changes. The diversity of plants on this small study area accelerates the environmental processes. Thus the study of microgeomorphic features is not only a simple tool for in-depth explanation of landform of any area but also very helpful to assess the geomorphic succession under certain environmental condition, micro-level function of environment, and environmental fluctuation.

References

1. Bloom A.L (1998). *Geomorphology-A Systematic Analysis of Late Cenozoic Landform.* New Delhi: Prentice-Hall Pvt Ltd. (Third Editon).
2. Dey S (2005). 'Microgeomorphology: A Simple Tool for Landform Analysis in the Tropical Coastal Area', *Swansea Geographer,* 40, pp.35-44.
3. Dey S (2002). 'Impact of Sea Level Change upon Landform Development along Digha Coastal Tract and Risk Assessment by Process Efficiency Process', *Indian Journal of Geomorphology,* I-7, pp. 111-117.
4. Dey S (2003). 'Morphodynamics of Tropical Mesotidal Sea Beach of Digha' *North-Eastern Geographers,* 1-32, (1 & 2), pp. 70-80.
5. Dey S (2005). 'Conceptual Models for the Assessment of Tertiary-Quaternary Geomorphic Evolution of Paleo-coastal Tripura', *Annals of the National Association of Geographers, India,* 25 (1), pp. 73-80.
6. Dutta G.N (1974). 'Some Geomorphological Aspects of Tripura State', in *Abstracts of Proceedings of Indian Science Congress.*
7. Menon K.D (1975). *Tripura District Gazetteer,* Agartala: Government of Tripura.
8. Nandi M (1977). 'Physiography of Tripura State', *Geographical Review of India,* 39(4), pp. 367-373.
9. Nandi M (1985). 'Geographical Account of Tripur' *in J.Can-Choudhnui (ed.). An Anthology of Tripura.* New Delhi: Inter-Indian Publication.
10. Zonn S.V(1986). *Tropical and Subtropical Soil Science.* Moscow: MIR Publications.

Short Communications

Oil Exploration and Production in Yemen

Oil has been a strategic commodity that plays a definite role on modernity and industrial growth. Oil production, refining and marketing have been a growing industry of greater importance. Incidence of oil resources is quite skewed in the world and Arab world has been the leading region for oil resources in the world. The present essay looks into the history of exploration of oil in Yemen, a country in the coastal strip, south of Saudi Arabia, during 1980-2007. Oil is the main resources for economic development in Yemen, and no serious study has been so far carried out on the development of oil resource in the context of general economic development. The current exercise describes the progress made in oil exploration and exploitation, especially after the unification of Yemen. Necessary data for this description were drawn from reports of the United Nations, and the Central Agency for Statistics, Yemen National Information Centre, and Yemen Strategic Report of 2007.

Yemen

The Republic of Yemen is situated in the southwestern area of the Arabian Peninsula within latitudes 12° - 20° North of the Equator and between longitudes 41° - 54° East of Greenwich. The area of the country is about 5,27,973 Sq.km (3). Yemen is bordered by Saudi Arabia in the north, by the Arabian Sea and Indian Ocean in the south, by the Red Sea in the west and by the Sultanate of Oman in the east (Fig 1).

Phases of Oil Exploration

Phase One (1980-1989)

Yemen was the last country in the Arab world in commercial exploitation of oil resources. Oil was first discovered in the South of Yemen, in a commercial way in Sharmah field -1 in Al-Mukalla – Saihout basin in the Gulf of Aden by the Italian company in 1982 with a production of 3000 barrels a day. This company, for some political reasons, withdrew in 1985 from exploration. In 1986, the Soviet Techno Exportish started exploration in Shabwah province, and most of the oil exploration in the southern provinces was controlled by Soviet companies till the unification of Yemen in 1990. Before unification, the Government of Sana in the north signed a joint deal for oil exploration in 1981 with an American company, Hint, giving a grant area (Safer-Aljawf) of about 16800 sq.km in Marib and Aljawf provinces. The deal

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was for six years distributed in three phases, researching, exploration and drilling, and the length of participation in the production after the exploration was for twenty years (2).

The Hint Company along with Oxon Company discovered oil in a large, commercial quantity in the filed of ALIF, situated in Marib –Basin, about 60 km away from the East of Marib. The production in the beginning was about 7800 barrels a day. The company drilled about 130 wells in the course of time, and the production reached about 220,000 barrels a day in the year of 1990 (7). With the findings of oil for commercial use, a large number of companies took interest to come to Yemen for oil exploration, and the important ones are International Canadian Acosy Afshour, Arab Union Company (came in 1987 for exploration in the South district of Masila, an area of about 36,000 Sq.Km), the Kuwait Independent Petroleum Group (in the district of Bilhaf in Shabwah), The French Petroleum Alf Ekteen Petroleum (Aden-Abian district in 1987, with an area of about 19,000 sq. km). French Total Company (East of Shabwah, with an area of about 16,000 sq.km (1).

Production was very active in Marib – Aljawf in the north Yemen. Due to political conflicts and violence, the progress in Shabwah and Mukalla-Sayhut sector got retarded. The

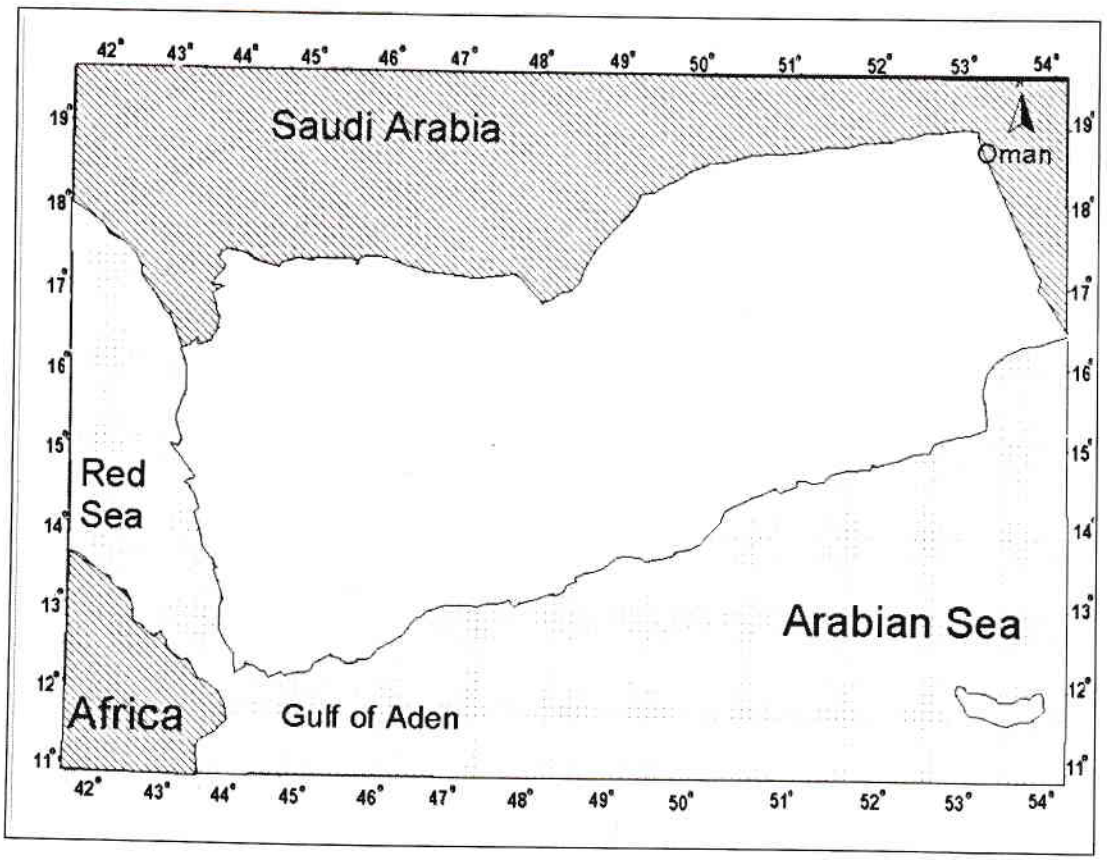

Fig. 1 Location of the Republic of Yemen

collapse of Soviet Union too caused the slow-down or interrupted the progress of oil exploration in Yemen.

Phase Two (1990-1994)

After unification of the two parts of Yemen (now Yemen Republic) in May 1990, Yemen Republic got a political stability, and the Ministry of Oil and Mineral Wealth played a very pro-active role in oil production. This unity opened the door for a new age of investment and economic initiatives. As a result, a large number of international and foreign companies came for oil grants in Yemen in the areas identified by the Ministry of Oil and Mineral Wealth. In this period, new contracts and agreements were made to suit the new changes after the unification of Yemen, and many of the previous agreements with these companies were re-considered. Also, new schemes of division of oil sectors were was introduced, and the places of oil in

Table 1

Distribution of Oil Companies in Yemen during the Year 1990-1991

Block No.	Block Name	Governorate	Area (Sq.Km)	Opening Company
1.	Onaqueen	Shabwah	2189	Sun Oil
2.	Almasaber	Shabwah-Hadhramount	4015	Crescent P
3.	Gordan	Shabwah	2950	Sheveron
4.	Aiad	Shabwah	1993	Namir
5.	Partner Area	Shabwah	2180	Total
6.	Eryam	Shabwah-Hadhramount	3224	Starake
7.	Burquah	Shabwah	4942	B.P
8.	Asaker	Hadhramount- Shabwah	4730	B.P
9	Al-hagir	Shabwah	4728	Crescent
10	East Shabwah	Shabwah	15827	Total
S1	Damis	Shabwah	4484	Sodec
S2	Al-Uqlah	Shabwah	2808	Oxy
12	Saar-hazar	Hadhramount	47217	Alf
13	North Sanaw	Hadhramount	15910	Bin Ham
14	South Masila	Hadhramount	35548	Oxy canada
18	Marib-Aljawf	Marib-Aljawf	8445	Hunt
20	Aljawf	Aljawf	4222	Philips
23	Antofach	Hodiedah	13010	B.P.
28	North Behalf	Shabwah	3771	Jalik
30	Hebroot	Al Mahara	12083	Petro Canada

Source : Yemen Statistics Oil and Gas, Ministry of Oil and Minerals, Sana'a 2004, 2205, 2006

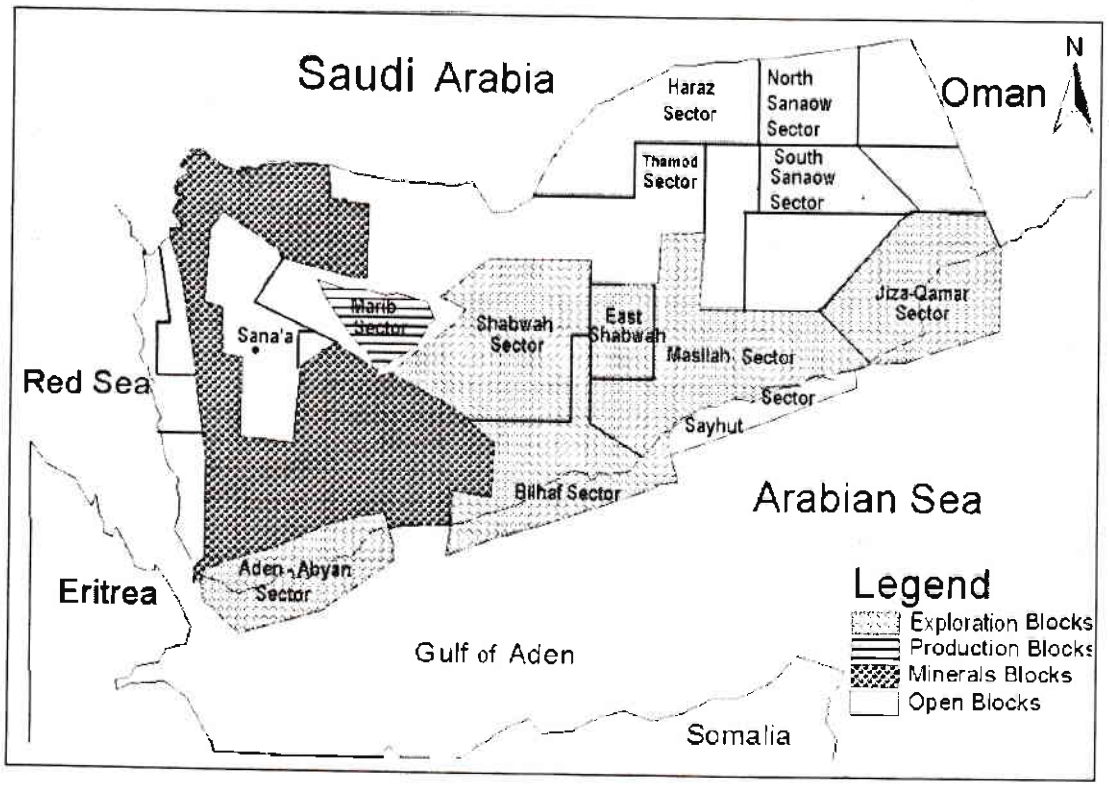

Fig. 2 Sectors of Oil in Yemen during 1980-1989

Yemen Republic were gathered under 30 sectors of oil. The former oil centre which was under the control of the Soviet Union companies was given to Namir Saudi Company which paid for tools, pipelines and exploration to the Soviet Union companies (1). During 1990-1991, 18 international companies were permitted to operate for oil production (Fig.3).

The international companies that signed the deals, hail from different countries, and had better knowledge, experience and expertise in oil exploration, and so were able to bring about a turning point in the oil production of Yemen Republic (6). Eighteen companies worked in 20 oil sectors of the country, and their contracts varied in content so as to suit to their expertise and local facts. Concrete development of exploration took place during 1992-1994, when number of oil sectors got increased to 40 (Table 2 and Fig.3).

The second phase (1990-1994) was the most significant phase when the Oxy Canadian Company explored the largest findings in the South Yemen (Masilah basin), and the French Total company which discovered a large number of promising oil and gas fields in the sector of Jannah.

Phase Three (1995-2000)

During 1995-2000, landmark agreements with well-known companies were made for oil exploration. In the beginning of 1995, an agreement was signed between Yemen Republic and the French Total company. The purpose of this agreement was to explore the

natural gas and the other accompanying liquid gases in the fields of sectors. The oil explorations developed through the period between 1995-2000. This period saw a significant development of oil exploration, especially the period between 1995 to 2000. In this period Yemen was re-divided into new 54 sectors of oil exploration, an area of about 2000-4000 sq. km. In some areas, it was about 4000 to 8000 square kilometres. The total areas under exploration till the year of 2000 reached 236, 0000 square kilometres (5). These areas were also distributed between the oil companies, and a number of agreements were also signed and authorized with some of these companies for more exploration (Fig. 4).

Phase Four (2001-2007)

In this phase the production of oil, exploration, open blocks and total companies increased significnatly (Table 4 and Fig. 5).

Table 2
Exploration of Oil Development - 1992-1994

Block No.	Block Name	Governerate	Area (Sq. Km)	Operating Company
15	Mukallah	Hadhramout	12.570	Oman Strong Hand
16	Qamar	Mahara	10.864	Namir
22	Al Zaidah	Al Hudaiadah-Hajjah	8.151	Adeer
24	Alkathib	Alhuddyadah	10827	Adeer
28	North Behalf	Shabwah	4.465	Adeer
29	South Sanaw	Al Mahara	9.237	Namir
31	South Behalf	Shabwah	13.014	Namir
32	Hwarim	Hadhramout	6924	Kalki
33	Al Furt	Hadhramout-Mahara	6017	Namir
34	Gezah	Al Mahara	7934	Namir
35	Hood	Hadhramout	7.397	Larmo
36	Thmud	Hadhramout	10.660	larmo
37	Mara'eet	Al Mahara	7.221	Larmo
38	Socotra	Hadhramout	17500	British Gas
39	Damghoot	Al Mahara	8777	British Gas
10B	Saar	Hadhramout	1100	British Gas
R2	Sector 40	Hadhramout	2856	Ith Kalid
R3	Sector 40	Hadhramout	2441	Ith Kalid
R5	Sector 40	Hadhramout	737	Ith Kalid
S1	Damis	Shabwah	-	Shell

Source : Yemen Statistics Oil and Gas, Ministry of Oil and Minerals, Sana'a 2004, 2005, 2006

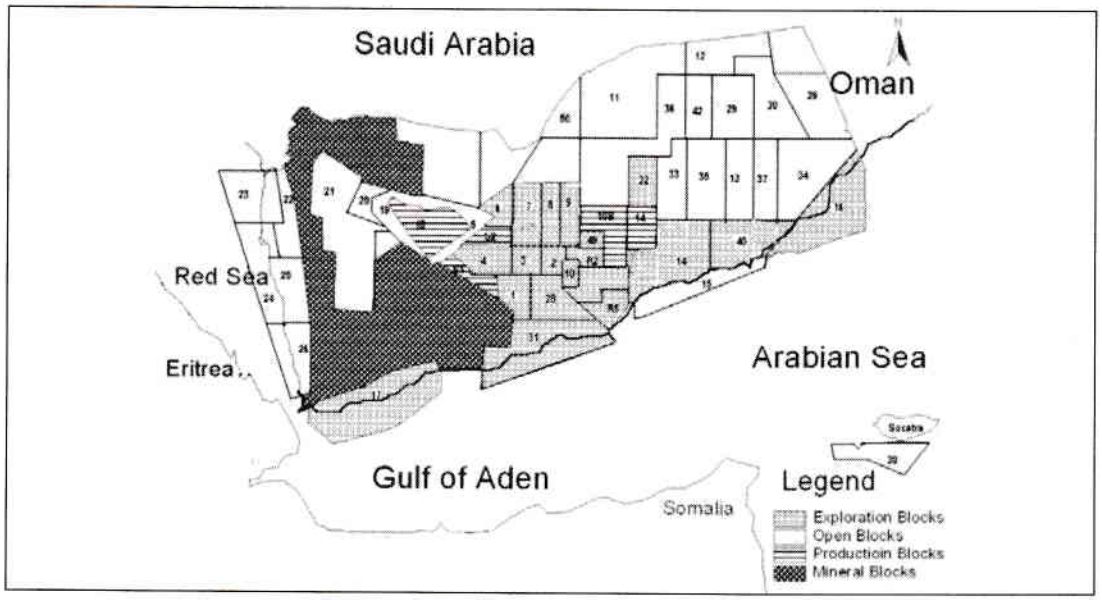

Fig. 3 Sector of Oil in Yemen during 1990-1994

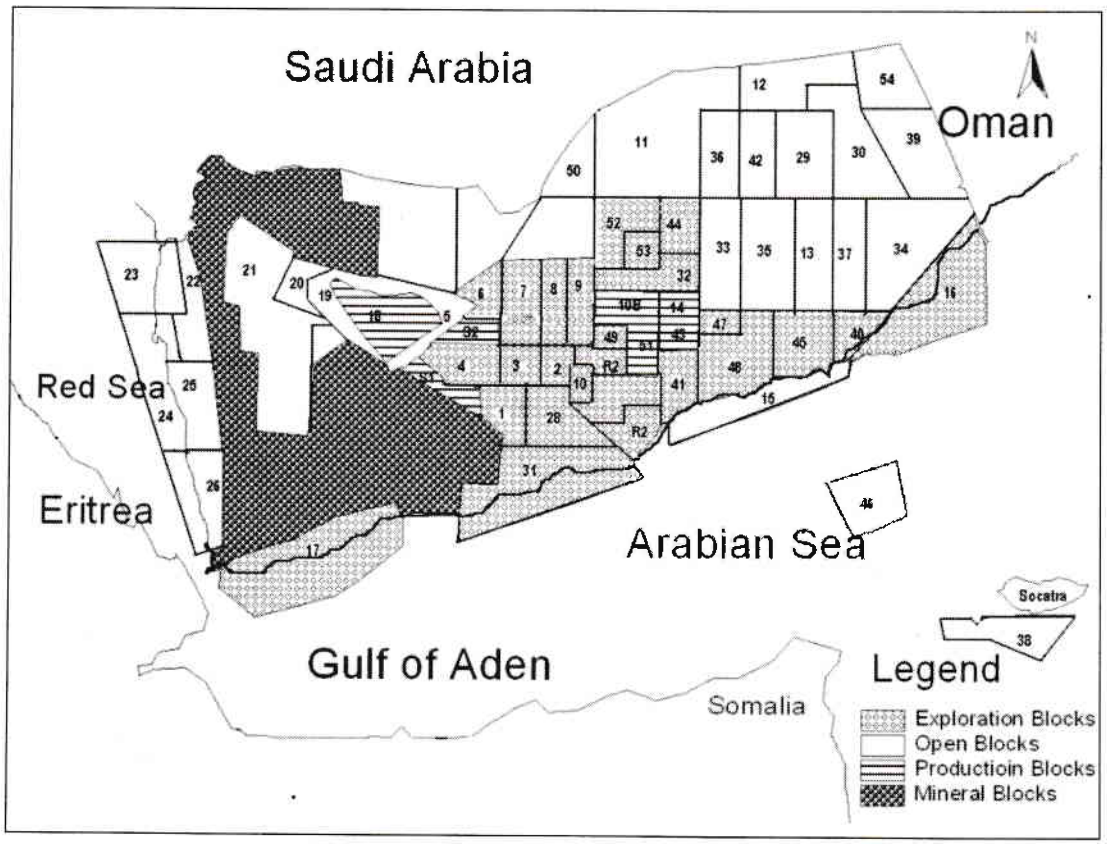

Fig. 4 Sectors of Oil in Yemen during 1995-2000

Table 3
Exploration of Oil Development - Oil and Gas 1995-2000

Block No.	Block Name	Company Name	Govern	Area Sq. km
41	West Mukalla	Oil, gas and minerals	Hadhramount	5492
43	South Hwarim	Oashen Anbargy	Hadhramount	2717
47	South Hood	Oil, gas and minerals	Hadhramount	7606
48	North Mukallah	Moal	Hadhramount	6020
49	South West Mabar	Moal	Hadhramount	3000
50	Hazar	Krimag	Hadhramount	6408
53	E/Saar	Dove	Hadhramount	474
54	Hathoth	Canadean Peroleum	Al Mahara	7412
R2	E/Maabar	AlBikary	Hadhramount	2850
13	Alarma	AlBikary	Al Mahara	7418
12	North sanaw	Canadean Peroleum	Al Mahara	7867
36	Thmud	Canadean Peroleum	Hadhramount	10660
S1	Damis	Pirostag	Shabwah	2000
S2	S2	Fantag	Shabwah	2500
9	Malik	Calkaly	Hadhramount	3530
51	E.AlHajjr	Krimag	Hadhramount	2004

Source : Yemen Statistics Oil and Gas, Ministry of Oil and Minerals, Sana'a 2004, 2005, 2006

Table 4
Evaluation of Oil Development, 2001-2007

Description	Years	2001	2002	2003	2004	2005	2006	2007
Blocks	Producing Blocks	7	7	9	9	11	12	26
	Exploration Blocks	13	24	20	22	20	26	58
	Open Blocks	31	39	49	53	56	49	96
	Total of concessions (Blocks)	51	70	78	84	87	87	11
Companies	Production Companies	7	7	9	9	9	10	11
	Exploration Companies	13	16	14	13	13	16	16
	Total No. of Companies	20	23	23	22	22	26	27

Source : Yemen Statistics Oil and Gas, Ministry of Oil and Minerals, Sana'a 2004, 2005, 2006

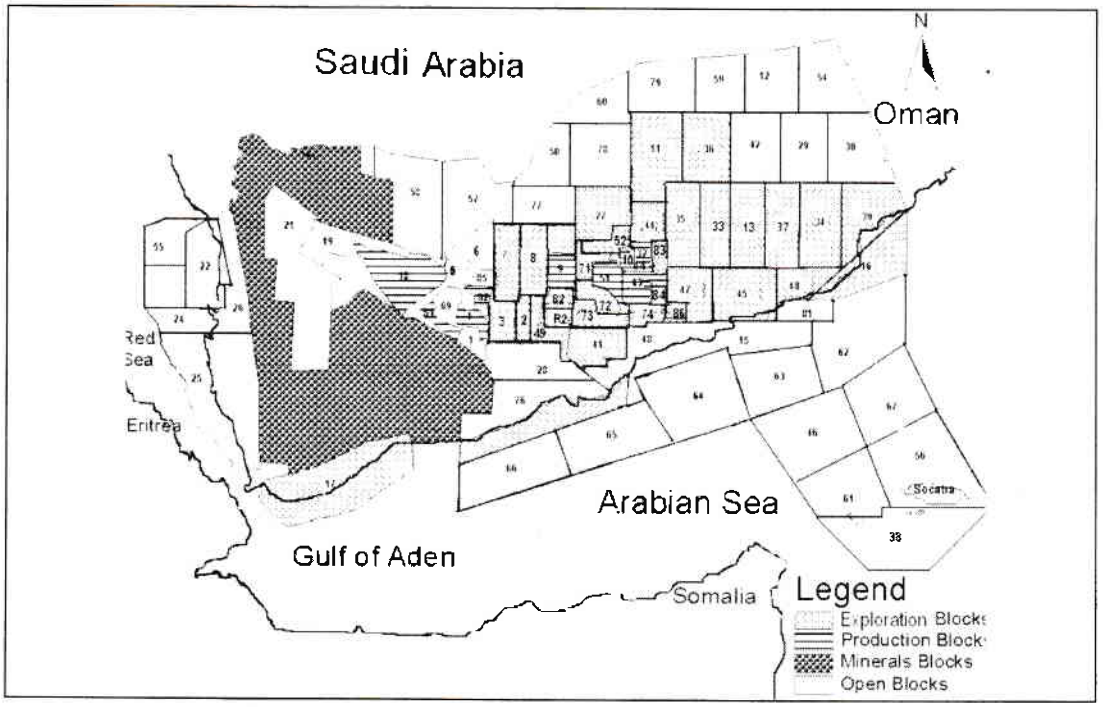

Fig. 5 Sectors of Oil in Yemen during 2001-2007

Conclusion

The analysis of the Oil Exploration and Production in Yemen concludes:

The oil map after the unity of Yemen brought about positive changes and developments in the oil sectors. This led to expand the exploration of oil in Yemen in the land and sea. The agreements with exploration companies increased from 7 companies before the unity to 27 in 2007 distributed in 96 oil sectors.

The total of oil concession sectors in Yemen were 12 in 1980 and 30 in 1990. This increased to 51 oil sectors in 2001and reached 78 sectors in 2003, and 96 oil sectors in 2007.

References

1. **Atif, M. Ali (2002).** *The Oil in Yemen: Study in Geographical Power.* **Sharjah: Sharjah Publication.**
2. **Barakat. A Qaud(1991).** *Oil in Yemen. Al- Afif Publication.*
3. *Yahya .A Alwashaly (2007).Yemen: Study in Politics.*
4. **Yemen Republic Statistics (2004).***Oil, Gas and Minerals.*
5. *Yemen Republic Statistics (2005). Oil, Gas and Minerals.*
6. **Yemen Republic Statistics (2006).***Oil, Gas and Minerals.*
7. Yemen Republic(1994). *Saba News Agency*

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Poverty and Local Livelihoods in Udadumbara Area, Sri Lanka

Poverty affects the quality of life and local livelihoods. World Bank classified Sri Lanka as a middle-income country and poverty is wide-spread among the rural households. In 2002, urban poverty in Sri Lanka was estimated as 6.2 per cent while rural poverty, 20.8 per cent. There have been a number of poverty alleviation programmes being implemented, and according to the Central Bank Report of Sri Lanka, in 2004, 1.9 million families (about 45 per cent of the population of the country) got benefited directly from this programme (Samurdhi). In 2002, the government of Sri Lanka brought a Poverty Reduction Strategy Paper (PRSP), *"Regaining Sri Lanka"*, and six major strategies were outlined in this paper as a foundation for future poverty reduction.They are building a supportive macro economic environment, reducing conflict-related poverty, creating opportunities for the poor to participate in economic growth, investing in people, empowering the poor and strengthening governance, and implementing an effective monitoring and evaluation system.

According to the United Nations National Human Development Report on Sri Lanka (1998), Kandy district, the study area of this paper, recorded the lowest Human Development Index (HDI) value in the country, and second lowest district in terms of Gross Domestic Product (GDP) per capita. Nevertheless in terms of education, health services and sanitation facilities, the Kandy district has attained considerable progress. However, this does not mean that the development in the Kandy district is even. Development is more significant in and around Kandy town and it is poor in the areas beyond the urban fringe of Kandy. Poor development and poverty lead to chain of other problems like unemployment, ill-health, social unrest, and the like. The present study looks into the complexities of development problems and poverty. The objective of this research is to explore the relationship between poverty and livelihoods in rural households, taking a sample village, Madugalla, in Kandy district (Udadumbara Divisional Secretariat Division) in Sri Lanka.

Economic Background of the Area

(Historical Evaluation)

The economy of the area is mainly dependant on agriculture for long. Most prominent agricultural activity was *chena* cultivation. People deforested the area and had their cultivation. Mainly family labour was used for the cultivation and harvest is mainly used for consumption. The system failed in the long run, as it led to land degradation, low fertility of land, land scarcity and labour supply problems.

Paddy cultivation has been the principal activity of the households and it has defined the life style of the people and their culture. It was largely carried out as rain-fed one for long and latter, it was more dependant on irrigation. However paddy cultivation has been now declining due to shortage of water, less profit, long duration of cropping, availability of non-agricultural opprortunities, high cost of farming, increasing pest attacks, and the like. Of course, still paddy cultivation is quite significant; but land owners leave the land for

cropping on some form of rent. During the 70s, tobacco cultivation was introduced and many farmers switched over to it from paddy cultivation. As it was a commercial crop, it increased the economic status of the farmers, thereby upgrading their livelihood quite significantly. Now tobacco cultivation also declines because of resource scarcity and environmental degradations.

Non-farm employment opportunities have grown in the recent years; for instance, there have come a few garment factories, providing remunerative jobs to rural people. There are two main garment factories in the Udadumbara area and they disburse total wage of about 2 million rupees a year to the labourers working in these factories. Increasing income improves the standard of life of the rural and urban people, bringing a lot of changes to their livelihood. People spend more money on food, telephones, household goods, and electrical and electronic goods. Next to garment factories, carpentry industries provide employment opportunities to rural people. There are 13 carpentry units in the study area, and of course, they are large scale ones. There are 10 rice-processing mills, and 8 grinding mills. All of them are small scale ones only.

Assets, Poverty and Living Standard

Standard of life of the people is dependant on a number of factors. Poor with their reduced social capital are more vulnerable. Available assets define the capabilities of the people and their livelihood strategies, helping them to realize desired standard of life.Income of a person plays an important role for building up the capabilities that is to be looked into in the context of poverty. The field data from the study area indicate that two-third of the households surveyed get an average monthly income of about Sri Lankan Rupees (SLR) 2000-5000. Only about 11 per cent of surveyed households receive a higher monthly income (SLR 5000-7000). A larger size of households earn more income, as there are more number of members in the family to work. Of course, it may also be true that larger family size means a larger expenditure too.

Higher income level of some of the households may be related to non-farm employment, especially in garment factories. As per the local government records, there are 17 females and 4 males from the villages, working in the garment factory. But after they started working in the garment factory, their *Samurdhi* benefits are reduced or stopped by the government. However, due to high cost of living, their poverty situation is yet to be changed fully for good in a short period. Some respondents said that their children stopped going to schools, and they get engaged in some jobs like working in garment factories or as labourers outside the village. It appears that parents depend on children too for their economic requirements; and though they want their children to continue their studies, they are compelled to send them for jobs because of economic difficulties in managing the household. Now the parents are worried about their children's missing opportunities and their future. However at the same time, in some households, additional income the children are bringing in, help in overcoming the poverty situation.

Ownership of the Houses

House is an asset for a household and every one wants to own a house. Normally men own

the housing properties, as parents tend to hand over the properties to their sons. Among the surveyed households, nearly 75 per cent of the houses is owned by men.

Electricity and Water Supply Facilities

Electricity and water supply are other two factors to measure the living standard. In the study area, in two-thirds of the houses, electricity is available and in rest of the homes, kerosene is the energy source for households. School-going children find it very difficult to cope with kerosene lamps. Many of the houses in the town do not have piped water supply. About 47 per cent of households use wells for their water requirement and another 28 per cent depend on the water taps located on the streets. Only one fourth of the households have water connections at home. On the contrary, in villages, water scarcity is more felt during dry seasons. Many villagers complain that water supply by the local authorities is not regular, and water is supplied once or two times a week. In dry months of July and August, many of the wells go dry. Irregular and insufficient water supply has an adverse bearing on the day-to-day life of the people both in town and villages.

Sanitation Facilities of the Housing Units

Availability of sanitation facilities at home may be an indicator of living standard of the people. Good sanitation facilities at home mean a healthy environment for those living there. As expected, sanitation facilities are poor in those homes where poor live in. Proper toilet facility is not available in more than half of the households. About 57 per cent of the surveyed households have pit type toilets. Most of the toilets do not have water inside the room. Though some poor houses are in good condition, they do not have good toilet facilities. When compared to the town, Kandy, sanitary facilities in villages around are relatively poor.

Health Facilities and Health Situations of the Area

Health is another parameter to measure the living standard of the people. Udadumbara town has some medical facilities, but accessibility to this town by public transport for the villagers around is not appreciable. Most of the households, about 77 per cent, access the government hospital in Udadumbara town for their medical requirement. In villages, we find the households using traditional medicines too. It is interesting to note that most of the households visiting the government hospital in the town are satisfied with the facilities and service in the hospital; sometime, they have to wait for long to see a doctor, as there may not be sufficient number of doctors in the hospital. It is good that the government hospital is able to provide them a good service to the rural people of the study area, and it is a good sign of development. However, due to poor public transport facilities, villages face problems of accessing the facility of the hospital on emergency. Interviews conducted with households provide necessary data to assess the health conditions of the households. Many visit doctors once a month due to some diseases of their family members. Three-fourth of the households have visited the hospital to take medical facilities once or more than once during. It may indicate that health of households may not sound well.

Social Assets

According to the livelihoods approach, social

networks are also important in assessing the living standard. Social network allows the people in public participation, thereby leading a joyful and enduring life. From the field survey, it is noted that poor households find some difficulties in maintaining their social relations, and as they are not in a position to contribute any fund towards social functions which villagers arrange once in a while. One female respondent comments like this:

"You know that we do not have enough income for even maintaining our day-today life. Sometimes we have to offer some amount of money for public activities in the village. We know that giving away some thing is a good thing. But if we do not have even for us how can we give away? I am thinking about the festival in the village temple which is going to take place next weekend. I have to contribute some money for that, but at the moment I do not have money to spare, and I am embarrassed as we have to continue living in this village..."

However according to the key informants and interviews with *Samurdhi* beneficiaries, there is no discrimination of the poor people in the village. But poor themselves feel shy and bad for their difficulties for not making their share available to temple festivals. In terms of social network, the village has a considerable good social relationship among the villagers, and they are ready to help each other.

Livelihood Strategies of the People in the Study Area

It appears that poor have learned to live with poverty. They manage their available assets and capabilities to maintain their living, and in the process, they developed livelihood strategies. Livelihood strategies are the activities undertaken by poor households to provide a means of living. The main goal of these livelihood strategies is to ensure the households economic and social security. These strategies are influenced by their economic situation and their position in the society. They follow multiple activities to escape from poverty; farming is the principal activity; to augment the income, they work in garment factories and as casual labourers; they may promote their own small enterprises; they pawn their assets and borrow; and even they get engaged in illegal liquor preparation.

Sustainability of Livelihoods Strategies

There are good opportunities for generating non-farming activities in Udadumbara area but in the village studied, Madugalla, opportunities are not many. In the Udadumbara Divisional Secretariat Division, nearby forest area provide various possibilities for jobs. Collection of wild flowers and medicinal plants, bee honey collection, home-made garments, toddy extraction, tourism-related activites may form some of the livelihood activities to the people living near to forests.

Evaluating the *Samurdhi* Programme

Samurdhi programme was introduced in 1995 to improve the living conditions of poor families by strengthening the rural production base. It includes an income supplement programme, food subsidies, social security programmes and saving programmes for poor families. According to the Grama Niladhari and the Samurdhi Development officer, 72 households received Samurdhi benefits in Madugalla (North). It constitutes about 61 per cent of the families in the village.

Sixty per cent of the surveyed households receive SLR 400 value of *Samurdhi* benefits. From the secondary information and field visits, it is understood that poor who get benefit from the current *Samurdhi* programme, received benefits from the earlier poverty alleviation programme, Janasaviay and food stamp scheme. This reveals the chronic poverty situation in rural areas in Sri Lanka. Though poor received food stamps and Janasaviya, they could not overcome their poverty. Does this mean no end to the poverty or is it a weakness of the poverty alleviation programme or both? The question can't be answered easily. This happens due to weaknesses in the poverty alleviation programmes and in the way the rural economy has developed. Successive governments of Sri Lanka introduced schemes of poverty alleviation with new names. About 54 per cent of the current *Samurdhi* beneficiaries had received Janasaviya. Other 20 per cent were the beneficiaries in both Janasaviya and Food Stamp. Only 6 per cent had received benefits from the Food Stamp system only. This implies that poor are trapped in poverty cycle and it is not easy to escape from it.

Sufficiency of the Current *Samurdhi* Benefits

It is interesting to note that 91 per cent of respondents answered that the benefits received from *Samurdhi* programme were not enough to overcome the poverty. If *Samurdhi* benefits are compared with present cost of living, it is only a subsidy those poor people receive for maintaining their life. It is obvious that *Samurdhi* benefits are not enough to maintain or fulfill household necessaries throughout a month. All the respondents feel that they should get the sufficient amount under *Samurdhi* scheme for their monthly requirement. But most of the respondents think about their responsibilities for a better living.

People's Plans to overcome Poverty

Poor may have plans to overcome the poverty, and it is tried to assess these plans from the field interviews. Many think about plans but they could not initiate any one of them due to various constraints. Some thought about self-employment like a petty stall in front of their houses, poultry farm and the like. Still they could not materialize their ideas. One female respondent thinks about a plan like this: *"I continue to think about how I can escape from this terrible problem. But I could not visualize a good solution to the problem. Now I have some hopes on my younger children. They are about to leave from the school. Fortunately, I could give them a good education with a lot of difficulties. So after they leave the school, they will be able to have a good job out side the village,and I hope that they may be able to upgrade our family situation"*

It seems that her plan was to give a good education to her children in the hope that they rescue her from poverty.. But can we think of her plan as a proper one to overcome poverty? If her children were not able to attain good education, what will happen to her plan? Further, after they finish their studies, if they could not get a good job, they have to live in poor situation.

Another respondent said: *"You know that the main problem we face at the moment is low income of our families. So I think if there is a training programme for the poor people like us on some kinds of profession such as mason,*

carpentry, small industries etc. it will help us to increase our income"

It is a good plan in terms of overcoming their poverty situation. However if they had such a training, their progress will also depend on the availability of such working opportunities. Finally it seems that there are no more plans with poor people in the study area to escape their poverty condition. However, their thoughts will help to develop some useful livelihood strategies. Certainly poor requires guidance and training to find a way out. Government and other institutions should promote job opportunities for people with different skills. Poor do not have any funding sources for establishing some self-employment. Level of education is yet to be improved among those in the village looking for non-farm activities. Income-generating opportunities are less in villages. Natural endowments of the village and human capabilities of villagers have to match so that poverty-reduction is possible. Social relation in the village is reasonably good and this can be profitably exploited for improving the livelihood of the villagers.

Conclusion

Farming is the main occupation of the village studied. General health conditions are not bad in the village studied, though accessibility to government hospital by public transport is not good. Water supply to the households is quite erratic and undependable. Especially in dry seasons, water scarcity is wide-spread. Poverty seems to be a chronic problem in the study area, and the government has been taking a number of initiatives to reduce the poverty in the villages. Benefits from these government-sponsored schemes like *Samurdhi* are not sufficient in the context of current cost of living. So savings of the households that encourage investments are negligible. Poor households are not thus in a position to plan livelihood strategies so that they can come out of poverty. Main reason for poverty thus seems to be the non-availability of opportunities in the villages for increasing the household income. Non-farm activities should supplement the farm income and that may help the household to escape from poverty. Garment and furniture factories do provide this opportunity to some extent. In the meantime, villagers should get some guidance and training in getting different skills for the job market.

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The Place of Spaces in Internet Matrimony

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The Internet is facilitating and changing the ways in which people find potential mates. This paper explores the interwovenness and interactions between cyberspace and geographic space in the contexts of Internet partner search. Specifically, various constructions of identity and forms of self-presentation are spatially charted. The concepts of bridgespace and cyberpossibilism are applied to data collected from an Indian Matrimonials website and are used to understand the ways in which online self-presentation is situated between virtual and physical places .

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Numerous commentators have put forward positions that modern communication technologies will render physical distance and thus physical space meaningless [8, 41]. However, social theorists such as Manuel Castells and Stephen Graham [11,22] posit against notions that computers are able to create aspatial alternate spheres of social relations, arguing instead that a variety of constructions of self are brought to cyberspace from culture at large. Thus, a variety of spatially-grounded identities, which are attributed to everyone in cyberspace, are selectively employed according to their context [60].

One increasingly important manifestation of this is the way the internet is facilitating and changing the ways in which people find potential mates. The range of activity encompasses both socially acceptable relationships and the means to pursue

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marginalized social relations. This paper explores the interwovenness and interactions between cyberspace and geographic space in the context of Internet partner search. Specifically, various constructions of identity and forms of self-presentation will be spatially charted.

Cyber-possibilism

The forces that constrain and enable human agency in cyberspace can be thought of in terms of 'cyber-possibilism.' This term is used to provide a way of understanding identity construction and presentation in cyberspace that is similar to the 'social affordances' described by Wellman (63). The concept of social affordances speaks to the notion that physical properties of media affect the interactions that can be made through them (19, 42). Cyber-possibilism likewise accepts that the presentation and construction of identity in cyberspace is in part shaped by the physical (or virtual) properties of cyberspace. Specifically, I use the term to describe a conception of identity representation in cyberspace which allows for fluid and ephemeral, yet spatially and socially influenced and centered representations of self (17, 67). In other words, the dual forces of cyberspace and geographic space that many people inhabit provide constraints, and some degree of causal power, over identity formation, construction, and presentation, but also afford a range of possible outcomes for the people who inhabit those spaces.

Obviously the societal and cultural forces enabled by the space of places can only explain a limited amount of differences in the content of self-presentation. Previous studies have found age (45), sex (30, 65), race (46), sexual preference (52, 53), socio-economic class (14), and indeed geographic location (35) all to be factors in explaining variance in the content of self-presentation records. Yet, the work just mentioned is part of a limited body of existing research which attempts to draw causal or relational links between personal attributes and aspects of self presentation. Much work has instead chosen to focus on how various personal attributes affect the desired attributes of a mate during partner search (5, 9, 10, 39, 47, 48).

This paper begins with a review of various positions on the causal relationships between technology and cyberspace, and place-based processes. The ability of the Internet to foster or enable rich and romantic forms of social networking will then be examined. In order to engage with the larger question of the relationships between cyberspace and geographic space, this paper will focus on a specific research topic; namely the content of self-presentation posted by users of an Indian matrimonial website.

Flows and Places

Some of the first commentaries on the effects of cyberspace (and indeed technology in general) hypothesized that the space-transcending ability to communicate afforded by technology would eventually render geography meaningless. Heilbronner posited that certain forms of technology would necessarily result in particular forms of societal organization (27). An argument based on similar premises, namely the formidable causal power of technology, is presented by Gillespie and Williams in partial reaction to the ability to engage in non-proximal instantaneous communication (20). They

argue that the convergence of time and space brought about by communication technologies will eliminate the geographic frictions which help to shape spatial differences. Cairncross argues that time-space compression renders many traditional geographic, economic, and sociological theories void and has the potential to fundamentally alter society (8). It can de-centralize space and transform any form of agglomeration into a mere holdover and relic of the past (44).

There are two inherent flaws in such technological deterministic reasoning. First, even upon acceptance of a technological determinist ontology, space continues to have significance. Spatial differences endure, because, far from being uniformly distributed, communication technologies and opportunities for production and consumption have a distinct geographic bias (11, 15, 59, 66). Furthermore, we do not interact solely through communication technologies and so the frictions of distance inherent to non-technologically enabled interactions remain relevant. The spatial distances still present in human relations continue to foster and nurture cultural differences.

Secondly, monocausal positions such as technological determinism can rarely account for the myriad complexities embedded in any cause and effect relationship. Many approaches to social science research have long since moved beyond purely deterministic ontologies and monocausal explanations to recognize the limitations of scientific methodologies in understanding and tracing every cause of an occurrence in space and time.

A variety of positions has been put forward to provide a non-deterministic framework for understanding the relationships between technology and society, or more specifically between place and cyberspace. Stephen Graham argues for complex and parallel considerations of electronic and physical propinquity (22). Technology is described as a supplement to place-based existence and communication rather than a replacement. So, while communication technologies have the power to redefine distance, they are unable to cancel out geography, and as a result we live in a state of suspension between our de-localized presences and our physical existences (11, 50). Warf approaches cyberspace by envisioning it "as a socially constructed discourse that simultaneously reflects and constitutes social reality" in order to focus on the social outcomes it brings about (62). Kitchin draws on similar ideas by recommending that cyberspace be conceptualized as existing in a symbiotic relationship with geographic space (31).

In reference to the discussion regarding the relationship between place and cyberspace, Castells distinguishes between a space of places and a space of flows. The space of flows joins all connected places within the global network. The space of places, on the other hand, is defined by the distinct characteristics of localities (12).

It is in a hybrid space between the dual forces of flows and places (and dependence and engagement) that our lives, personalities, and cultures are situated (68, 69). This is not to suggest that society can be explained in its entirety through the push and pull of spaces of dependence and engagement and places and flows. To do so would be to fall back into a

form of monocausal explanation. The complex, non-linear, and inherently human nature of all people who inhabit hybrid spaces complicates any sort of deterministic grand theory. Furthermore, dividing the world into ontologically separate categories of place and flows or dependence and engagement is not an attempt to construct arbitrary categories or deny the 'hypercomplexity' of space (33). The hypercomplexity of space should not deter us from "attempting to construct theoretical vocabularies through which to decode critically some of its main dynamics and contours" (7). Thus, using the distinct categories of space outlined by Castells as a theoretical framework in a study of the content of records of self-presentation will allow some understanding of the influences of the spaces of flows and places on people who live in the space of places but communicate and present themselves to others in the space of flows.

Identity

New and non-traditional social spaces exist and are constantly being created in cyberspace (40). Cyberspace frees the human body from some elements of its physical and spatial constraints, and alters the social construction of identity (37, 56). Various aspects of identity can also be explored, altered, and masked in communications through cyberspace (17, 64). However, this does not mean that computers are able to create aspatial alternate spheres of social relations, as a variety of constructions of self are brought to cyberspace from the space of places (25, 58, 60). So, while identities cannot be entirely freed from their physical (and thus spatial) ties, it remains that they can be selectively employed in cyberspace according to their context (60). This conception of identity representation in cyberspace, hereafter referred to as cyber-possibilism, allows for fluid and ephemeral, yet spatially influenced and centered, representations of self (4, 17). Or, in other words, our identities, as presented in cyberspace, are in a constant state of flux between the space of flows and the space of places (16, 31).

All aspects of presented identities within this flux are not consciously constructed. The complex nature of language and visual images means that while major or obvious elements of profiles are presented for a specific purpose (perceived truth statements, references to one's credentials or authority, and the desire to appear appealing to potential mates), much other information is given off by the posters (21, 49). People leak information that can send textual and visual clues to profile viewers. Much of this information which might not have been consciously considered by the poster of the profile (such as language usage or visual cues in photographs such as a person's haircut or jewelry) is used by both the poster and viewer to judge another's cyber-presence. This is particularly crucial in matrimonial or dating sites where potential interaction partners are identified.

This means that identity cannot be explained in a framework solely in terms of its situated state between place and flows. The relationships between identity and the manner in which it is represented, and the myriad forces of places and flows are fundamentally gordian. However, the absence of a guiding positivist framework should not preclude an attempt to establish an interpretation and understanding of various ways in which places and flows influence identity.

The Internet and Social Networking

The primary reason that most people use the Internet is to communicate with other people. The maintenance or creation of interpersonal relationships is the goal of most of this computer-mediated communication (3, 24). However, interestingly, computers have often been referred to as unsuitable tools for engaging in rich or nuanced communication. This is largely due to the absence of traditional non-verbal cues of interaction and the perceived impersonality and insensitivity of the medium (54). In other words, the nature and structure of the Internet is thought to limit the usefulness of the communication that occurs through it (54, 55).

This position is challenged by Walther and his model of hyperpersonal communication (61). The hyperpersonal communication model states that online relationships can be more social and intimate than face-to-face relationships, because online communicators have a large degree of control over their self-presentation (28, 61). Empirical research has shown that relationships with high levels of intimacy can be formed through computer-mediated communication (43), that relational intimacy increases at a faster rate in computer-mediated communication than in face to face interactions (28, 38), and that the Internet can have beneficial effects on already existing relationships (6). Yet, while the Internet may foster a greater degree of intimacy, the commitment to and seriousness of those cyber-relationships has been found to be lower (13). This 'flash-intimacy' is perhaps a source of the conflicting understandings of the suitability of computer-mediated communications for intimate relationships. Outside the realm of theoretical discussions, and regardless of the particular merits of computer-mediated communication, millions of people globally seek to establish interpersonal relationships via computer-mediated communication on websites dedicated to partner search (23). Social networking websites exist along a spectrum of specificity. A core feature of all of these sites is the ability to search for a partner based on personal attributes and geography. The ability to specify and search for interests, abilities, and traits of a desired partner allows users to transcend their social and spatial lived constraints. The 'Vice President of Romance' at Match.com succinctly captures this trend by commenting that "we bring people together who share core values and a lifestyle but who otherwise would never have met" (57).

Methods

The cyberpossibilist theory of self can be empirically examined on a general and aggregate basis by studying instances of self-presentation (profiles and photographs) on Internet websites. Meta-level spatial differences in the content of profiles and photographs would shed light on the continuing embeddedness of Internet users in the space of places, and would elucidate specific geographic constraints. Broad similarities would hint at a growing influence of the space of flows in the daily lives of Internet users and speak to the space-transcending and enabling properties of cyberspace.

An Indian matrimonials website has been selected over other types of partner search websites for three reasons. First, this project builds on research by Adams and Ghose relating to 'bridgespace' (2). Bridgespace

refers to links and cyberspaces made possible by people and ICTs that connect and facilitate flows between non-contiguous geographic spaces. Adams and Ghose point out that it is important to recognize that "bridgespaces do not create links between places; links are created by people ... thus bridgespace is an environment, not an actor" (p.420). Furthermore, it is an environment that can be framed within cyber-possibilism. A bridgespace puts constraints on human possibilities, but also provides a wide range of possible or probable outcomes (1, 2).

Second, the current IT boom and rapid economic growth in some segments of Indian society mean that a study of the content of self-presentation can be conducted within a framework of a relatively recent overlap between spaces of flows and spaces of places. Finally, it is assumed that users of matrimonials

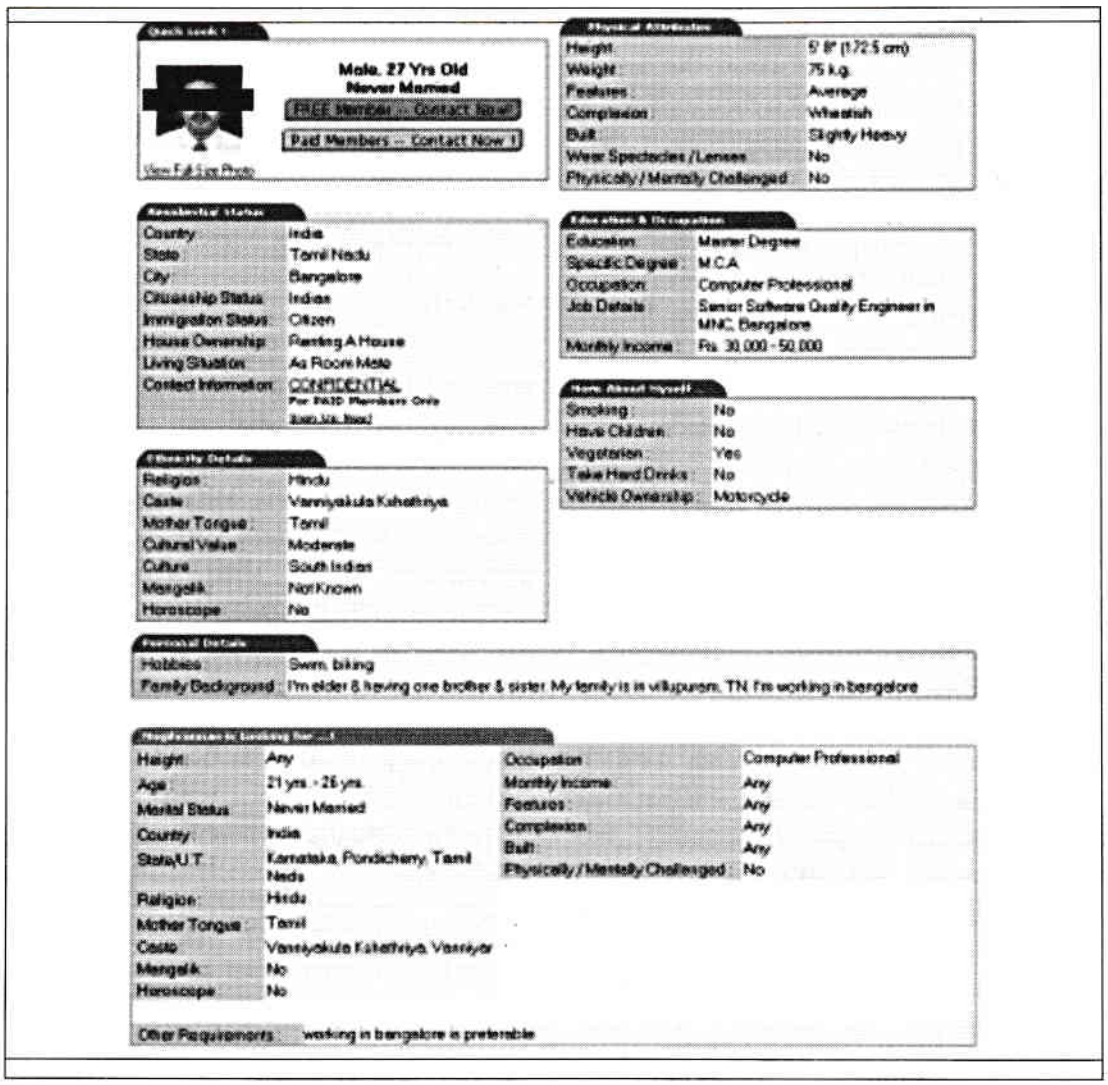

Fig. 1 Screenshot from MatrimonialsIndia.com

websites are more resolved in their commitment to finding a partner than users of dating websites, and therefore more serious about their self-presentation.

All partner search websites also allow profiles to be posted by members. Participants are able to choose responses from a number of closed-response questions, upload a photograph, and often provide open-ended essays to describe themselves and the desired criteria of a partner. A computer programmme has been written to download 20,000 profiles from www.MatrimonialsIndia.com and parse them in a database. A random number generator is built into the programmme in order to minimize potential bias. The profiles contain information about physical appearance, geographic location, religion, caste, and a variety of other personal descriptors. The profiles also list traits and characteristics that the profile owners are looking for in a partner. As an example, a screenshot of record 65776 is presented in Fig. 1.

As part of this analysis, all entries in the database have been graphed based on four variables: geography (country and Indian state), sex, and citizenship. While these descriptive summaries reveal larger patterns and an understanding of the demographic characteristics of website users, they provide relatively little insight into the cultural contexts which produced the records. A content analysis has thus been used to examine photographs uploaded to the website.

Content analysis has been chosen as a methodology because, although it is recognized that objectivity is a slippery and elusive goal, content analyses remain more replicable and less subjective than other visual methodologies, such as semiology, psychoanalysis, and discourse analysis, while at the same time allowing observations and interpretations to be made and extrapolated from the results. It is recognized that a detailed analysis of the textual data in each profile would be similarly useful in gaining insights

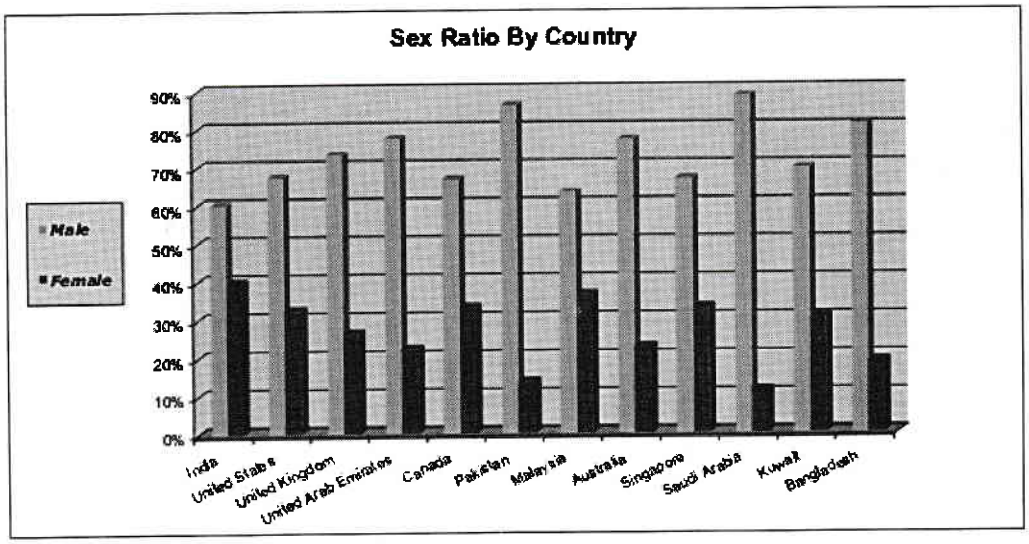

Fig. 2 Sex Ratio by Country

into the content of profiles, however such an analysis will be conducted at a later stage of this research project.

In summary, this study is intended as a first step to empirically understand cultural impacts of the Internet. General differences in the self-presentation of people from different geographic regions would lend support to the continuing relevance of the space of places within the space of flows, while broad similarities would speak to a growing influence of the space of flows in the daily lives of Internet users.

Findings

Fig. 2 displays the sex ratio by country of residence. In all countries there are more men than women registered on the website. The smallest disparity is in India, with about 60% males and 40% females. It can be seen that men outnumber women in every country and state, but more dramatically so outside of India itself. The number of male Indians who work abroad is (and historically has been) larger than the number of females who leave the country for work (26, 36). This suggests that these men lack a sufficient pool of potential spouses in their resident countries and so turn to the Internet to increase the number of potential brides they can meet. It thus seems that the sex-disparity of Indian emigrants is a major impetus in the creation of this specific bridgespace.

The strength of this bridgespace can be seen upon an examination of self-reported cultural values. Users of the website are asked to specify their cultural values and are given three choices: conservative, moderate, and modern. When the responses are graphed by country (as shown in Fig. 3) metalevel similarities are observed between the ratios of people who identify with the three available values. For example, self described conservatives comprise less than ten percent of members; this holds true in every country ranging from the United Kingdom to Bangladesh to Saudi Arabia. These cultural

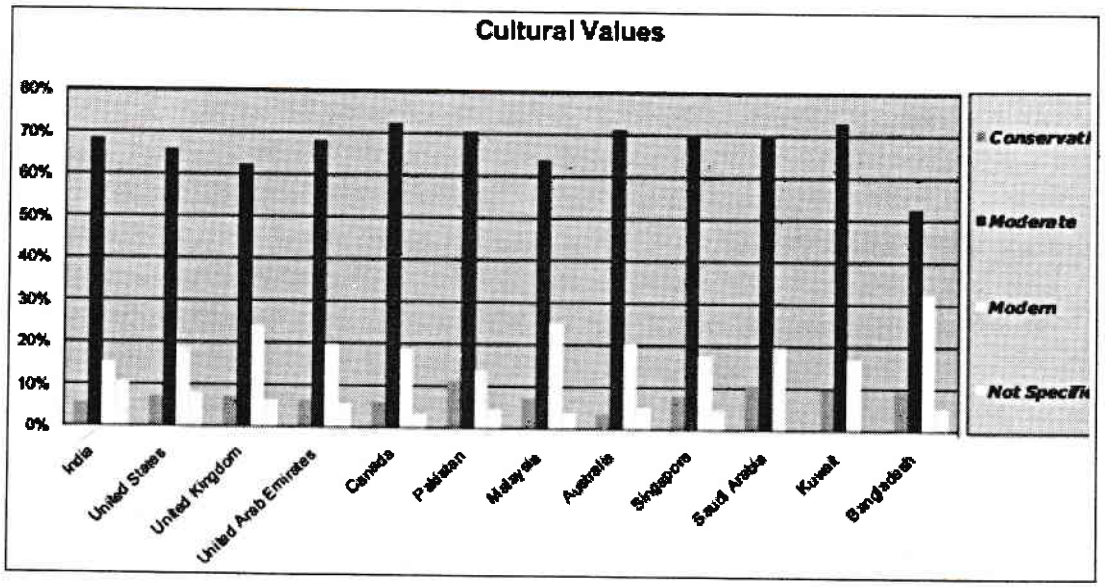

Fig. 3 Cultural Values

breaks into which people assign themselves are staggeringly similar in various parts of the globe. Characteristics of specific places, on both a small and large scale, have relatively little impact on the ways in which people assign themselves into the three cultural categories.

However, another explanation for the general similarities in cultural values across the globe may be the paucity of categories to choose from. Most website users might be characterizing themselves as 'moderates' in order to appear as middle-of-the-road as possible in order to maximize the number of potential partners that they appeal to. By looking at the same data with 'moderates' removed, spatial variation clearly can be observed (Fig. 4). Without proving root causes for this relationship, it can nonetheless be seen that the space of places correlates onto this aspect of identity representation.

Members of the website are also asked to post various information about their physical attributes. Some of this information such as height and weight is relatively non-subjective in that it, to some degree, reflects some objective measure of a person's physical appearance (height and weight are reported in cm. and kg.). Other information, such as a description of features (the options are sharp, beautiful, handsome, and average) is more subjective and socially influenced. Member's descriptions of their features have been graphed by state and separated by sex, owing to the significant role sex plays in the description of physical features (Figs. 5 and 6). It should be pointed out that a mapping of self-reported physical characteristics by sex does not push this research into the traps of essentialism and naturalism long cautioned against by feminists and anti-racists (29, 32). It cannot be denied that information posted on the website is imbued with essentialist qualities. However, the categorical and somewhat essentialist nature of this information should not preclude a study of it. Furthermore, the conclusions of this research

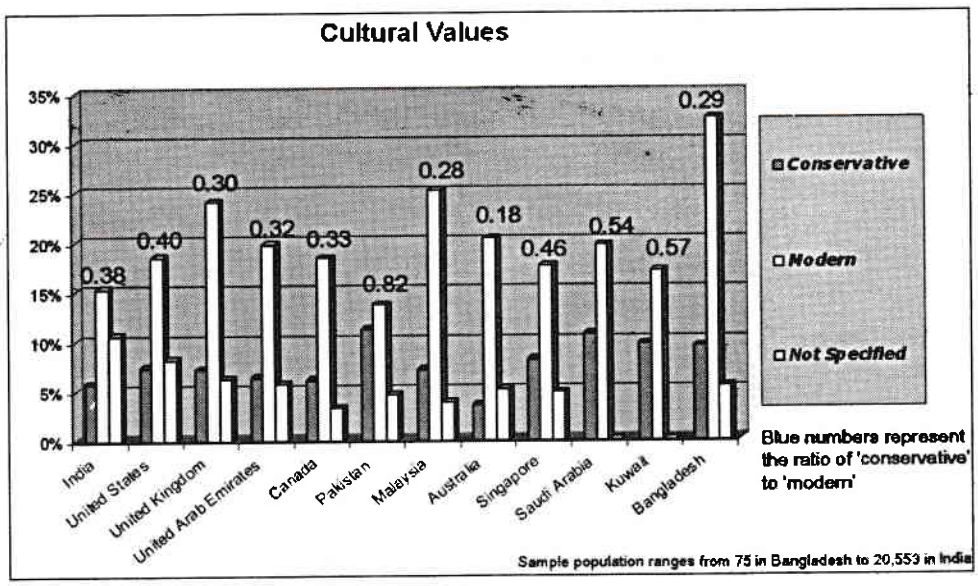

Fig. 4 Cultural Values (2)

by no means ascribe immutable qualities to groups of people based on their race or sex.

Within India a striking geographic pattern is observable in the self-description of features. Women in northern states have a higher chance of being listed as 'beautiful' and a lower chance of being classified as 'average' than women in southern states do. Similar patterns can be seen in the physical descriptions of men. The north-south differences, by Indian state, observed with female members, are less pronounced and clear with male users of the website. The geographic distinction can, however, still be seen: there are a larger percentage of men

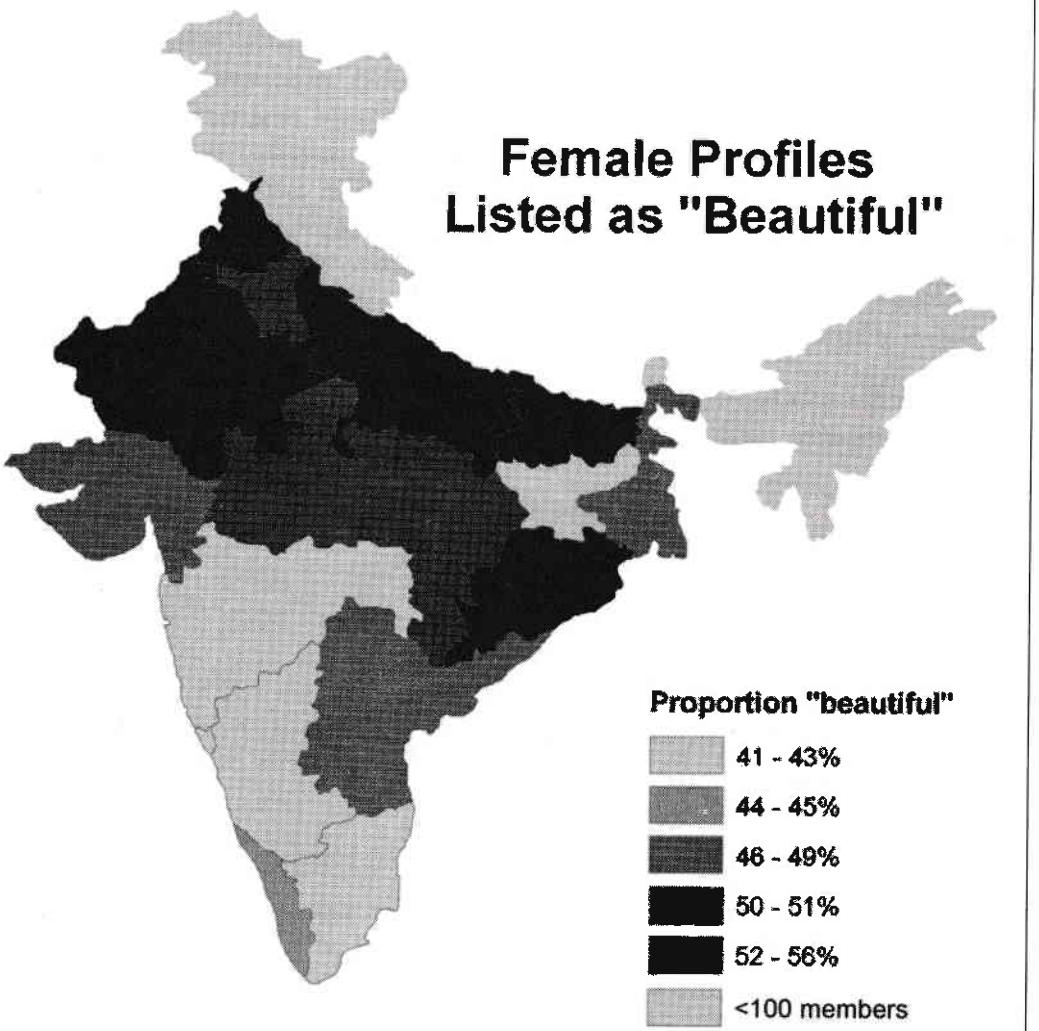

Fig. 5 Female Profiles - Listed as beautifil

described as 'handsome' in the north as there are in the south.

Self-reported complexion of members exhibits a similar north-south pattern (Fig. 7). Most Indian nationals would agree that Indian society generally defines people with lighter skin as being more beautiful or handsome than people with darker skin (2). Statistical correlations of 0.69 and 0.61 at the state level exist between fair complexions and being self-reportedly beautiful and handsome- respectively. Indian attitudes relating to the relationship between skin colour and physical beauty are clearly reflected in members' profiles. Place-based cultural trends are thus being reproduced within cyberspace.

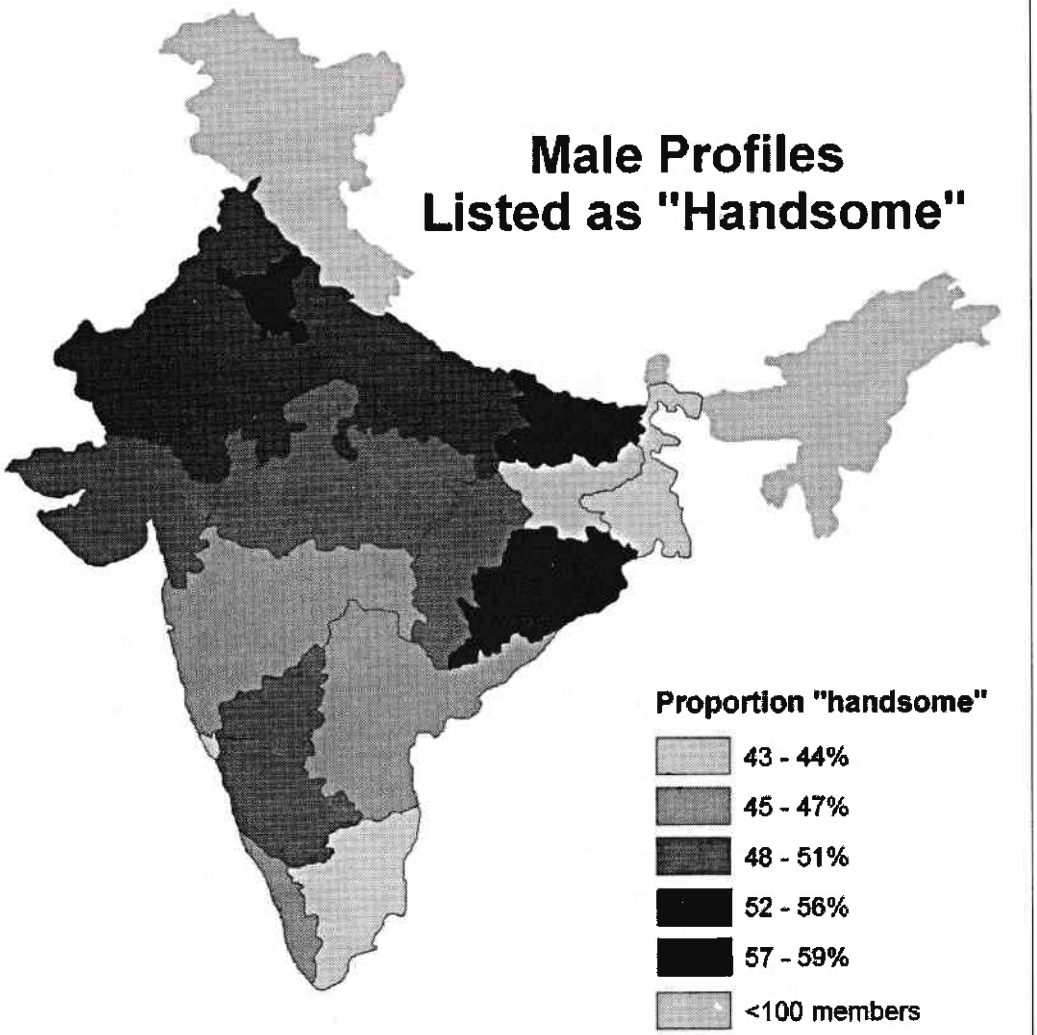

Fig. 6 Female Profiles - Listed as handsome

Visual Analysis

Following Gillian Rose, four steps are used in the content analysis: finding images, devising categories for coding, coding the images, and analyzing the results (51). I decided to combine two sampling strategies to select images from the database. Stratified sampling was initially used to sample from geographic subgroups (Delhi, Gujurat, Kerala, Punjab, and the U.S.) within the database. Systematic sampling was then used to select the first 50 photographs in the database from each of the five regions. Each sample consisted of 25 females and 25 males, resulting in a total sample of 125 females and 125 males.

Twenty-five pictures were randomly selected from the stratified sample of 250 photographs

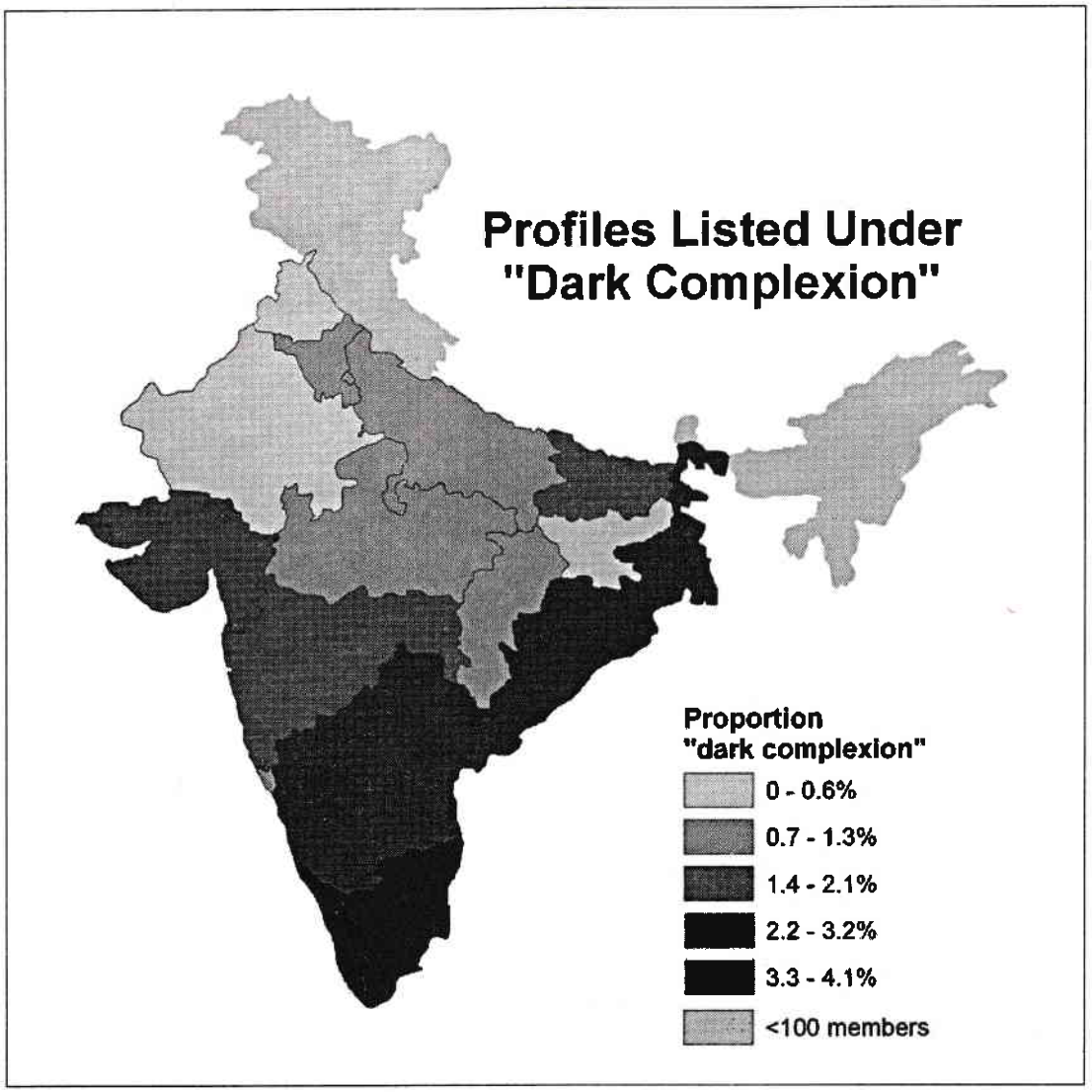

Fig. 7 Profiles listed under Dark Complexion

and thoroughly studied in order to assign all noticeable differences into categories. A number of these categories were chosen because they represented dialogs that the images appeared to be telling.

A binary coding system was employed, and a value was only assigned to a category if that category could be clearly observed in an image. Thus, a value being absent from a category does not necessarily mean that an element is not present; it could also indicate that the element in question is partially obscured, blurred, covered, or made unclear in any number of other manners.

The place-based differences in virtual self presentation revealed through the visual content analysis are presented in figures 8-10. Most surprising were the meta-level similarities between photo backgrounds, clothing styles, and facial expressions across diverse geographic areas. Nonetheless, a few differences can be noted in the results. Users of the matrimonials website in the U.S. are significantly less likely to have a picture taken indoors or in a photo studio than users in India (Fig. 8). Perhaps unsurprisingly, American-based users are more likely than Indian- based users to wear western clothes (Fig. 9). Thus, despite the search for Indian matrimonial partners, this suggests that Indians living in the U.S. are integrating, to some degree, with American culture. Users of the matrimonials service in Delhi and the U.S. are more likely to be smiling than users in other states (Fig. 10). More than half of users of the service in the U.S. who are smiling have their mouths open, while users of the service in India tend to display more reserved smiles. These three charts suggest that general Indian cultural norms exist that are not overly influenced by more local cultural forces within India. It could further be argued that the variation in content displayed by pictures of people in the U.S. could be attributed to a relative isolation of the subjects from Indian culture and a simultaneous immersion in American culture. The non-photographic data collected from the website supports these ideas; however, subsequent research is clearly necessary to test any claims.

The Place of Space

The analysis of profiles and photographs has

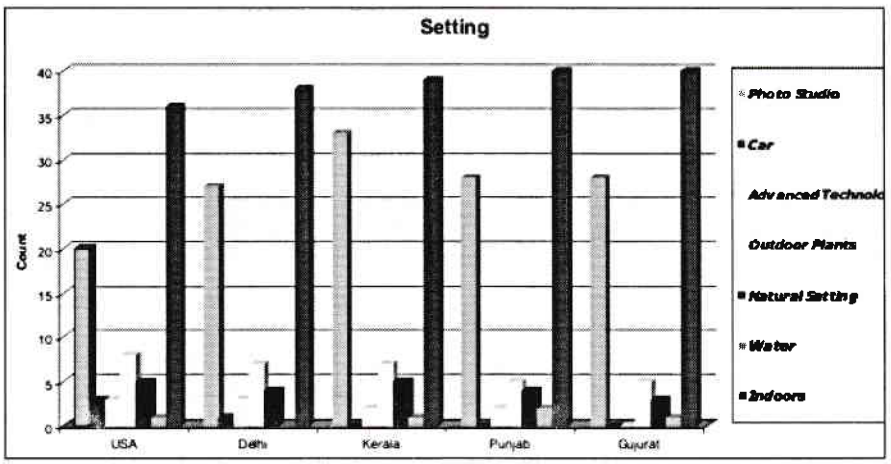

Fig. 8 Setting of Photogrpahs

revealed both a number of similarities and differences by geographic regions. The distributions of members' cultural values are very similar between countries and states. At the same time, spatial differences, probably highly influenced by common cultural attitudes regarding skin colour, clearly exist in the descriptions of physical attributes. Photographs likewise reveal broad metalevel similarities in content, while, at the same time, expressing minor regional differences in content.

Before conclusions can be drawn, a number of gaps in this project will be discussed. First, this specific matrimonials website (like all-websites) is assumed to have a demographic bias. Yet, even with a representative sample of all Indians connected to the space of flows, this study ignores other cyberplaces in which identity is presented and constructed. Future research should address this problem by exploring further matrimonial and dating websites. While the reliance on one website is

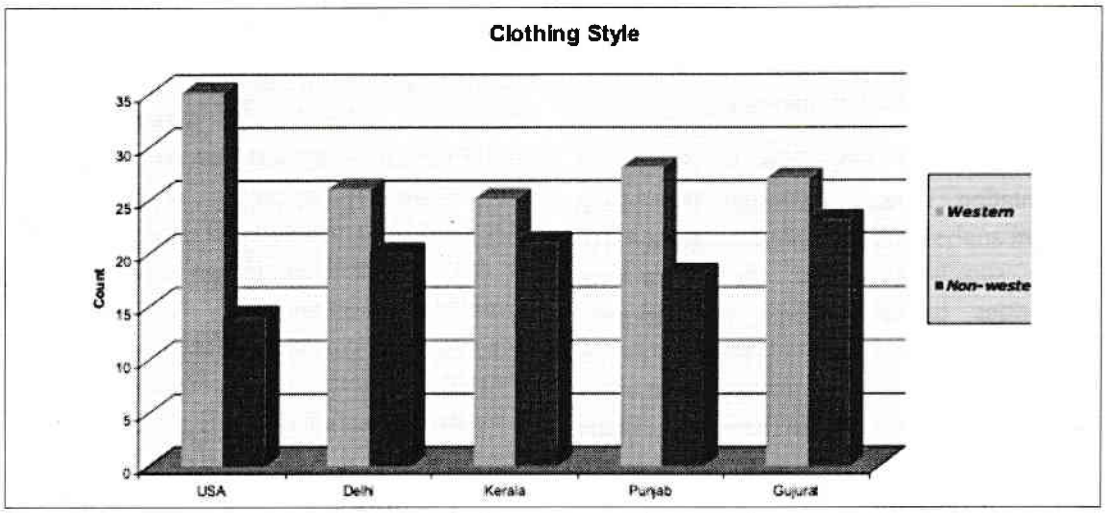

Fig. 9 Clothing Style in Photograph

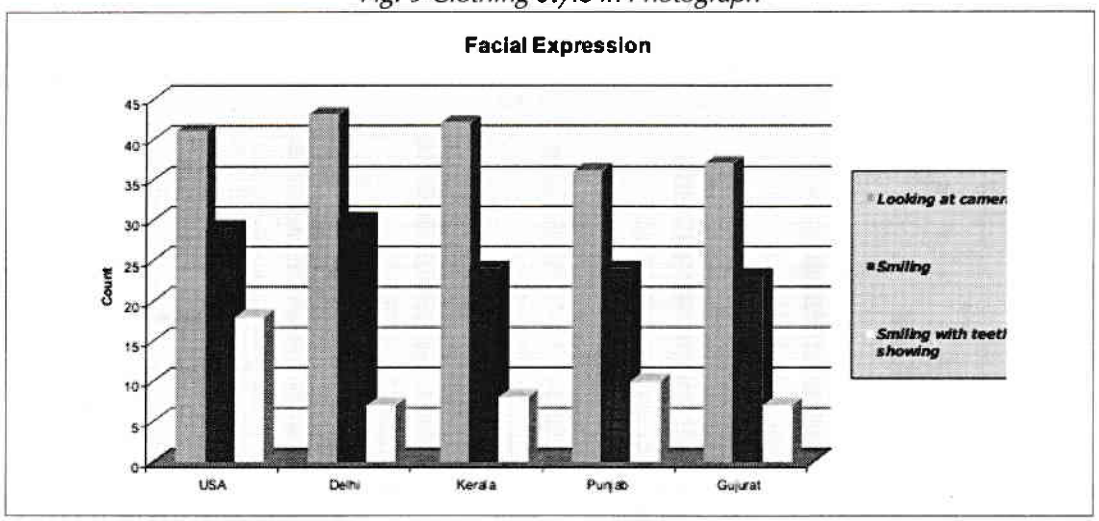

Fig. 10 Facial Expression in a Photograph

a concern, it does not negate the situatedness of the studied identities between the space of places and the space of flows. An even more promising research strategy would be to talk to the profile owners and study their open-ended answers listed on the website in order to move beyond closed response answers to limited questions.

Despite these limitations four conclusions can be drawn. First, the large number and the cultural and geographic diversity of profiles illustrate how something as personal, intimate, and physical as marriage can adapt to the space of flows. A bridgespace of matrimony clearly exists and is able to connect potential mates who live in distant places. Second, the surprising amount of uniformity in profiles and photographs suggests that a vibrant and strong bridgespace, of which matrimonials websites are only a part, and which is centered on the Indian subcontinent, has been created by Indians connected to the space of flows. The bridgespace does not necessarily afford place (or place specific cultural or structural forces) a primary or dominant role, as in many cases we see little spatial variation in the data.

However, the bridgespace does not dissolve the relevance of place because spatial differences are a necessary precondition in the creation of bridgespace. Furthermore, the space of places remains important because spatial variation exists in a number of variables such as 'cultural value,' illustrating the continuing importance of the space of places in identity representation. Finally, because of this continued importance of the space of places, the website replicates place-based cultural trends and social values such as the relationships between skin colour and attractiveness. These conclusions are in accordance with the idea of cyberpossibilism, because places (or places as substitutes for place specific cultural or structural forces) constrain aspects of identity, but interactions and identity construction in a bridgespace enabled by the space of flows also allow for new possibilities outside of traditional socio-spatial constraints.

These conclusions raise a number of interesting questions for further study. Moreover, this project has highlighted cultural trends, such as spatial differences in individually held concepts of attractiveness within India, which have previously been problematic to empirically illustrate. While uncovering a number of such patterns, this project was not intended to conclusively uncover their causes and reasons for existence. Further research can examine why north-south differences in conceptions of attractiveness exist within Indian bridgespace, why there are higher conservative to modern ratios in the bridgespace of predominantly Muslim countries, and why there are such sweeping similarities across geographic regions in the regional levels of visual elements in photographs and regional ratios of categorical breaks into which people assign themselves.

This project has illustrated some aspects of the interwoveness and interactions between cyberspace and geographic space in the contexts of Internet partner search and identity presentation. The spaces of places and flows have been shown to both constrain and enable human possibilities, thus illustrating the concept of cyber-possibilism as it applies to Internet matrimony.

References

1. Adams P.C (1998). 'Network Topologies and Virtual Place', *Annals of the Association of American Geographers,* 88, pp.88-106.
2. Adams P.C and R.Ghose (2003). 'India.com: The Construction of a Space Between', *Progress in Human Geography,* 27, pp.414-437.
3. Bargh J.A and K.Y.A.McKenna (2004). 'The Internet and Social Life', *Annual Review of Psychology,* 55, pp.573-590.
4. Baym N.K (1995). 'From Practice to Culture on Usenet', in Star SL (ed.). *The Cultures of Computing.* Oxford: Blackwell.
5. Bolig R, P.J.Stein and P.C.McKenry (1984). 'The Self-Advertisement Approach to Dating: Male-Female Differences', *Family Relations,* 33, pp.587-592.
6. Boneva B and R.Kraut (2002). 'Email, Gender, and Personal Relationships', in Wellman B, Haythornthwaite C (eds). *The Internet in Everyday Life.* Malden, MA: Blackwell.
7. Brenner N (2001). 'The Limits to Scale? Methodological Reflections on Scalar Structuration', *Progress in Human Geography,* 25, pp.591-614.
8. Cairncross F (1997). *The Death of Distance: How the Communications Revolution Will Change Our Lives.* Cambridge, MA: Harvard Business School Press.
9. Cameron S and A.Collins (1997). 'Estimates of a Hedonic Ageing Equation for Partner Search', *Kyklos,* 50, pp.409-418.
10. Cameron S and A.Collins (2000). 'Random Utility Maximiser Seeks Similar: An Economic Analysis of Commitment Level in Personal Relationships', *Journal of Economic Psychology,* 21, pp.73-90.
11. Castells M (2002). *The Internet Galaxy.* Oxford: Oxford University Press.
12. Castells M (1996). *The Rise of the Network Society.* Oxford: Basil Blackwell.
13. Cornwell B and D.C Lundgren (2001). 'Love on the Internet: Involvment and Misrepresentation in Romantic Relationships in Cyberspace vs. Realspace', *Computers in Human Behavior,* 17, pp.197-211.
14. Crawley S. L (2001). 'Are Butch and Fem Working-Class and Antifeminist', *Gender and Society,* 15, pp.175-196.
15. Dodge M and R.Kitchin (2001). *Atlas of Cyberspace.* London: Addison-Wesley.
16. Dodge M and R.Kitchin (2005). 'Code and the Transduction of Space', *Annals of the Association of American Geographers,* 95, pp.162-180.
17. Dodge M and R.Kitchin (2001). *Mapping Cyberspace.* London: Routledge.
18. Donn J. E and R.C.Sherman (2002). 'Attitudes and Practices Regarding the Formation of Romantic Relationships on the Internet', *CyberPsychology & Behavior,* 5, pp.107-124.
19. Eaver W.W (1996). 'Situating Action II: Affordances for Interaction: The Social is Material for Design', *Ecological Psychology,* 8, pp.111-129.
20. Gillespie A and H.Williams (1988). 'Telecommunications and the Reconstruction of Regional Comparative Advantage', *Environment and Planning A,* 20, pp.1311-1321.
21. Goffman E (1959). *The Presentation of Self in Everyday Life.* New York: Doubleday.
22. Graham S (1998). 'The End of Geography or the Explosion of Place? Conceptualizing Space, Place and Information Technology', *Progress in Human Geography,* 22, pp.165-185.
23. Hamilton A (1999). 'You've Got Male' in *'Time'*, p.83.
24. Hampton K and B.Wellman (2001). 'Long Distance Community in the Network Society:

Contact and Support Beyond Netville', *American Behavioral Scientist*, 45, pp.476-495.

25. Hardey M (2002). 'Life Beyond the Screen: Embodiment and Identity through the Internet,' *Sociological Review*, 50, pp.570-585.
26. Hatton T and S.W Price (1998). 'Migration, Migrants and Policy in the United Kingdom', in *CEPR Research Program on European Migration from Economic Analysis to Policy Response*. Commission of the European Communities, pp. 1-72
27. Heilbronner R (1967). 'Do Machines Make History?' *Technology and Culture*, 8, pp.335-345.
28. Hian L.B *et.al.* (2004). 'Getting to Know You: Exploring the Development of Relational Intimacy in Computer-mediated Communication'; *Journal of Computer Mediated Communications*, 9.
29. Jackson P (1991). 'The Cultural Politics of Masculinity: Towards a Social Geography', *Transactions of the Institute of British Geographers*, 16, pp.199-213.
30. Jagger E (2001). 'Marketing Molly and Melville: Dating in a Postmodern Consumer Society', *Sociology: The Journal of the British Sociological Association*, 35, pp.39-57.
31. Kitchin R (1998). 'Towards Geographies of Cyberspace', *Progress in Human Geography*, 22, pp.385-406.
32. Kobayashi A (1994). 'Coloring the Field: Gender, "Race," and the Politics of Fieldwork', *Professional Geographer*, 46, pp.73-80.
33. Lefebvre H (1991). *The Production of Space*. Cambridge, MA: Blackwell.
34. Lenhart A, L.Rainie and O.Lewis (2001). 'Teenage life online: The Rise of the Instant-Message Generation and the Internet's Impact on Friendships and Family Relationships', in Pew Internet & American Life Project, Washington, D.C.
35. Linlin P (1993). 'Matchmaking via the Personal Advertisements in China versus in the United States', *Journal of Popular Culture*, 27, pp.163-170.
36. Markovits C (1999). 'Indian Merchant Networks Outside India in the Nineteenth and Twentieth Centuries: A Preliminary Survey', *Modern Asian Studies*, 33, pp.883-991.
37. Martin L.H, H.Gutman and P.H Hutton (1988). *Technologies of the Self: A Seminar with Michel Foucault*. Amherst, MA: Univeristy of Massachusetts Press.
38. Merkle E.R and R.A.Richardson (2000). 'Digital Dating and Virtual Relating: Conceptualizing Computer Mediated Romantic Relationships', *Family Relations*, 49, pp.187-192.
39. Miller E.J, J.E Smith and D.L Trembath (2000). 'The "Skinny" on Body Size Requests in Personal Ads', *Sex Roles*, 43, pp.129-141.
40. Morley D and K.Robins (1995). *Spaces of Identity: Global Media, Electronic Landscapes and Cultural Boundaries*. London: Routledge.
41. Negroponte N (1995). *Being Digital*. New York: Knopf.
42. Norman D.A (1999). 'Affordance, Conventions, and Design.' *Interactions*, May-June, pp.38-42.
43. Parks M and K.Floyd (1996). 'Making Friends in Cyberspace', *Journal of Communication*, 46, pp.80-97.
44. Pascal A (1987). 'The Vanishing City', *Urban Studies*, 24, pp.597-603.
45. Pawlowski B and R.I.M Dunbar (1999). 'Withholding Age as Putative Deception in Mate Search', *Evolution and Human Behavior*, 20, pp.52-69.
46. Phua V.C, J.Hopper and O.Vazquez (2002). 'Men's Concerns With Sex and Health in Personal Advertisements', *Culture, Health, and Sexuality*, 4, pp.355-363.
47. Phua V.C and G.Kaufman (2003). 'The Crossroads of Race and Sexuality: Date Selection Among Men in Internet "Personal"

Ads', *Journal of Family Issues*, 24, pp.981-994.

48. Rajecki D.W, S.B.Bledsoe and J.L.Rasmussen (1991). 'Successful Personal Ads: Gender Differences and Smiliarities in Offers, Stipulations, and Outcomes', *Basic and Applied Social Psychology*, 12, pp.457-469.
49. Rheingold H (2003). *Smart Mobs: The Next Social Revolution*. Cambridge, MA: Perseus Books.
50. Robins K (1995). 'Cyberspace and the World We Live In', in `Featherstone M, Burrows R (eds). *Cyberpunk/Cyberspace/Cyberbodies*. London: Sage.
51. Rose G (2001). *Visual Methodologies*. London: Sage Publications.
52. Smith A (2000). '"Safety" in Gay Men's Personal Ads', *Journal of Homosexuality*, 39, pp.43-49.
53. Smith C.A and S.Stillman (2002). 'What Do Women Want? The Effects of Gender and Sexual Oreientation on the Desirability of Physical Attributes in the Personal Ads of Women', *Sex Roles*, 46, pp.337-342.
54. Soukup C (2000). 'Building a Theory of Multi-Media CMC: An Analysis, Critique and Integration of Computer-Mediated Communication Theory and Research', *New Media & Society*, 2, pp.407-425.
55. Spears R and M.Lea (1994). 'Panacea or Panopticon: The Hidden Power in Computer-Mediated Communication.' *Communication Research*, 21.
56. Stone A.R (1991). 'Will the Real Body Please Stand Up? Boundary Stories about Virtual Cultures', in Benedikt M (ed.). *Cyberspace: First Steps*. Cambridge, MA: MIT Press.
57. Stone B, A.Rogers and K.Platt (2001). 'Love Online', *Newsweek*, pp. 46-52
58. Streeter T (2003). 'The Romantic Self and the Politics of Internet Commercialization', *Cultural Studies*, 17, pp.648-668.
59. Townsend A.M (2001). 'Network Cities and the Global Structure of the Internet', *American Behavioral Scientist*, 44, pp.1697-1716.
60. Turkle S (1995). *Life on the Screen: Identity in the Age of the Internet*. New York: Simon & Schuster.
61. Walther J.B (1996). 'Computer-mediated Communication: Impersonal, Interpersonal and Hyperpersonal Interaction', *Communication Research*, 23, pp.3-43.
62. Warf B (2001). 'Segueways into Cyberspace: Multiple Geographies of the Digital Divide', *Environment and Planning B: Planning and Design*, 28, pp.3-19.
63. Wellman B (2001). 'Physical Place and Cyberplace: The Rise of Personalized Networking', *International Journal of Urban and Regional Research*, 25, pp.227-252.
64. Wilbur S.P (1997). 'An Archaeology of Cyberspaces: Virtuality, Community, Identity', in Porter D (ed.). *Internet Culture*. London: Routledge.
65. Winn L.L and D.L Rubin (2001). 'Enacting Gender Identity in Written Discourse: Responding to Gender Role Bidding in Personal Ads', *Journal of Language and Social Psychology*, 20, pp.393-418.
66. Zook M (2000). 'The Economic Geography of Commercial Internet Content Production in the United States', *Environment and Planning A*, 32, pp.411-426.
67. Zook M (2005). 'The Geographies of the Internet', *Annual Review of Information Science and Technology*, 40.
68. Zook M and M.Graham (2007). 'From Cyberspace to DigiPlace: Visibility in an Age of Information and Mobility', in Miller HJ (ed.). *Societies and Cities in the Age of Instant Access*. London: Springer.
69. Zook M and M.Graham (2007). 'The Making of DigiPlace: Merging Soft-Ware andHard-Where via GoogleLocal', *Environment and Planning B: Planning and Design*, 34, pp.466-482.

Agglomeration Economies, New Economic Geography and Industrial Clusters

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Spatially clustered firms benefit in multiple ways: firms are able to exploit economies of scale, enjoy cost savings from proximity to input suppliers and customers, take advantage of the specialization that is facilitated by local market size and diversity, and experiment with new modes of production, pricing and management. The agglomeration economies and location decisions are the subject matter of the review in this paper. Agglomeration economies are reflected in high productivity, employment, wages and rents, factor mobility and innovations. They are also noted in competition, industrial organization, and business culture, and transmit themselves at many levels. The concentrated economic activities in geographical locations foster further interactions and networks, offering scope for coagglomeration.

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World has been getting more and more urbanized since 1900s, and it is expected by 2025, world urbanization will reach to 57 per cent. Obviously most industrial and economic activities take place in urban centres, and as such, urbanization and economic activities get accelerated one another, leading to a pattern of locations of spatial concentration of economic activities, and thereby resulting regional differences in development. Probably each town or region in India can be identified after a specialized product and business. The latest UNIDO industrial development report identified Chennai leather cluster among the top ten dynamic industrial locations in the world. The governments also create clusters of industrial estates and Special Economic Zones around urban locations, thus fuelling spatial concentration of industries. The industrial clusters create conducive investment environment, generate employment and was able to compete in the international market, thus encouraging further concentration.

The global industrial evolution also shows spatial clustering in specialization and localization within countries or groups or regions, and that too, in and around cities. Cities form industrial hubs, and many examples may be cited from different part of the world. Probably the most famous clustering of industries in the world is the Silicon Valley for software and computer industry and the Boston's Route 128 and Detroit for car industry in the US. In India, Sriperumbudur in Chennai is one of recent hub which does not has its own comparative advantage, but Nokia and Hyundai have been able to release their millionth product in a short span of time. In the Silicon Valley it is the localization difference in the organization of resources – local institutions and culture, industrial structure and corporate organization – that drives its success, rather than the

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conventional natural advantage nor a traditional agglomeration economy (76). Global production pattern also shows a heavy geographical concentration. In 1995 the OECD countries produced 78 percent of the world's manufacturing output, despite having only 15 percent of the world's population. During the late 20th century the third world countries, especially the Southeast Asian countries have emerged as the major producers of IT manufacturing. There are cross-country similarities in the most and least localized industries; for example, 446 out of 459 industries are more localized than expected (26). In the industrialized economies, hosiery, jewellery, carpets and spirit distilling are in the top 20 most concentrated industries in both UK and USA, while cutlery, wollen and periodicals are among the top 20 most localized industries in France and the UK. Recent measures of specialization and localization show that countries are becoming less dissimilar to one another; 71 out of 91 bilateral comparisons show increasing dissimilarity (62).

Geography and Growth

Geography matters for economic growth. An increasing number of recent endogenous growth theories have convincingly demonstrated that geographical advantages of nations or regions foster economic growth (24, 25, 64). In the cross-country growth analysis context, it has been consistently shown that the structural features of an economy, like the geography such as climate, country size, location, coastal area, urbanization, and ethnic composition as well as the sectoral composition and diversification infrastructural spread are correlated with the total factor productivity and factor accumulation and a large number of these variables in one form or another qualify as candidates for proximate determinants of growth (32). The major dimensions of economic development are density (local), distance (regional/national) and division (international). Differences in natural endowments may also account for income differences across countries (73). The new economic geography view, following Krugman (57), stresses market access (remoteness) in explaining spatial variation in economic activity. Out of the 43 distinct growth theories and 145 proposed regressors identified in (24, 74) one of the robust determinants of growth is the geography (64).

More recent literature on growth economics is concerned more with social interactions, which is particularly directed towards geographical and identity features, in reaction to the criticism that the conventional neoclassical economics operates "with an atomised and undersocialised conception of human action" (38 p.55). The literature is concerned with the implications of social interactions either in pre-determined groups (2, 12) or on group formation (10). It is also related with the institutional economics (47, 75, 80). A study that uses a geographic variable (distance from the equator) to proxy social infrastructure, finds just four of the non-standard economic variables account for 41 percent of the cross-country variation in social infrastructure and 60 percent of the cross-country variation in income per capita (40). Similarly, the percentage of population close to the coast along with four other non-economic factors alone explain about 70 per cent of the variation in per capita income for a sample of 83 developed and developing countries (32). Consequently, economic

activities tend to be concentrated in those locations and clusters which promise advantage for the producing units. The recent World Development Report observes that as economies grow, production becomes unbalanced (but development can still be inclusive) (81).

Agglomeration Economies and Industry Location

The concept of clustering first started in the field of business, and then was introduced in the discussions of industrial and innovation areas. It is found that regionally-established firm clusters attract other firms and mobile factors to self-reinforcing processes of within-industry clustering and innovation dynamics (6). The agglomeration model shows that industries are localized because the overall activity is agglomerated and the activity within the industry is concentrated in a few non-randomly located plants (26). The forces that lead to such concentration, both of industries in clusters and of aggregate activity in cities are known variously as agglomeration economies or external economies of scale. The literature on agglomeration economies analyses the sources and nature of agglomeration in urban areas and cities that produce increasing returns to firms and the local or regional scales of economies that generate externalities, and the relation between the amount of activities and their interactions in raising firm productivity. The three main factors which influence the clustering of economic activities are: (i) technological or non-pecuniary externalities (29), (ii) increasing returns to scale (20, 31, 56), and (iii) imperfect/spatial competition (20, 31). The three sources of agglomeration economies are: (i) at the firm level – from improved access to input and output markets, (ii) at the industry level – intra-industry localization economies, and (iii) at the regional level – inter-industry urbanization economies (60).

Geographers normally assume that activities cluster. In fact, the geographical concentration of economic activities, at a local or sub-national level, is the norm not the exception. The most systematic evidence on overall agglomeration comes from regional science. The agglomeration concept has the underlying analytical and empirical works in early regional science and location theory (49, 78). However, difficulties in modeling the increasing returns to scale were one of the main reasons for the marginalization of geographical factors in mainstream economic analysis (56). As the standard neoclassical production theory is based on the constant returns to scale assumption and perfect market conditions, geography doesn't matter for producing firms. With recent improvements in mathematical modeling, examination of the economics of agglomeration has been made possible (3).

The principal nature of agglomeration economies is in the form spatial agglomeration externalities. External economies exist when the scale of the urban environment adds to productivity, known as 'scope' (72), which has three dimensions. The first kind of scope is the industrial scope – the degree to which agglomeration economies extend across industries and all industries in a city rather than being confined within industry boundaries. The former is known as urbanization economies and the later as localization economies. Urbanization economies give rise

to localization of industries not only to reap urban specialization, but also because of urban diversity. The second kind of scope is geographic – cities have the advantage of proximity. If agents are physically closer, then there is more potential for interaction. The third scope is temporal – the degree to which the time-separated interactions continue. External economies are shifters of a firm's production function. The aggregate urban external effect arises as the sum of a large number of individual externalities.

When choosing the location of plants and start ups, firms have to weight large scale production against proximity to consumers and suppliers. This cost and demand linkages arise as firms are able to use intermediate goods (like transportation) more cheaply and to face a greater consumer demand where other firms and consumers are concentrated. These effects are magnified in the presence of increasing returns to scale leading to a concentration of employment in one location. As a result local demand increases and give rise to Krugman's (55) 'home market' effect: as transport and trade is still costly and local demand is increasing, more firms are attracted by large markets leading to clustering of industrial activity.

Firms from knowledge intensive services benefit most from being and operating in a cluster like environment, i.e. from agglomeration economies, where strong linkages, contacts, and spillover effects within and between different industries create sufficient gains to overcome sharp competition inside the same business area. Cooperation and network are at the very heart of the cluster paradigm as they lead to externalities due to interactions and the provision of high quality services by public authorities to such clustered areas lower the costs of all firms.

The sources of agglomeration ranges from simple natural advantage to more individual micro-foundations, like input sharing (48), knowledge spillovers (52), innovative activity (5), human capital spillovers (63), labour market pooling and mobility (35), home market effects (55), consumption (37) and rent-seeking (1), and are reflected in high productivity, employment, wages and rents (which reflect the presence of agglomeration economies).

The source of agglomeration economies has origins in two different strands: the conventional Marshallian externalities and the new economic geography (56, 57). Marshallian externalities arise from three principal sources (30, 67): (i) sharing of inputs whose production involves internal increasing returns to scale (and therefore reduces costs at the firm level), (ii) labour market pooling where agglomeration allows a better match between an employer's needs and a worker's skills and reduces risk for both, and (iii) the production of new ideas and spillover effects – spillovers in knowledge that take place when an industry is localized allowing workers to learn from each other. Two other sources are home market effects and economies in consumption. Sometimes the availability of specialized input services and the modern infrastructure provided by governments may also provide externalities. Thus, externalities are crucial for the formation of industrial agglomeration and the clustering of firms. Where such concentrations and networks of

activities exist, innovations and specializations arise, self-reinforcing R&D and further innovations, prompting further concentration in that region propelling its further capacity.

In contrast, in the new economic geography framework, increasing returns, intra-industry interactions, and inter-industry interactions are propelling agglomeration and clustering. Initially, a significant change in the main source of spatial agglomerations, commonly labeled as *first nature* – physical geography and endowments of natural resources – following Krugman – lead to different patterns of industrial and economic activity which help to explain industrialization and early economic development (58). However, they fail to further industrialization and specialization of regions. Such processes are driven by individual's decisions and actions whose driving forces are the access to raw materials, optimizing consumption, and enhancing returns of investments, which are the Krugman's concept of *second nature* (58). Thus, the spatial configuration of economic activity is mainly the outcome and balance of *second nature* – the geography of distance between economic agents – pulling and pushing consumers, firms and production factors.

The Folk Theorem of Geographical Economics

Geographical analysis of production activities is based on the returns it can generate and the advantages it can confer. The location of a firm in a cluster generates both intra-industry (internal) and inter-industry (external) benefits to the firm. Increasing returns to scale are essential for explaining the spatial concentration of economic activities. This implies that under non-increasing returns, production will be for only personal consumption, and the location would be the base where goods are produced on an arbitrarily small scale, as shown by the 'folk theorem' of geographical economics (30). However, when there is a decline in the average production cost as scale of production increases at either the firm/industry or regional level, then it would be advantageous to concentrate production in the beneficial locations. Specifically a region with good access to markets and specialized labour attracts entrepreneurs to increase production to meet the increasing demand, and to reduce cost. When aggregated, this creates agglomeration economies. For example, a firm that is located in close proximity to other firms in the same industry can take advantage of the so-called localization economies. These intra-industry benefits include access to specialized knowledge (diffusion), presence of buyer-seller networks, and opportunities for efficient subcontracting. Another case of agglomeration economies is the so-called urbanization economies – benefits that accrue from being located in close proximity to firms in other industries, an external economic benefit to the firm. These inter-industry benefits include easy access to complementary services, information transfers, variety of specialized labour and less costly infrastructural services. Thus, the agglomeration economies resulting from industry clusters generate a network structure to the advantage of the firms in that cluster cutting across industries, and this enables the firm to reap the scale economies. The new entrants tend to agglomerate to benefit from higher diversity and specialization in both

production processes and production variety. The workers would also benefit from being in an agglomeration as they can exploit higher wages and have access to a larger choice set of employers. There would also be more production at less cost, and so the consumers also benefit.

Two related measures of the location of activity are: how localized a particular economic activity, and how specialized is a particular geographical unit. Typically the relative share of employment or production of particular industry or location is measured using the location quotient. Some studies also construct specialization, absolute as well as relative, measure of a location using the Herfindahl index.

Much of the traditional geography focused on the implications of market potential for the location of economic activity, using largely the gravity model. The sets of geographical issues – geography and trade flows, geography and income, and geography and location of activity – are much of interest for modern industrialization. Localization of industries generates the cumulative causation, agglomeration and multiple equilibria. Production structure and trade flows lead to spatial variations in goods as well as factor prices. The geographic impact of income may not come just through the mechanism of goods process and transport costs, but also through spatial differences in institutions and in technology (69).

The New Economic Geography

Much of the interest of economic geography derives from the fact that the location of demand (determining market access) and input supply (determining supplier-access) is not exogenous. The new economic geography credited with Paul Krugman stems from the early seminal work on the new international trade theory developed by Paul Krugman himself, which emphasizes the significance of market size (41). The new economic geography models view reducing the costs of transporting goods as the driver behind agglomeration (31, 65). By making market size endogenous, the new spatial economics, building on the monopolistic competition framework of Dixit and Stiglitz (20), formalizes agglomeration mechanisms. The trade models predict that sectors characterized by increasing returns to scale, imperfect competition and transportation costs will be disproportionately active in locations with good market access – the home market effect of Krugman (55). The new economic geography models add cumulative causation to this home market effect: hosting a large share of increasing returns, and of increased local demand and profitability. If there is factor mobility, then more of these factors will locate in turn in the already large market, and endogenous agglomeration results from this mechanism. Therefore, initially asymmetric regions might end up hosting very different sectors as increasing returns activities have a tendency to locate in few places (30, 31). Endogenizing market size and migration of the factor used intensively in the increasing returns sector Krugman (56) develops the general theory of New Economic Geography.

Krugman (56, 57) starts with firms and workers, not with regions as in the regional science literature. Economic interactions between firms and consumers are at the core of understanding divergent spatial outcomes. As

transaction costs fall, relocation of the firms and workers could change regional economic environments, endogenously separating identical regions into core and periphery. Extending the range of economic interactions to input-output relationships between firms so that firms are linked to both customers and suppliers which lead to the emergence of specialized regional economic environments the full fledged inter-temporal New Economic Geography model has been developed (7).

The presence of increasing returns to scale and transport costs in the monopolistically competitive markets imply a home market or magnification effect, whereby an increase in demand for a good results in a more than proportionate increase in production of the good (69). The increasing returns to scale imply that firms would like to concentrate production in a single location, while the transportation costs imply that this concentration will occur close to markets.

Krugman's (56) approach can be considered as an extension of neoclassical model to explain trade, specialization and agglomeration, relaxing the frequently used assumptions of perfect competition and constant returns to scale. It basically is a microeconomic theory that explains the existence and persistence of agglomerations in terms of rational decisions of economic agents. Assuming increasing returns to scale at the firm-level, and imperfect competition between firms, Krugman shows that agglomeration can occur without having to assume regional differences or external economies. In particular, with transportation costs falling, a critical point is reached when both firms and workers find it more profitable to cluster in one region. The transition point depends on the balance between internal scale economies for firms and economies of product variety for consumers related to clustering on the one hand, and inter-regional transportation costs on the other hand.

In the full range of models in this new economic geography tradition, the increasing returns to firms is analytically modeled as primarily driven by agglomeration economies, such as technology, agglomeration, clustering, networks and information (8, 30, 31). As information is a public good and as different firms produce different information, inter-firm information spillovers provide incentives for agglomeration and clustering of economic activity. As the firm interactions are informal, the extent of information spillover decreases with increasing distance and hence, the entrepreneur has every incentive to locate the firm in close proximity to other firms, leading to agglomeration and industry clustering. However, concentration of firms in a single area increases congestion, wages and rents not only in the agglomerate but also in the peripheral areas, which in effect will deter further agglomeration. As a result, the equilibrium is established when the centripetal forces of increasing returns for clustering balance the centrifugal forces of negative externalities (56, 59). When moving from partial to general equilibrium analysis of new economic geography models, the logic of proximity to reduce costs disappears as transaction costs fall, meaning that traded interdependencies can no longer explain the persistence of agglomerations (33). However, the falling transaction costs can generate new agglomeration patterns and help enforce existing ones (68). Allowing for capital accumulation and capital mobility

between rich and poor regions in the Baldwin model, the productivity effects of public expenditure on agglomeration can be accounted (17).

Though the structure of new economic geography models rests on the agglomeration economies, the underlying agglomeration mechanism - factor migration, input-output linkages, endogenous capital formation - is not the same. It is these intangibles as identified by early new economic geography models that form the basis of the substance for the recent new economic geography models, where soft factors that is relational, social and contextual aspects of economic behaviour, are emphasized (refer the collection of papers in (4, 53).

Coagglomeration

While much of the work, both theoretical and empirical, on agglomeration has concentrated either on urban location or industry-(mostly manufacturing) specific aspects, studies on the agglomeration economies due to 'clustering' of 'activities' – coagglomeration – is virtually negligible. Studies on the agglomeration economies by 'industrial distance' show that there are many instances of industries apparently affecting each other (26), and that cities emphasize managerial and information-oriented activity of the type that benefits from face-to-face contacts (23). The coagglomeration literature examines not just whether input-intensive industries are agglomerated, but whether they are located near the industries that produce their inputs (28). Thus, coagglomeration effects are greater when there are upstream-downstream linkages. This coagglomeration of pairing industries fully exploit Marshall's theory of industry agglomeration: saving transport costs by proximity to input suppliers and final consumers, labour market pooling, and intellectual spillovers. Studies also examined coagglomeration using the relationship among industries, and the degree to which industries grow more robustly in locations where other industries use similar labour mixes, are linked technologically, and are related to suppliers of inputs or demand (21), finding strong evidence for labour market mixing. Similarly, there are evidences for input-output dependencies, followed by labour pooling, in support of coagglomeration (28). The Silicon Valley studied by Saxenian (76) explains that firms locate near one another so that the firm's leaders can learn from each other. Evidences also indicate that urbanization and the consequent high density of human capital intensive industries like finances and biotechnology have important roles speeding the flow of ideas and intellectual spillovers (35).

Networks and Innovations

Technological innovations and their diffusion are very important as, for example, 50 percent of the total growth in OECD countries depends upon innovations in the US, Germany, and Japan (11). Ever since Marshall's seminal work on location choice and industrial districts the cluster idea has been getting more prominence. According OECD (66) "both, firms keen to improve their competitiveness, and governments keen to exploit new sources of economic growth, need to understand how innovation works in order to better stimulate it". There are many evidences that increasingly regional growth and innovation emerge from innovative complexes of firms and organizations. Within the geograph-

ically-concentrated networks or clusters, regional value-added and employment growth are realized, as ascertained by UNIDO (77). The new endogenous growth theory, new economic geography, the concepts of regional innovation systems, and innovations in technologies like information and communications technology, biotechnology, nanotechnology, environment technology and cognitive technology provide the basis for spatial clustering of firms and increasing concentration of innovative activity in a few regions. The common feature of the different approaches to this spatial clustering of innovative firms is that spatial proximity offers opportunities for intense collaboration and frequent exchange of knowledge and experiences. Face-to-face contacts are essential for the diffusion of new ideas and tacit knowledge among innovating firms, research institutions and the policy sphere (13).

The literature on geography of knowledge spillovers distinguish between information and knowledge as well as knowledge diffusion and knowledge spillover. Using innovation counts, a study finds that innovation activities present a greater propensity to cluster spatially in those industries in which industry R&D, university research, and skilled labour are important inputs (13). Further, the positive associations are present at the level of states, regions, and cities as the manifestation of localized knowledge spillovers, i.e. pure technological externalities bounded in space. Such knowledge that spills over is mainly tacit, i.e. highly contextual and therefore more easily transmitted through face to face contacts and personal relationships, which require spatial proximity. Thus, knowledge spillovers are geographically localized. In such contexts, the two principal mechanisms through which knowledge spillovers are transmitted are social networks and labour mobility. As long as knowledge is not embodied in the worker, labour mobility may well be an important source of knowledge diffusion, without being a source of knowledge spillovers. The works on social capital provide ample evidence for the existence of networks among social groups in business and exchange. The network structure among research institutions and industries is elaborate and it is these connections that carry on the knowledge spillovers. But this literature also suggests that the knowledge does not spill over indiscriminately, rather it follows specific firm-level, geographical, and technological trajectories.

Empirical Evidences

Empirical research on agglomeration uses data either at the firm/plant or city or industry level. Also they model agglomeration economies as being Hicks neutral, which assumes constant marginal rate of substitution among factor inputs, and neoclassical production framework. Empirically, attempts to measure and estimate the agglomeration economies effects follow either the direct production function approach or the indirect proxy approach. The direct estimates are hampered by data availability and measurement problems (15, 43). Henderson (42) uses a panel of plant level data to estimate the direct effects of agglomeration on productivity. Indirect approaches fall into four strands (72). The first examines the impact of agglomeration on employment growth (36). Alternatively, the start of new enterprises and their employment is used to study the scope and effect of agglomeration on productivity (14, 71). Still

another approach is to study wages/rents, where in more productive locations wages/rents would be higher (19, 34,79). Statistically significant home market effects are found in manufacturing sectors (18).

To distinguish between the relative impacts of the factors of agglomeration on productivity, most studies use the variation among industries. Industries are more concentrated when the share of inputs purchased from mining and agricultural sector is greater, confirming natural advantage (5). In studies that use Herfindahl Index of concentration and proxies for all three sources of localization – labour market pooling, knowledge spillovers, and reduced transportation costs – data provide evidence for agglomeration economies at all levels – local, regional, country – of geography (26, 27). The elasticity of transport costs and trade volumes with respect to distance is 0.2 to 0.3 and -0.9 to -1.5 respectively (50), and the elasticity of trade with respect to transport costs is -2 to -5 (61). Apart from distance from markets and sources of supply, spatial variations in factor prices may arise due to technological differences, which arise also because knowledge spillovers diminish with geographical space. Knowledge spillovers are much greater within than between countries. Geographical proximity offers diffusion of ideas: a 10 per cent higher distance from a major technology-producing country such as the US is associated with a 0.15 percent reduction in productivity (9, 16, 52, 54).

There are several related but separate strands to the empirical research on agglomeration economies. One strand attempts to assess the importance of localization versus urbanization economies in explaining the location activity. Localization economies occur when there is a positive externality on firm productivity from other firms in the same sector; urbanization economies occur when there is a positive externality on firm productivity from other firms in different sectors. Either type of externality could arise from Marshall's three agglomeration forces – knowledge spillovers, labour market externalities or input-output linkages. Various proxy measures are used to examine the benefits of agglomeration economies as there is no direct information on the mechanisms through which agglomeration economies influence firm or worker productivity or profitability. Some of the scale economies are captured by some measures of improved market accessibility or distance to transport hubs; localization economies are measured by own industry employment in the region or an index of concentration; and urbanization economies are measured by city size, or population density.

Early economic geography models consider only the regional aspects in the quantitative assessments of the influence of geography and development. Recently, geographical economists are open to the idea that some sort of technological externalities should be added to formal models of economic geography. Indeed, Baldwin, *et al.* (2003) model includes both linkages and technological spillovers. In such an environment ideas surrounding untraded interdependencies and the development of localized relations and conventions as a way of facilitating the interactions offer more insights than simple technological spillovers. German data shows that within-industry agglomeration economies

are important for low-tech but not for high-tech firms, while no evidence for between-industry economies for firms (39).

Recent empirical studies attempted to discriminate between comparative advantage and agglomeration of specialization as well as factor endowment effects (operating at an aggregate level) and geography effects (operating at a disaggregate level) (18, 62). Studies find some sort of agglomeration economy operated in the firm's location decision, besides the conventional factors. A related literature examines the effect of scale or density of economic activity on productivity levels. Doubling the employment density in a country increases labour productivity by six per cent and total factor productivity by four per cent (15). In analyzing the micro-economic mechanisms that cause agglomeration economies – input and output linkages, labour market agglomeration and information flows – input-output tables are used to construct measures of supplier and customer presence, plant's labour mix relative to the average labour mix in the area, and co-ownership across multiple industries (21). It is observed that 20 per cent of the variation in the state-industry employment shares is explained by the industry and state characteristics, which highlights the role of states in industrial promotion (27).

Studies on industrial scope show that urbanization increases productivity in the range of 3-8 per cent, and localization effect is much stronger than urbanization effects (72). The other industrial scope is the degree to which a city's employment is specialized. The specialization and diversity in employment in cities encourage new industries and growth (36), especially among high-technology firms (44), moving of industries evolved in diverse cities to specialized cities (25), and more importantly, the 'Jacobs externalities' breeds cross-fertilization of technology and innovation (36, 51). In studies on geographic scope, a positive effect of density, with a doubling associated with a five per-cent increase in productivity is observed (15). One important finding is that the agglomeration economies attenuate rapidly across geographic space (42). Some empirical results provide evidence of wage gradients across geographical space: locations that are remote from markets and sources of supply of intermediate inputs are characterized by low wages (19). The temporal scope of the aspects of agglomeration economies show that agglomeration economies have a dynamic component, reporting an urban wage premium to the tune of 20 per cent (34, 36, 44).

Conclusion

There is ample theoretical and empirical evidence to strongly suggest the importance of geography in general and agglomeration in particular in determining economic activities, in inducing industry interactions, in influencing cross-country income distribution, and in shaping the structure of production across space. The new economic geography has demonstrated that the interaction among trade costs, increasing returns and factor mobility shape the location of economic activity and the emergence of spatial core-periphery patterns. The increasing returns due to industrial scope arising from outside the own industry, unlike the externalities arising from activity in an own industry, in urban agglomeration are enormous. The geographical dimensions and

spatial clustering of firms are the fundamental aspect of modern innovation process. The regional specialization provides proximity and face-to-face interactions for innovating firms, researchers, institutions and policy makers. The network of industrial clusters enhances competitiveness and cooperation side by side. The specialization and diversity in cities spur localization and innovation through inter- and intra-industry networks. Agglomeration economies are there in urban centres and they coagglomerate and are dynamic too. The agglomeration economies not only favour firm clustering, but also offer productivity advantages. They tend to materialize in factor price premiums paid to labour and land in cities. They are not only confined to manufacturing and technological in phenomena, but also are in 'competition', 'industrial organization' 'business culture', and transmit themselves at many levels and among different types.

The internal returns to scale play an important role in understanding the distribution of activity at the sub-national level. There is localization in a large number of industries that cannot be purely explained by industrial concentration (plant size). Both comparative advantage and economic geography factors matter for determining location. Sub-national level analyses show that both endowments and geography matter in determining location. However, not all types of industries tend to co-locate in close proximity. The net benefits of industry concentration and location in dense urban areas are disproportionately accrued to technology intensive and innovative sectors only. This is because the benefits of knowledge sharing and access to producer services are considerably higher in the innovative sectors than in low-end manufacturing that employ standardized production processes. With less competitive and more complementary behaviour, these upcoming sectors can afford the high wages and rents in dense urban locations and industry clusters.

In future the focus should be more on allowing for the fact that location decisions are made over a continuous rather than discrete space. Attempts should also be made to take into account randomness, and risk and uncertainty in firm location decisions and the ways and means by which agglomeration economies reduce the costs associated with such contingencies. Dynamic aspects also need further exploration. Another area in which a great deal of work needs to be undertaken is in the refinement of the concepts of agglomeration economies, localization, scope, costs, benefits, and the methodologies in measuring these over space and time and designing proper estimation strategies. More importantly, any research has only limited relevance unless it implies policy and programmes. On this policy perspective, the latest World Development Report 2009 argues for the development and strengthening of institutions that unite, infrastructure that connects, and interventions that target.

Note

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References

1. Ades A.F and E. Glaeser (1995). 'Trade and Circuses: Explaining the Urban Giants', *Quarterly Journal of Economics*, 110, pp.195-227.
2. Akerlof G (1977). 'Social Distance and Social Decisions', *Econometrica*, 65, pp.1005-1027.
3. Anselin L (1988). *Spatial Econometrics: Methods and Models*. Boston: Kluwer.
4. *Antipode*, 33, 2, 2001.
5. Audretsch D.B and M.P. Feldman (1996). 'R&D Spillovers and the Geography of Innovation and Production', *American Economic Review*, 86, pp.630-640.
6. Audretsch D.B and M.P. Feldman (2004). 'Knowledge Spillovers and the Geography of Innovation', in J.V. Henderson, and J.F. Thisse (eds.). *Handbook of Regional and Urban Economics, Volume 4*, Amsterdam: Elsevier, pp.2713-2739.
7. Baldwin R (1999). 'Agglomeration and Endogenous Capital', *European Economic Review*, 43, pp.253-280.
8. Baldwin R, R. Forslid, P. Martin, G. Ottaviano and F. Robert-Nicoud (2003) *Public Policies and Economic Geography*. Princeton: Princeton University Press.
9. Branstetter L (2001). 'Are Knowledge Spillovers International or Intra-national in Scope?', *Journal of International Economics*, 53, pp.53-79.
10. Benobou R (1993). 'Working in a City: Location, Education and Production', *Quarterly Journal of Economics*, 108, pp.619-652.
11. Breschi S and F. Malerba (2005). (eds.). *Clusters, Networks and Innovation*. Oxford: Oxford University Press.
12. Brock W and S. Durlauf (2001). 'Interaction Based Models', in J. Heckman, and E. Leamer (eds.). *Handbook of Econometrics, Volume 5*, Amsterdam: North Holland, pp.3297-3380.
13. Brocker J, D. Dohse and R. Soltwedel (2003). *Innovation Clusters and Interregional Competition*. Berlin: Springer.
14. Carlton D.W (1983). 'The Location and Employment Choices of New Firms', *Review of Economics and Statistics*, 65, pp.440-449.
15. Ciccone A and R.E. Hall (1996). 'Productivity and the Density of Economic Activity', *American Economic Review*, 86, pp.54-70.
16. Coe D and E. Helpman (1995). 'International R&D Spillovers', *European Economic Review*, 39, pp.859-887.
17. Commendatore P, I. Kubin and C. Petraglia (2008). 'Productive Public Expenditure in a New Economic Geography Model', *Economie Internationale*, 114, pp.133-160.
18. Davis D. and D. Weinstein (1999). 'Economic Geography and Regional Production Structure: An Empirical Investigation', *European Economic Review*, 43, pp.379-407.
19. Dekle R and J. Eaton (1999). 'Agglomeration and Land Rents', *Journal of Urban Economics*, 46, pp.200-214.
20. Dixit A and J. Stiglitz (1977). 'Monopolistic Competition and Optimum Product Diversity', *American Economic Review*, 67, pp.297-308.
21. Dumais G, G. Ellison and E. Glaeser (2002). 'Geographic Concentration as a Dynamic Process', *Review of Economics and Statistics*, 84, pp.193-204.
22. Duranton G and D. Puga (2001). 'Nursery Cities: Urban Diversity, Process Innovation, and the Life-Cycle of Products', *American Economic Review*, 91, pp.1454-1477.
23. Duranton G and D. Puga (2005). 'From Sectoral to Functional Urban Specialization', *Journal of Urban Economics*, 57, pp.343-370.
24. Durluaf S, P. Johnson and J. Temple (2005).

'Growth Econometrics', in P. Aghion, and S.N. Durlauf (eds.). *Handbook of Economic Growth, Volume 1A*. Amsterdam: North-Holland, pp.556-677.

25. Easterly W (2001) *The Elusive Quest for Growth*. Cambridge and London: MIT Press.
26. Ellison G and E. Glaser (1997). 'Geographical Concentration in US Manufacturing Industries: A Dartboard Approach', *Journal of Political Economy*, 105, pp.889-927.
27. Ellison G and E. Glaeser (1999). 'The Geographic Concentration of Industry: Does Natural Advantage Explain Agglomeration?', *American Economic Review*, 105, pp.889-927.
28. Ellison G, E. Glaeser and W. Kerr (2007). 'What Causes Industry Agglomeration? Evidence from Coagglomeration Patterns', NBER Working Paper No.13068.
29. Fujita M (1989). *Urban Economic Theory: Land Use and City Size*. Cambridge, Mass.: Cambridge University Press.
30. Fujita M and J.F. Thisse (2002). *Economics of Agglomeration: Cities, Industrial Location and Regional Growth*. Cambridge: Cambridge University Press.
31. Fujita M, P. Krugman and A. Venables (2001). *The Spatial Economy: Cities, Regions and International Trade*, Cambridge, Mass.: MIT Press.
32. Gallup J.L, J. Sachs and A. Mellinger (1999). 'Geography and Economic Development', *International Science Review*, 22, pp.179-232.
33. Glaeser E (1998). 'Are Cities Dying', *Journal of Economic Perspectives*, 12, pp.139-160.
34. Glaeser E and D.C. Mare (2001). 'Cities and Skills', *Journal of Labour Economics*, 19, pp.316-342.
35. Glaeser E and M. Kahn (2001). 'Decentralized Employment and the Transformation of the American City', *Brookings/Wharton Papers on Urban Affairs, Volume 2*.
36. Glaeser E, H.D. Kallal, J.A. Scheinkman and A. Shleifer (1992). 'Growth in Cities', *Journal of Political Economy*, 100, pp.1126-1152.
37. Glaeser E, J. Kolko and A. Saiz (2001). 'Consumer City', *Journal of Economic Geography*, 1, pp.27-50.
38. Granovetter M (1985). 'Economic Action and Economic Structure: The Problem of Embeddedness', *American Journal of Sociology*, 91, pp.481-510.
39. Hafner K.A (2008). 'Agglomeration Economies and Clustering – Evidence from German Firms', CEGE Discussion Paper No.72.
40. Hall R and C. Jones (1999). 'Why Do Some Countries Produce So Much More Output Per Worker Than Others?', *Quarterly Journal of Economics*, 114, pp. 83-116.
41. Helpman H and P. Krugman (1985). *Market Structure and Foreign Trade*. Cambridge, MA: MIT Press.
42. Henderson J.V (2003a). 'Marshall's Scale Economies', *Journal of Urban Economics*, 53, pp.1-28.
43. Henderson J.V (2003b). 'The Urbanisation Process and Economic Growth: The So-What Question', *Journal of Economic Growth*, 8, pp. 47-71.
44. Henderson J.V, A. Kuncoro and M. Turner (1995). 'Industrial Development in Cities', *Journal of Political Economy*, 103, pp.1067-1085.
45. Henderson V, Z.Shalizi and A. Venables (2001). 'Geography and Development', *Journal of Economic Geography*, 1, pp.81-105.
46. Henderson J.V and J.F. Thisse (eds.). *Handbook of Regional and Urban Economics. Volume 4*, Amsterdam: Elsevier.
47. Hodgson G.M (1998). 'The Approach of Institutional Economics', *Journal of Economic Literature*, 36, pp.66-192.
48. Holmes T.J (1999). 'Localization of Industry and Vertical Disintegration', *Review of Economics and Statistics*, 81, pp.314-325.
49. Hotelling H (1929). 'Stability in Competition', *Economic Journal*, 39, pp.41-57.
50. Hummels D (1999). 'Towards a Geography of Trade Costs'. Mimeo, Purdue University.

51. Jacobs J (1969). *The Economy of Cities*. New York: Vintage.

52. Jaffee A.B, M. Trajtenberg and R. Henderson (1993). 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', *Quarterly Journal of Economics*, 108, pp.577-598.

53. *Journal of Economic Geography*, 3, 2, 2003.

54. Keller W (2001). 'Geographic Localization of International Technology Diffusion', *American Economic Review*, 92, pp.120-142.

55. Krugman P (1980). 'Scale Economies, Product Differentiation, and the Pattern of Trade', *American Economic Review*, 70, pp.950-959.

56. Krugman P (1991a). *Geography and Trade*. Cambridge, Mass.: MIT Press.

57. Krugman P (1991b). 'Increasing Returns and Economic Geography', *Journal of Political Economy*, 99, pp.483-499.

58. Krugman P (1993). 'First Nature, Second Nature, and Metropolitan Location', *Journal of Regional Science*, 33, pp.129-144.

59. Krugman P (1998). 'What's New About the New Economic Geography?', *Oxford Review of Economic Policy*, 14, pp.7-17.

60. Lall S.V, Z. Shalizi and U. Deichmann (2004). 'Agglomeration and Productivity in Indian Industry', *Journal of Development Economics*, 73, pp.643-673.

61. Limao N and A.J. Venables (2001). 'Infrastructure, Geographical Disadvantage, Transport Costs and Trade', *World Bank Economic Review*, 15, pp.451-479.

62. Midelfart-Knarvik K, H.G. Overman and A.J. Venables (2000). 'Comparative Advantage and Economic Geography: Estimating the Location of Production in the EU', CEPR Discussion Paper No.2618.

63. Moretti E (2004). 'Human Capital Externalities in Cities', in J.V. Henderson, and J.F. Thisse (eds.). *Handbook of Regional and Urban Economics, Volume 4*, Amsterdam: Elsevier.

64. Moral-Benito E (2009). 'Determinants of Economic Growth: A Bayesian Panel Data Approach'. Policy Research Working Paper No.4830, The World Bank.

65. Neary P.J (2001). 'Of Hype and Hyperbolas: Introducing the New Economic Geography', *Journal of Economic Literature*, 39, pp.536-561.

66. Organization for Economic Cooperation and Development (1999). *Boosting Innovation: The Cluster Approach*. Paris: OECD.

67. Ottaviano G and J.F. Thisse (2004). 'Agglomeration and Economic Geography', in J.V. Hendersonand J.F. Thisse (eds.). *Handbook of Regional and Urban Economics, Volume 4*. Amsterdam: Elsevier, pp.2563-2608.

68. Overman H.G (2004). 'Can We Learn Anything from Economic Geography (Proper)?', *Journal of Economic Geography*, 4, pp.501-516.

69. Overman H.G, S. Redding and A.J. Venables (2003). 'The Economic Geography of Trade, Production, and Income: A Survey of Empirics', J. Harrigan, and K. Choi (eds.). *The Handbook of International Trade*. London: Basil Blackwell, pp.353-387.

70. Porter M.E (1990). *The Competitive Advantage of Nations*. London: Macmillan.

71. Rosenthal S.S and W.C. Strange (2003). 'Geography, Industrial Organization, and Agglomeration', *Review of Economics and Statistics*, 85, pp.377-393.

72. Rosenthal S.S and W.C. Strange (2004). 'Evidence on the Nature and Sources of Agglomeration Economies', in J.V. Henderson, and J.F. Thisse (eds.). *Handbook of Regional and Urban Economics, Volume 4*. Amsterdam: Elsevier, pp.2119-2171.

73. Sachs J and A. Warner (1997). 'Natural Resource Abundance and Economic Growth', *Brookings Papers of Economic Activity*, pp.1-95.

74. Sala-i-Martin X (1997). 'I Just Ran Two Million Regressions', *American Economic Review*, 87, pp.178-183.

75. Samuels W.J (1985). 'The Present State of Institutional Economics', *Cambridge Journal of Economics*, 19, pp.569-590.

76. Saxenian A (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route*

128. Cambridge, MA: Harvard University Press.

77. United Nations Industrial Development Organization (2009). *Industrial Development Report 2009*. Vienna: United Nations.

78. Weber A (1909). *Theory of the Location of Industries*. Chicago, IL: University of Chicago Press.

79. Wheaton W.C and M.J. Lewis (2002). 'Urban Wages and Labor Market Agglomeration', *Journal of Urban Economics*, 51, pp.542-562.

80. Williamson O.E (1985). *The Economic Institutions of Capitalism*. New York: Free Press.

81. World Bank (2009). *World Development Report 2009: Reshaping Economic Geography*. New York: The World Bank.

Landforms and Land Use Changes around Hyderabad, Andhra Pradesh

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Urban sprawl and growth has definite impact on land and drainage characteristics in the areas around the cities. The study here looks into landform and land use changes around Hyderbad city, India which is located in the basin of Musi river. The basin is known for semi-arid climate and granite topography. IRS 1D LISS III data were used along with Survey of India toposheets for the data requirement of the study. Weathering and erosion are the dominant geomorphic processes in the study region. Weathering and erosion get accelerated due to urban development, leading to land gradation. Channel area of Musi basin is found declining due to urban encroachments.

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Geomorphic processes continue to carve out landforms on the land surface, and they get altered with the urban sprawl and population growth in the recent decades. Urban growth process invariably has an impact on the land and drainage characteristics of the region, more so if the river passes through the city.Hyderabad, a city in Musi basin with a history of about 410 years, and a population of about 6 million now, is the capital of the state of Andhra Pradesh. Its rapid sprawl has its impact on its physical environment. Quarrying and encroachments degrade the land and change the character of landform development. In this paper, an attempt is made to study the initial forms and processes in and around Hyderabad and the environmental changes being witnessed currently.

Physiographic Setting of the Study Area

The Musi Basin is mostly located in Hyderabad and Rangareddy districts of Andhra Pradesh, and spreads over an area of 10673 sq.km (Fig. I). Musi flows in west - east direction for about 180 km, where it receives Aleru as its tributary. After that it traverses in southeasterly direction before confluencing with river Krishna after a course of 240 km. Several anicuts & cross bunds were raised and channels dug along either side of the Musi in different parts of its course and these channels act as feeders to big tanks or as sources of direct irrigation. The basin has a semi arid climate. It is generally hot during most of the year with temperature above 30^0C. May is the hottest month, with daily maximum temperature of 39^0– 40^0C. The coldest month of December has mean minimum temperature going down to 13^0C. Mean monthly evapo-transpiration is appro-mximately 350 mm in May and 160 mm at the end of monsoon. The average annual rainfall in the region is 780 mm with September being the rainiest month, and with

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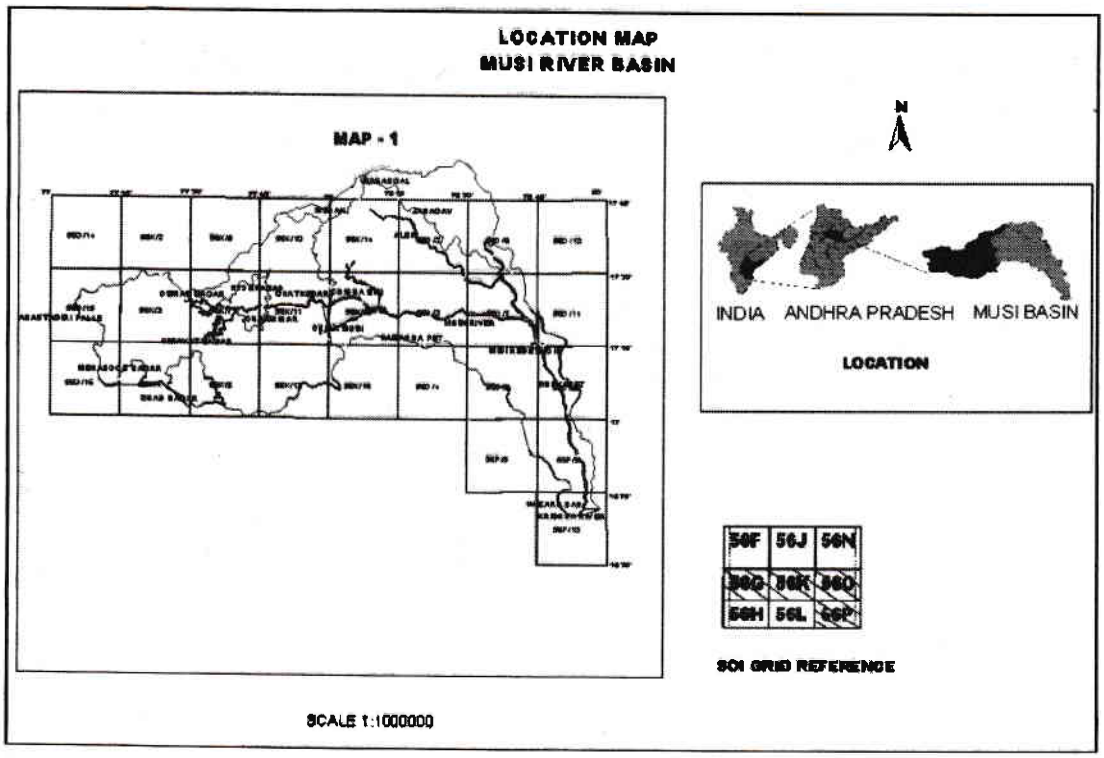

Fig. 1 Location Map

around 78% being received in southwest monsoon. The mean rainfall of the city seems to be declining and the city gets hotter and sultry in the recent decades.

Data and Methodology

Basic data for the study area were obtained from IRS – 1d /LISS – 3 and pan imageries for 2000 Survey of India topo sheets of 56 G, K and O series on 1:50,000 scale, and LISS - IV of 2006 with 56 k7, k11 on 1:12500 scale. Survey of India toposheets in the scale of 1:250000 that were prepared during 1914-1920 were also consulted. They are supplemented by non-spatial data obtained from various public records. As such, land use / land cover of the basin of the study area was mapped for time periods, 1920 and 2000. The land use categories were traced, scanned, digitized and vectorised using AutoCAD and Arc-info. The land use map of 2000 for the basin was obtained from Survey of India topo sheets of 1:250000 surveyed between 1970 and 1980, and were updated using IRS 1D LISS III and pan-merged geo-coded image dated 25th November 2000 (LISS) and 21st Feb. 2000 (pan). ERDAS was used to make an analysis of imageries.

Geological Formations

The general distribution of rocks according to the order of superposition is as under (Fig.2).

1. The Peninsular granitic complex – Archaean
2. The Bhima limestone – Purana

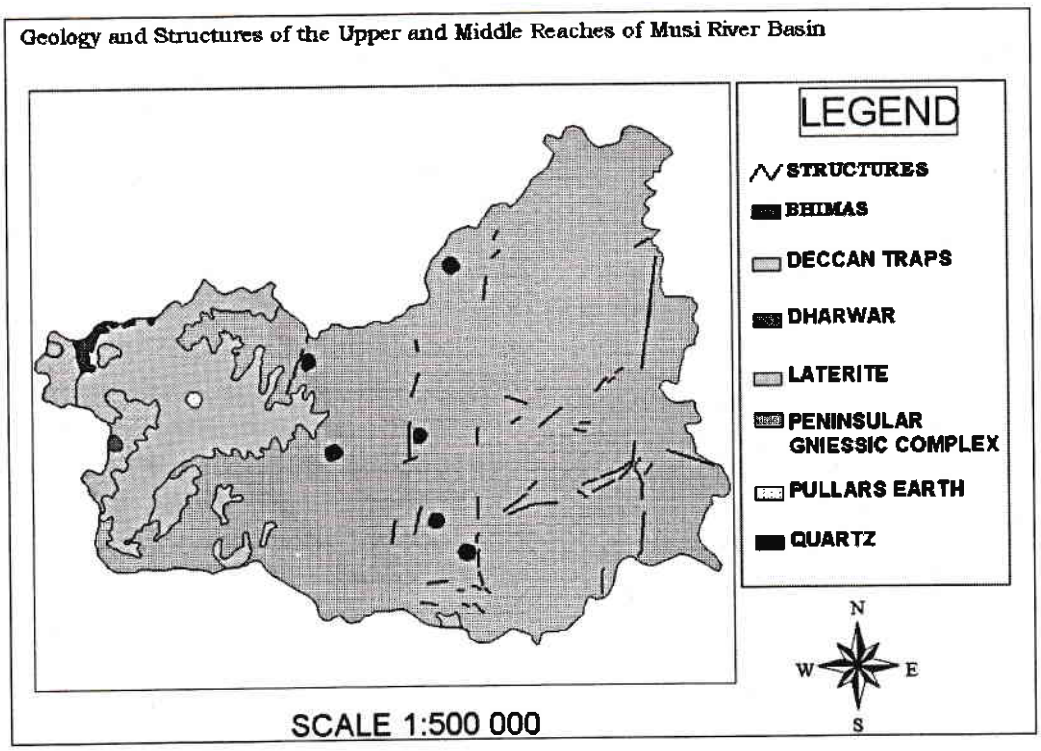

Fig. 2
Geology and Structures of the Upper and Middle Reaches of Musi Basin

3. Intratrappeans – Upper Mesozoic to Tertiary
4. Deccan Traps – Tertiary
5. Laterites & Alluvium – Pleistocene & Recent.

The granites are the predominant rocks in the basin, and they form a monotonous peneplain dotted with mounds of hills and rarely hill ranges consisting of relatively fresh rock. Among the granites are included a great variety of both porphyritic and equigranular, massive branded and streaky with erratic distribution of pegmatite veins.

The granites containing only quartz and feldspar frequently give rise to sandy plains with poor soils but rich in alkalis. The level of granite country rises towards northwest, and the groups of hills become more large and numerous to the west of Hyderabad City. Rest of the region is flat or gently undulating plain with overlying thin alluvium along river courses and younger group of sedimentary rocks (Bhima Series) to west and southwest of Hyderabad. The Deccan Traps and laterites are observed in Chevella and Vikarabad taluks in the west. About 70% of the basin has a slope category of $1^0 - 2^0$, and slope category of 2^0-3^0 accounts for 13% of the region.

Morphogenetic Characters

Morphogenetically, the basin comes under the semi-arid climatic condition, which was attained during Pleistocene. Earlier to this, the

area witnessed a humid climate in the Cenozoic era, further earlier a warmer phase was experienced in the Mesozoic era, and cold climates existed in the oldest Precambrian Period (5). These changes in the climate have had their impact on the denudation chronology of the basin.

As per CSIRO classification, four main land systems are identified in the basin (Fig. 3):

1. The denudation hills – pediment – plain system: comprising of denudational hills, dissected plateau, pediplain, inselbergs, tor & core stones.
2. The structural plateau – plain system: comprising of structural ridges, escarpments, mesas and buttes
3. The limestone – pediplain system
4. The river valley system

The units found in the river valley system are:

1. Collegial fills & collegial apron
2. Alluvial fills
3. River terraces
4. Point bars, channel bars and bluffs
5. Natural levees.

The morpho-dynamic processes identified in the basin are weathering and erosion. Weathering processes in the area are due to temperature changes (thermal expansion & contraction), geodynamic stress (unloading and offloading) and organic processes (root wedging). Due to repeated heating and

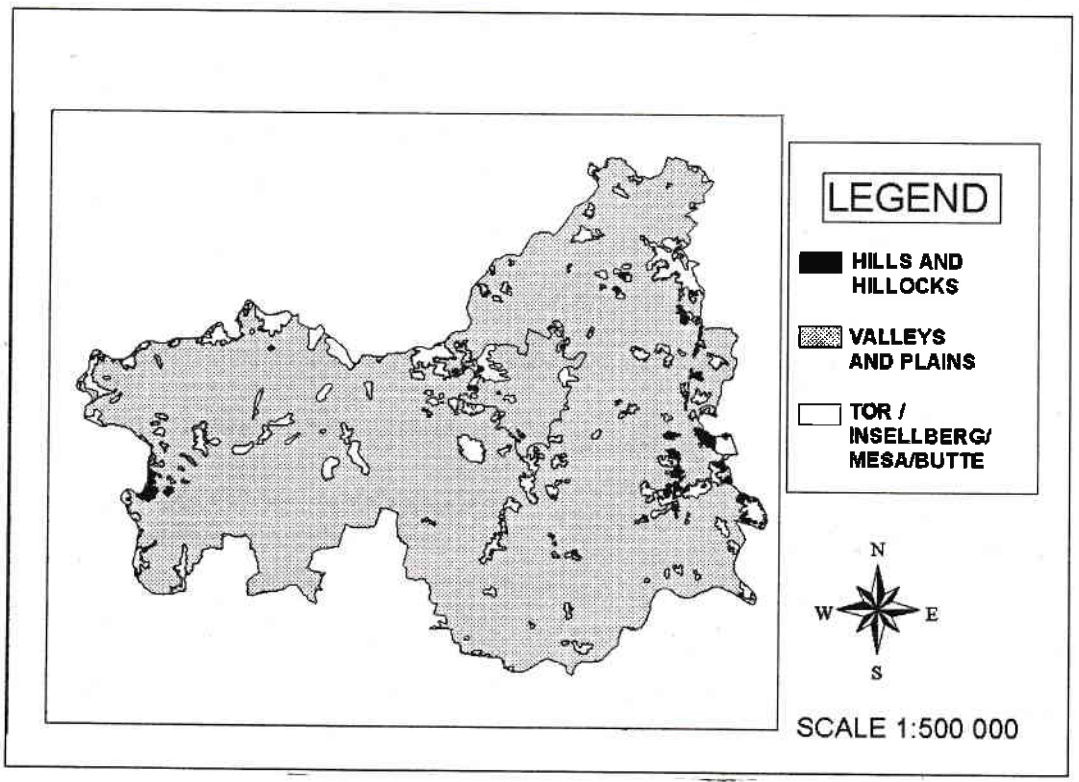

Fig. 3
Geomorphology of Upper and Middle reaches of Musi Basin

cooling of the rock surface, the spalling of surface layer takes place creating mass exfoliation domes. Giant cleavages of rocks were observed at some places because of changes in temperatures.

Biological weathering was noticed in some of the places. Spheroidal weathering in granite helped the surface to assume a roughly rounded surface. Chemical weathering caused exfoliation of dolerite dykes. Honeycomb weathering was noticed when faster decomposing feldspar in granite caused a network like structure. Due to chemical weathering granite exposed to water in wells disintegrated where orthoclase and feldspar suffered colonization. Algae and mosses growing mostly on rocks helped in the breaking down of rocks.

The other geomorphic processes identified in the area are:

1. Rill & gully erosion in the headward region leading to headward erosion
2. Sheet wash erosion in the river plain region
3. River bank erosion, along the banks of the river, with slumps and moderate falls.

Landforms

Erosional forms are primarily due to erosion aided by weathering processes. A few residual hills are found at the periphery of the main Deccan trap mass and a few small exhumed fragments of granitic gneiss from below the traps. The process of exhumation is thought to have resulted from the action of deep weathering and subsequent uplift by earth movements leading to accelerated erosion and removal of weathered rock layers.

Constructional forms are due to the sequential depositions over the previous erosional forms. The pediplain is formed by coalescing pediments of three types:

1. Fragments of active pediment or fresh pediment
2. Fragments of pediment under destruction
3. Buried pediments and residual hill masses forming Tor and Inselberg complexes.

Along with these, certain compound features like flood plains with black soil cover and dendritic drainage are found. In the pediplain are found some features like batholiths. The twin cities of Hyderabad and Secunderabad are basically built on batholiths. The river Musi and its tributaries are the main drainage causing the erosion of these rocks and the continual removal of material from the higher lands to the lower lands causing an undulating topography. The granitic country gives rise to hills and valleys. Level of the granitic country in this region raises towards the northwest and groups of hills become large and numerous to the west of city. Accordingly, the slope of the land is from west to east and southeast.

Land Use/Land Cover Changes (1920 – 2000)

Tables 1, 2 and 3 give the category wise land use changes from 1920 – 2000 (Figs. 4 & 5). Landuse changes between 1920 and 2000 seem to have taken place more characteristically in pockets. Some barren rocky areas that are found in the maps of 1920 are now filled with scrubs at Osmansagar and Himayathsagar area, and some scrublands are now developed into residential and agricultural areas. The concentration of change is felt more near 400 m contour line near Hyderabad region due to the obvious

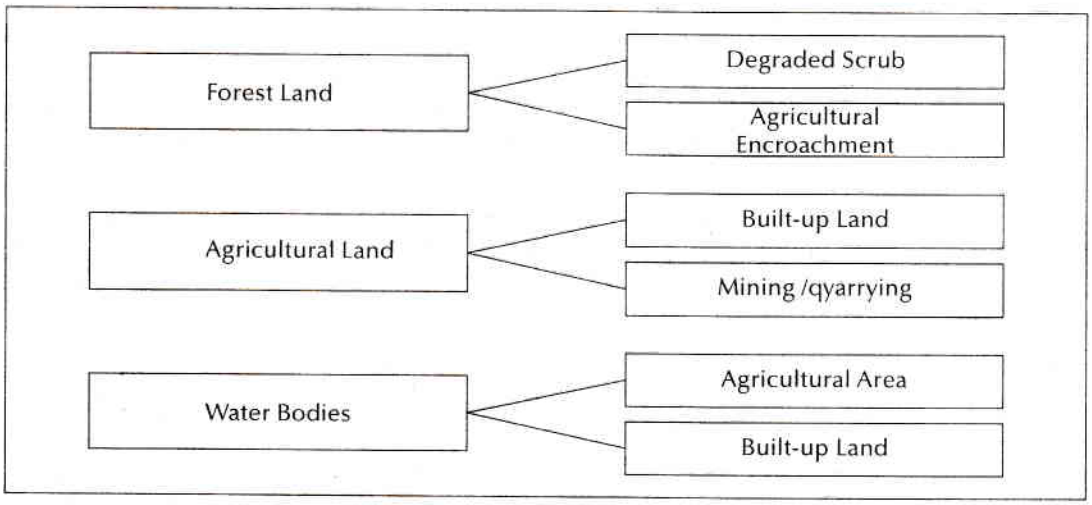

Fig. 4 Negative Landuse Changes

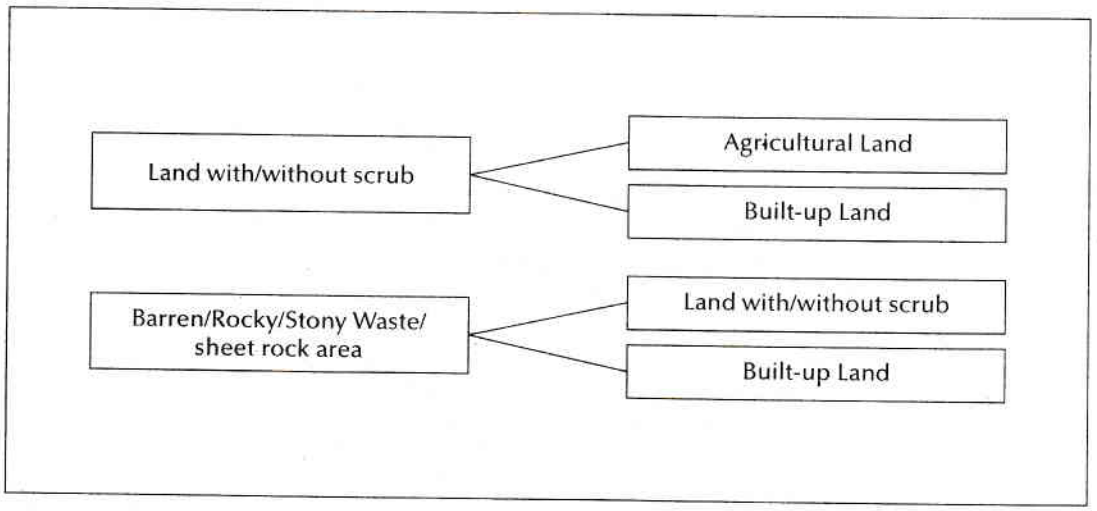

Fig. 5 Positive Landuse Changes

reason of urban growth and urban sprawl. (1&4)

Accelerated erosion and weathering processes due to human interventions have led to land gradation. Poorly managed mines & quarries are found causing landform degradation at Shahbad and Himayathsagar area. Tors and inselbergs get degraded due to ever increasing constructional activity (Table 3). The most rapid and environmentally negative change in the basin during the last 80 years is the rapid urban sprawl to an area of about 500 sq.km in and around the city with housing and industrial development. Cultivated lands were encroached upon and tropical landforms of tor and inselberg topography have been disappearing (4).

Table 1

Landuse/Land Cover of the Musi River Basin of 1920

Description	Area in Sq. km	% to the Total Geographical Area
Agricultural Land (Double Crop)	533.65	4.5
Agricultural Land (Single Crop)	5123.04	58
Barren/Rocky/Stony Waste/Sheet Rock Area	672.399	2.3
Fallow Land	180.3737	1.69
Built up/Settlement/Residential	213	8
Degraded Forest Land (Encroachment)	18	0
Degraded Forest Land (Scrub)	7.4711	1.7
Land with/without Scrub	2226.33	16
Mining/Quarry/Industrial Area (Waste Dump/Land Fill)	12.8076	0.04
Mining/Quarry/Industrial Area(Active)	0.21346	0.12
Plantations	512.304	3
Reserved/Protected Forest Land	747.11	5
Water Bodies/River	426.92	2.68
Total	10673	100

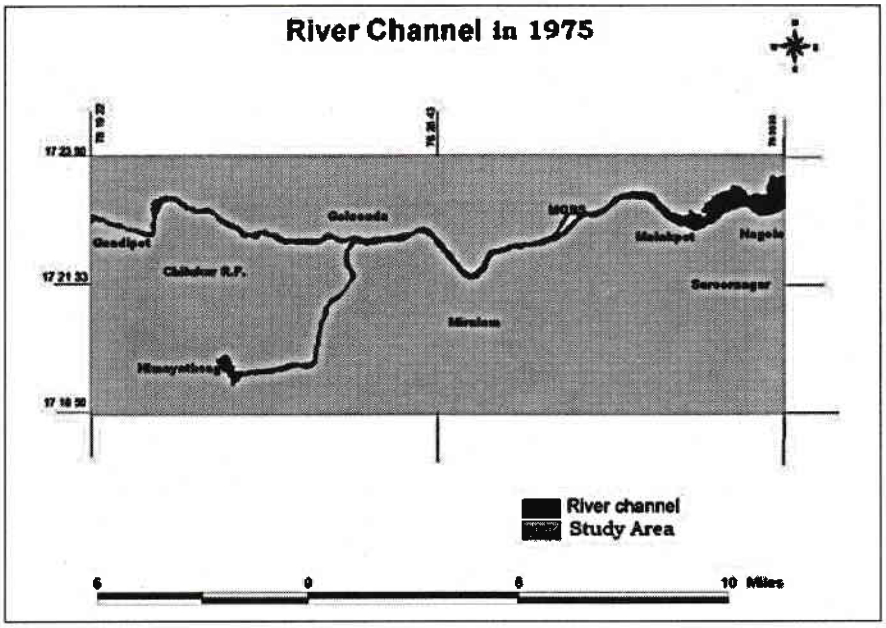

Fig. 6

Table 2

Landuse /Land Cover of the Musi River Basin of 2000

Description	Area in Sq. km	% to the Total Geographical Area
Agricultural Land (Double Crop)	512.304	5
Agricultural Land (Single Crop)	5870.15	4.8
Barren/Rocky/Stony Waste/Sheet Rock Area	245.479	6.3
Fallow Land	180.3737	1.69
Built up/Settlement/Residential	800.4750	2
Degraded Forest Land (Encroachment)	18.1441	0.17
Degraded Forest Land (Scrub)	181.4410	0.07
Land with/without Scrub	1707.68	21
Mining/Quarry/Industrial Area (Waste Dump/Land Fill)	4.2692	0
Mining/Quarry/Industrial Area(Active)	12.8076	0.002
Plantations	320.1900	4.8
Reserved/Protected Forest Land	533.6500	7
Water Bodies/River	286.0364	4
Total	10673.0000	

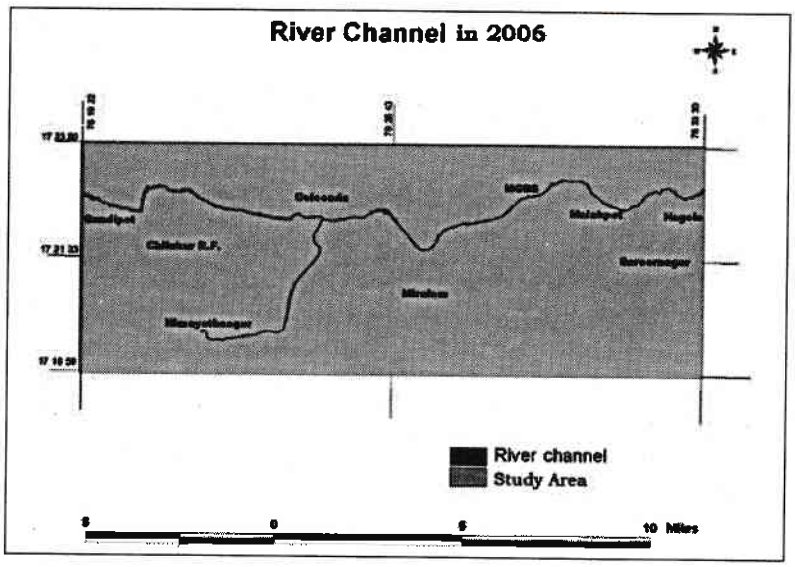

Fig. 7

Table 3
Category-wise Landuse Changes from 1920-2000

Description	Area in Sq. km
Agricultural Land (Double Crop)	0.2 %
Agricultural Land (Single Crop)	7 %
Barren/Rocky/Stony Waste/Sheet Rock Area	4 %
Fallow Land	0.29 %
Built up/Settlement/Residential	6 %
Degraded Forest Land (Encroachment)	0.12 %
Degraded Forest Land (Scrub)	- 1.63 %
Land with/without Scrub	5 %
Mining/Quarry/Industrial Area (Waste Dump/Land Fill)	0.4 %
Mining/Quarry/Industrial Area (Active)	0.118 %
Plantations	1.8 %
Reserved/Protected Forest Land	2 %
Water Bodies/River	1.3 %
Total	

Environmental degradation has occurred in the study area in several ways. Marginal agricultural lands have turned into open scrub, while farm lands have been waterlogged. About 106 sq.km area of productive land under vine yards has been abandoned, and there now lies scrub land (2). More recently, large developmental projects like the International Airport project at Shamshabad and Outer Ring Road project displaced the farming from large areas. Such growing pressure on land has promoted speculative activities that result in further degradation of productive lands.

Table 4 further proves degradation of farm land. Decrease in farm land and increase in built-up area are more in southeast and southwest. Change is least in northeast. Water bodies are encroached more in southeast and northeast. The quarrying activities in southeast and northwest sectors are indicators of land degradation (3).

Musi Channel Changes

A comparison of the data of 2006 with that of 1975 indicates a significant decline in channel area of the river, Musi. One can not expect any major geomorphological change in a period of 30 years; but channel area in the study region got declined from about 8 sq.km in 1975 to about 2 sq.km in 2006; and thus anthropogenic impact on landforms seems to be tremendous. River channel area was about 4 per cent of the study region in 1975 and it got reduced to 0.85 per cent in 2006. In this rate, in

Table 4
Land Cover Changes in Hyderabad Urban Agglomeration (HUA region) (1971 – 2000).

Change (from .... to)	Area (sq. km.)	Type of Degradation
Agriculture - Srub	570	Prime Agricultural land going out of production due to degradation
Vineyrd - Scrub	1.6	Degradation of land.
Water - Scrub	6.0	Encroachment in catchment area leading to drying up of water bodies.
Water - Vineyard	0.2	Encroachment on water body.

Source: Kausalya Ramachandran "Environmental Audit in the Vicinity of HUA' in the edited volume on EIA Studies and Planning Perspectives (forthcoming).

another 100 years, Musi river may disappear and may become a paleo-channel because of human encroachment. Musi river channel area is encroached by slums, residential colonies, government buildings, and graveyards. Central Bus Station of Hyderabad was constructed on an island of the Musi river.

The channel seems to have shrunk in size both in length & width as evident from Table 5. Though there is no significant change in its length as it got reduced by merely 1.3 km, width has decreased significantly. Channel got shrunk by an average width of 0.419 km.

There have been records of floods of varied magnitude in Musi valley. In 1908, a large scale flood occurred largely because of heavy rains. However, in 2000, flood in this valley happened largely due to encroachments on the banks and bed.

Conclusion

Musi landforms and land system around Hyderabad are found chaning with rapid urban growth and sprawl. Agriculture land, open scrub and water bodies have been encroached up on to a great extent; and about 37% of the channel area is replaced with built up areas in a span of just 30 years, thereby .causing flooding when rains are heavy.

References

1. Farooq S & S.Ahmad (2008). "Urban Sprawl Development Around Aligarh City : A Study Aided by Satellite Remote Sensing and GIS" *Journal of Indian Society of Remote Sensing*, 36, pp. 77-88.
2. Kausalya Ramachandran & H P Singh (2001). "Sectoral Shift in Land Use under Changed Economic Scenario – A Case Study of Hyderabad Region using IRS – 1D LISS – III Data". Hyderabad: ICORG, JNTU.
3. Kiran D.Purnendu & R. Kausalya (2001). "GIS for Non-point Source Pollution Studies in Rangareddy & Medak Districts of A.P". Hyderabad: ICORG, JNTU.
4. Laxmi S.B (2006). "EIA of Musi River Basin". Hydearabd: Osmania University. (Unpublished PhD Thesis).
5. Neelam A. Jeol (1993). "Integration of Land Systems and Resource Management in Rangareddy District". Hyderabad: Osmania University. (Unpublished Ph.D Thesis).

Wind Energy Potentials in Rajasthan

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The wind, one of nature's most abundant resources, is a form of solar energy. It is renewable, nonpolluting, universally available and free. It is a stream of moving air molecules circulated by the sun's unequal heating of the earth's surface. The power in the wind is the total sum of all moving molecules of air, and according to the law of fluid dynamics, is proportional to the speed of the wind. Wind power installation is the latest mantra in Rajasthan's endeavour to improve the power generation scenario. The paper deals with the estimation of basic parameters of wind resource assessment such as mean wind speed and energy resource, and wind speed frequency and power density at different height in Rajasthan.

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The power in the wind is the sum-total of all the moving molecules of air, and according to the law of fluid dynamics, is proportional to the speed of the wind. The amount of air in constant circulation around the earth is estimated to be 5 quadrillion tonnes. If we could extract 10% of the global energy potential of the wind, we would comfortably meet the world's energy requirements from that source alone. The uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth cause winds. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. The wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity. The wind energy provides environment-friendly and cheapest source of electric energy. Its power plants are known for the lowest gestation and fastest payback period with low maintenance cost, no man power investment and zero fuel cost. However, it has limitations too; for its location, winds should be strong and consistent for long.

Basic Processes

The wind turns the blades of a wind mill and the rotating blades turn the shaft to which they are attached. The turning shaft typically can either power a pump or turn a generator, which produces electricity. Most wind machines have blades attached to a horizontal shaft. The shaft transmits power through a series of gears, which provide power to a water pump or electric generator. They are called horizontal axis wind turbines. There are also vertical axis machines, such as the Darrieus wind machines, which have two, three, or four long curved blades on a vertical shaft and resembles a giant egg-beater in shape. The amount of energy produced by a wind machine depends upon the wind speed and the size of the blades in the machine. In general, when the wind speed doubles, the power produced increases eight times. Larger blades capture more wind. As the diameter of the circle formed by the blades doubles, the

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power increases four times.

Wind Resource Assessment

Mean Wind Speed and Energy Resource

The annual wind speed at a location is useful as an initial indicator of the value of the wind resource. The relationships between annual mean wind speed and potential value of the wind energy resource are listed below.

Mean Annual Wind Speed and the Potential

Annual Mean Wind Speed at 10 m Height	Indicated Value of Wind Resource
< 4.5 m/s	Poor
4.5 – 5.4 m/s	Marginal
5.4 - 6.7 m/s	Very Good
> 6.7 m/s	Exceptional

In locations where data are not available, a qualitative indication of a high annual mean wind speed can be inferred from geographical location, topographical features, wind-induced soil erosion, and deformation of vegetation. However, accurate determination of the mean annual wind speed requires anemometer data for at least 12 months. The power P due to the kinetic energy of wind is proportional to 1/2 Mass × (Velocity)^2, that is the mass of air passing through an area A at velocity V. The mass of air passing through an area A per unit time is ñAV and the total power available from wind is,

$$P = [(1/2) \times (pAV) \times V^2] = [(1/2) \times (pAV^3)] \quad \text{Eqn.(1)}$$

where p is the mass density, pAV air mass flow rate and V the air-steam velocity.

Adjustment of Heights of Anemometer

Anemometers at different meteorological stations are set at different levels. The measurements and wind speed recorded at each station, prior to any analysis, have to be adjusted to the same height. A level of 10 m is the standard for a typical meteorological station to measure the wind speed. The data collected at different heights are adjusted to 10 m by the India Meteorological Department, and according to which

$$(V1/V2) = (H1/H2)^a \quad \text{Eqn.(2)}$$

where V1 is wind speed at height H1 of 10 m above ground level, V2 wind speed at height H2 above ground level, and a the roughness factor (0.30).

Wind Speed Frequency Distribution

The wind speed frequency distribution at a given location is either tabulated from wind speed data measured as a function of time or approximated by a probability distribution function based on measured data or assumed wind resources characteristics. In recent years, much effort has been made to construct an adequate statistical model for describing the wind frequency distribution. The probability density function F (V) for wind data is given by,

$$F(V) = (k/c) \times (V/c)^{k-1} \times \text{Exp}[-(V/c)^k] \quad \text{Eqn. (3)}$$

The cumulative distribution function :

$$(\text{CDF}) \text{ is } M(V) = 1 - \text{Exp}[(-V/c)^k] \quad \text{Eqn. (4)}$$

where, k is a dimensionless shape factor, C is scale factor with units of speed, and F (V) the probability or percentage of occurrence per unit wind speed V.

$$EPF = \frac{\text{Total amount of power available in the wind}}{\text{Power calculated by cubing mean wind speed}}$$

$$KEm \text{ and } KEa = \frac{\text{Mean power density for the month}}{\text{Mean power density at monthly mean speed}}$$

$$KEm = \frac{\frac{1}{2} \times \rho \Sigma Vi^3 Nm}{\frac{1}{2} \times \rho \times Vm^3} = \frac{\Sigma Vi^3/Nm}{Vm^3}$$

Eqn. (5)

where Vi is the hourly wind speed during the month, Nm the number of hourly wind speed during the month and Vm the monthly mean wind speed while the annual energy pattern factor is,

$$KEa = \frac{\frac{1}{2} \times \rho \Sigma Vi^3 Na}{\frac{1}{2} \times \rho \times Va^3} = \frac{\Sigma Vi^3/Nm}{Vm^3}$$

Eqn. (6)

where Vi is the hourly wind speed during the year, Na is the number of hourly wind speed during the year and Va is the yearly mean wind speed.

The power density per unit area is given by,

$P = KEm \times [1/2 (\rho \times Vm^3]$ for the month Eqn. (7)

$P = KEa \times [1/2 (\rho \times Va^3)]$ for the year Eqn (8)

where, ρ is the density, and KEm and KEa the energy pattern factor (EPF) for month and year respectively.

Estimation of Output

Turbine efficiency of 40% and electric generator efficiency of 85% are used in the calculation. With this, an overall efficiency of 35% in wind-electric generator units could be achieved. A load factor of 0.3 is assumed in the computation of energy output. Apart from well-known day-night and seasonal variation of wind regime, it is to be noted that the wind is fairly reliable compared to hydro resources (rainfall). The coefficient of variation of mean wind speed is about 5.85 per cent compared to a higher variability of rainfall (of about 28%).

Climate of Rajasthan

The climate of Rajasthan is hot and arid. It is due to its location in the north-western part of the Indian subcontinent where maritime effects do not take place on account of its long distance from the sea. Moreover, Rajasthan is situated, just north of tropic of cancer, where the solar rays are perpendicular in the summer season.

Solar Radiation and Sunshine

The duration of sunshine and the intensity of solar radiation affect the soil moisture, evaporation from the earth's surface, evapo-transpiration from plants and trees, and the total effect of temperature on animals and human-beings. During summer months (May-June), the length of days is far more than in the winter months (December-January) and so there is more sunshine in the summers. In the rainy months, sunshine is frequently affected by cloud covers which are more in the eastern and southern Rajasthan.

Meteorological observations show that Barmer and Bikaner districts have the longest duration of sunshine of about $9^1/2$ hours on an average in the year while Kota and Baran districts have the least average sunshine of about 7½ hours on an average in a year. In the months of April and May, the duration of sunshine in Bikaner, Jaisalmer and Barmer

districts is about 11.0 hours. In the rainy season, it may reduce to 7 hours in the above three districts. In July and August, Mount Abu gets the shortest duration of sunshine which is about 2.5 hours on an average. However, In all these places, the amount of solar radiation reaching the earth's surface depends upon: the transparency of the atmosphere which may sometimes be blurred by dust-storms, clouds and fog; the angle of sun's rays which vary greatly in the summer and winter seasons; and the duration of the day and night, as in summer season days are longer and in winter season days are of shorter duration.

Variability of Rainfall

Rainfall is highly variable in the western parts of Rajasthan. Wide fluctuations are noticeable in all years while there are some phenomenal years when rainfall is either much less or very much in excess. A review of the past rainfall records show that in western Rajasthan, rainfall was deficient by 60 to 85 per cent in the years 1877 and 1918 and in eastern Rajasthan, rainfall was deficient by 53 to 66 per cent than the normal in the years 1877, 1905, 1915 and 1918.

Rajasthan had abnormally wet spells also in the past. In Western Rajasthan, rainfall was in excess by 60 to 119 per cent in the years 1876, 1893, 1908, 1917, 1992, and 1944 while in eastern Rajasthan it was in excess by 54 to 98 per cent in the years 1908, 1917 and 1942.

A review of the recent data shows that in the year 2000, Bikaner (+ 39 per cent) and Jaisalmer (+26 per cent) received excess rainfall than the normal while Sriganganagar (- 42 per cent), Pali (- 31 per cent), Jodhpur (- 31 per cent), Banswara (- 46 per cent), Rajasmand (-50 per cent), and Chittorgarh (- 42 per cent) received less rainfall than the normal. It shows that high variability of rainfall prevails all over the state.

Range of Temperature

Characteristic of the arid region, the annual range of temperature is highest in western Rajasthan which is more than 20°C; while in eastern Rajasthan, these ranges vary from 15° to 18°C. Similarly, the diurnal range of temperature in the arid west is higher than the sub-humid east. Places like Jaisalmer, Phalodi, Bikaner and Jodhpur may have a summer maxima of 45°C with night temperatures of 27°C on the same day.

Occasionally, in association with western disturbances originating from the Mediterranean sea and also from the cold waves coming out of the Himalayan high pressure belt in winter months from December through February, the temperatures fall to less than freezing point in the night while the day temperatures may be over 25°C. Such variations are most phenomenal in western Rajasthan where the effects of cold and hot winds are most severe due to sandy soil (Fig.1).

Wind Speed and Direction

High speed winds blow from west to east in the summer months (April - June) over most of the parts of Rajasthan, with a speed of 18 to 25 km/ hour. The wind speeds may sometime rise to 40-50 km/ hour depending upon the intensity of the low pressure created here. These high speed winds bring dust-storms from the west, as the winds are coming from the Great Thar desert. The frequency of dust storms in western Rajasthan is 8 to 10 per year while in eastern Rajasthan it is only 2 to 4.

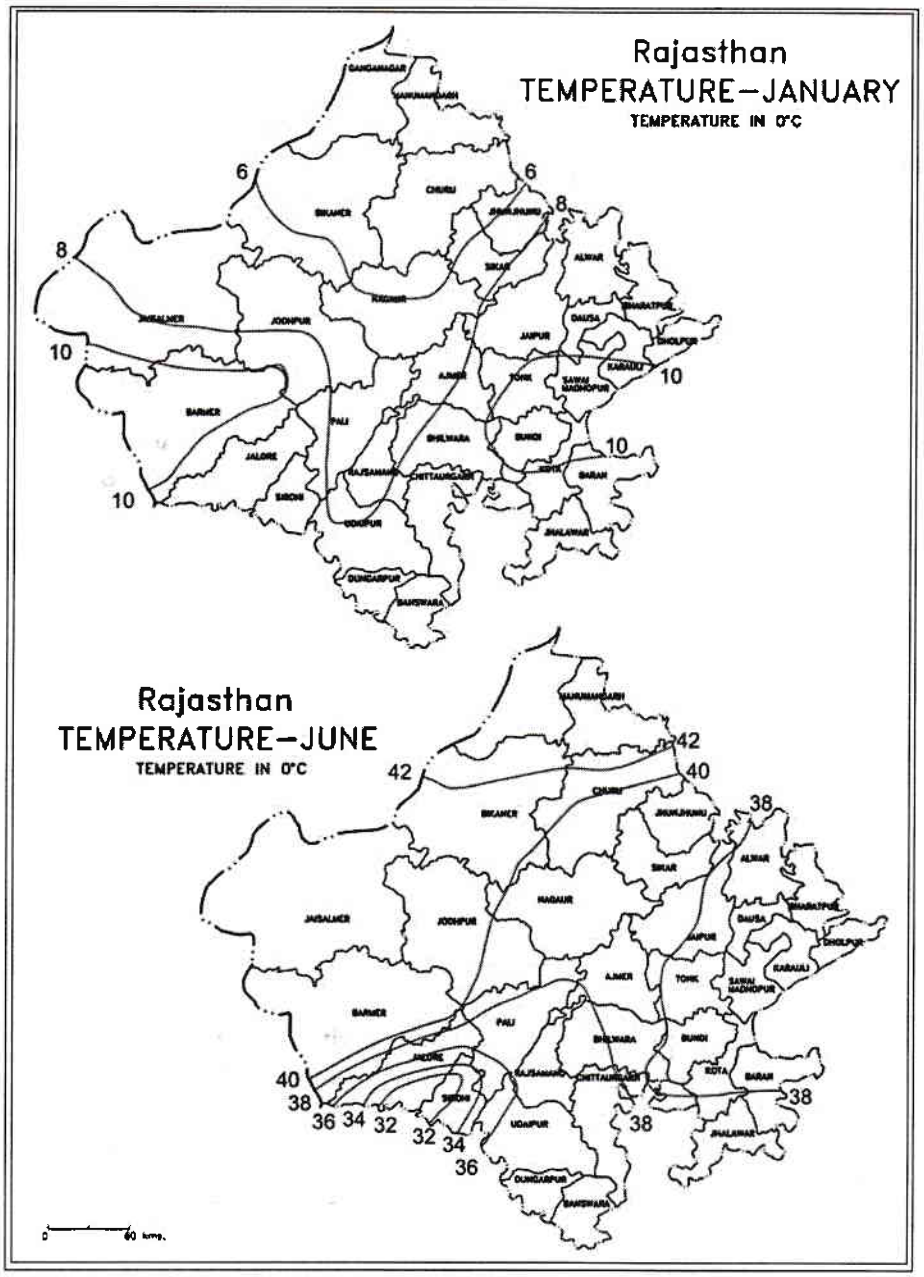


Fig. 1

In the monsoon months (July-September), the predominant direction of winds is south-west (Fig. 2). In winter months (December - February), the prevailing winds are north, north-east and north-west, closely following the direction of trade winds. But they are often punctuated by north-westerly, Mediterranean disturbances which bring light to heavy showers. Fog and mist usually occur at the ground level which lowers down the visibility.

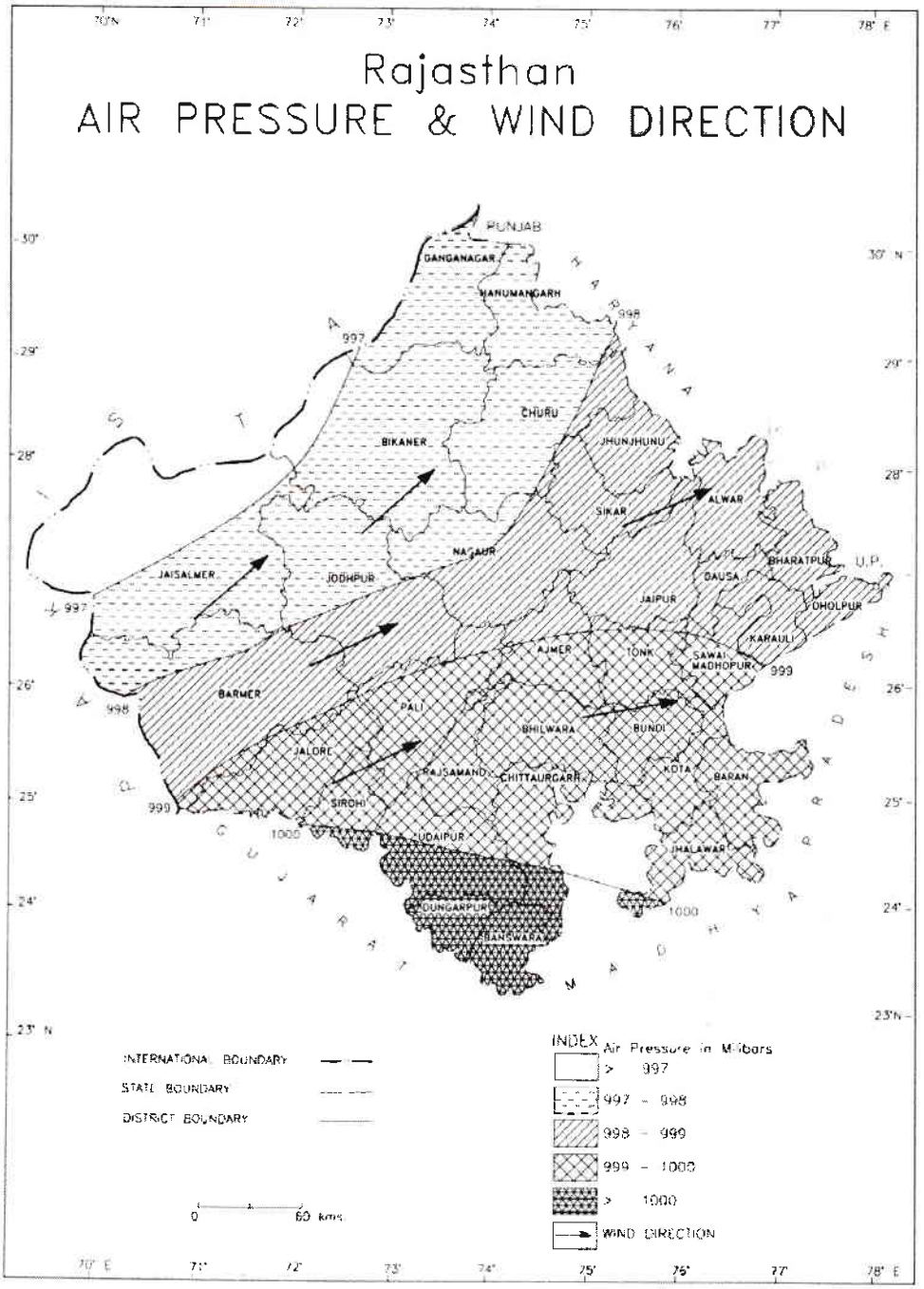


Fig. 2

Now-a-days, heavy fog with very poor visibility is found in eastern Rajasthan mostly in Bharatpur, Alwar, Dausa, Jaipur and Tonk districts. This fog formation is due to high

evaporation from the agricultural fields in the day and such water vapour descends down the atmosphere in cold nights, specially when the air is calm and stable. Annual wind direction and speed of 12 districts selected for the wind potential are shown by wind rose diagram in Fig. 3.

Wind Resource Assessment of Rajasthan

For the wind resource assessment of Rajasthan, twelve districts (32 stations) have been selected (Fig. 4). On the basis of data obtained from the meteorological department (Table 1) and data given by wind mast stations (Table 6), wind speed and density have been evaluated respectively.

For evaluating the wind potential regarding speed the following formulae were used. Calculated values of annual wind speed are shown in Table 2 and monsoonal wind speed is shown in Table 3.

Average Wind Speed

With reference to Table 2 and Fig. 5, we derived three categories to study the average wind speed of Rajasthan. The categories are as follows:

Rajasthan Wind Speed & Direction

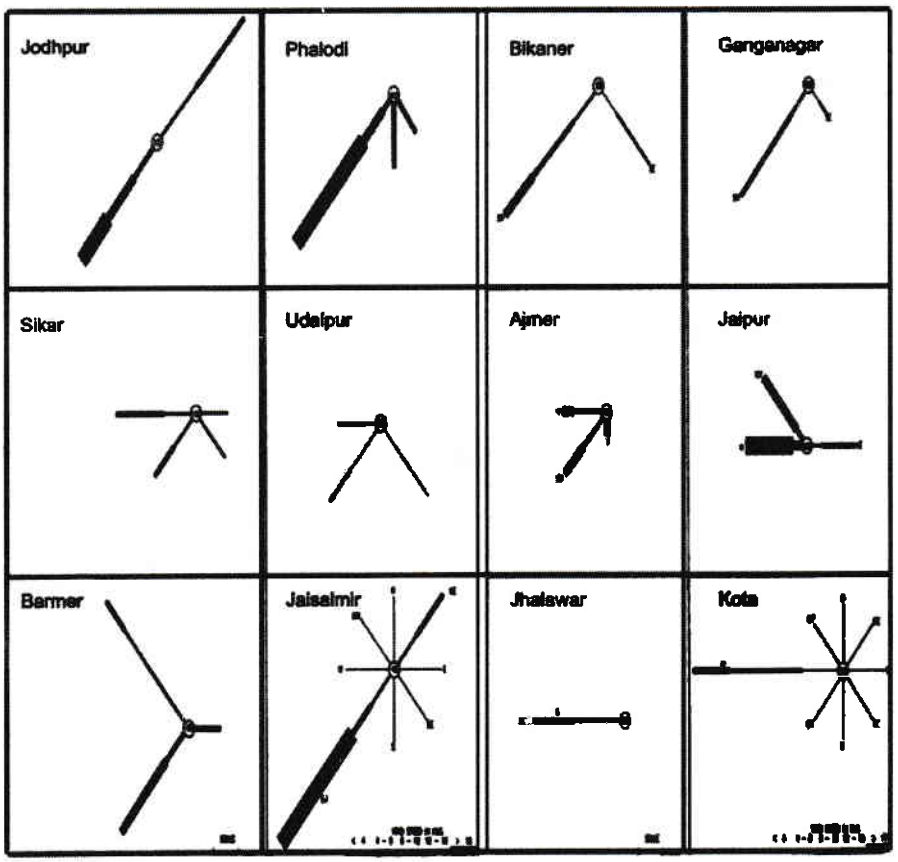
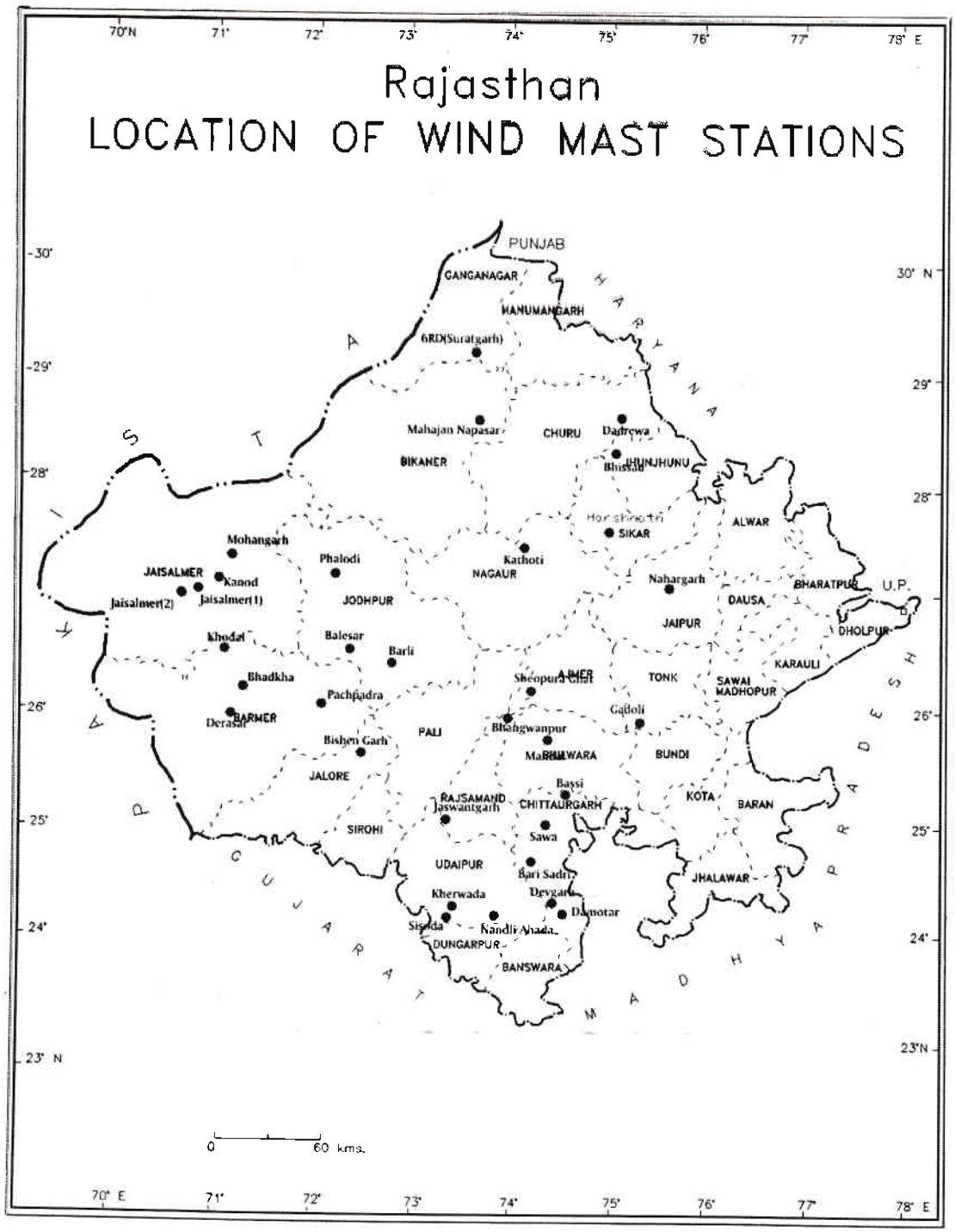


Fig. 3



Source MNES 2004

Fig. 4

Table 1

Mean Wind Speed (km/h) and Predominant Wind Direction

Station		Jan	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	2	3	4	5	6	7	8	9	10	11	12	13	14
Barmer	A	7.5	7.5	9.1	10.6	12.9	14.2	12.4	10.6	9.6	7.2	5.3	6.4
	M	NW	NW	NW	Var	SW	SW	SW	SW	SW/W	C/NW	NW	NW
	E	NE	Var	Var	SW/W	SW	SW	SW	SW	SW	Var	C/NE	NE
Bikaner	A	4.6	5.1	6.5	7.3	10.3	13.3	12.8	11.0	9.4	5.3	3.6	3.7
	M	C/SE	C/SE	SE/SW	SE/SW	SW	SW	SW	SW	SW	SW/SE	C/SE	C/SE
	E	NE/NW	SW/SE	NW/SW	NW/SW	SW	SW	SW	SW	SW	NW/SW	NW	NE/NW
Ganga Nagar	A	4.0	5.0	6.4	6.8	8.0	10.7	9.6	8.0	6.2	4.7	3.3	3.4
	M	C/Var	C/Var	C/Var	Var	SW	SW	SW	SW	SW	C/SE	C/SE	C/var
	E	NW	NW	NW	NW	NW/W	SW	SW/E	SW	SW/W	C/NW	C/NW	C/NW
Jaisalmer	A	8.6	8.2	10.9	12.7	18.3	27.2	24.8	21.7	16.1	8.5	5.5	6.5
	M	NE	C/NE	S/W/NE	SW	SW	SW	SW	SW	SW	SW	C/NE	C/NE
	E	NE	NE/NW	SW	SW	SW	SW	SW	SW	SW	SW	NE	NE
Jodhpur	A	8.9	8.8	9.8	10.2	15.0	18.5	16.6	12.9	10.6	6.6	5.8	7.5
	M	NE	NE	NE	S/W/NE	SW	SW	SW	SW	SW	C/NE	NE	NE
	E	NE	Var	W/S/W	W/S/W	S/W/W	SW	SW	SW	SW	SW	C/NE	NE
Phalodi	A	10.0	8.8	12.9	14.1	20.7	25.6	23.6	18.4	16.6	11.6	11.8	8.3
	M	C/SE	SE/S/C	S/SW	SW	SW	SW	SW	SW	SW	SW/S	S/SE	NE
	E	N/NE	N/NW	W/SW	Sw/W	SW	SW	SW	SW	SW/W	SW/W	N/NW	N
Ajmer	A	3.4	4.4	6.3	8.4	13.1	14.6	11.6	9.5	8.4	4.0	2.3	2.5
	M	C/Var	C/Var	C/Var	C/SSW	W/SW	S/SW	W/SW	W/SW	W	C/Var	C/Var	C/Var
	E	C/Var	W/c	W	W	W	W	W/SW	W/SW	W	C/W	C/Var	C/Var
Jaipur	A	11.0	11.5	12.0	13.1	16.5	17.8	16.2	12.4	12.3	10.0	7.6	8.1
(Sanganer)	M	C/E	C/E	C/E	C/NW	W/NW	W	W	W/SW	W/NW	NW	NW/C	NW/C

Source: Meteorology Department, Jaipur

(A) Mean Wind Speed in km per hour

(M) Predominant direction in the morning

(E) Predominant direction in the evening

(Var) Variable

(c) Calm : The next predominat direction is also indicated when calm is mentioned

* Hill station - Not considered for sub-divisional means.

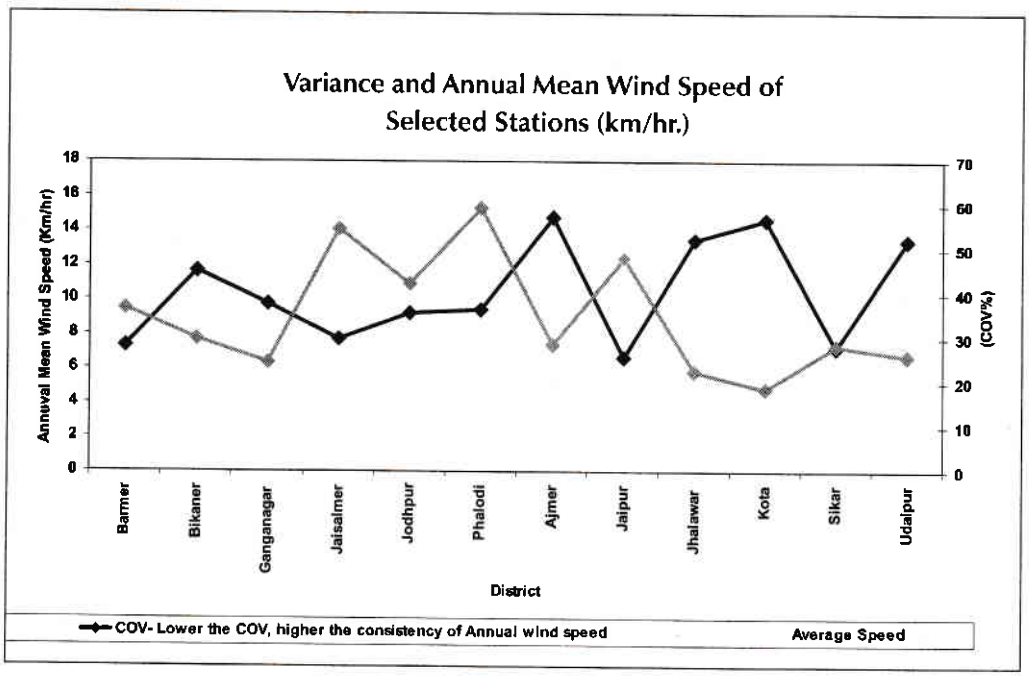


Fig. 5

Table 2
Annual Wind Speed

Districts	Average Speed	Standard Deviation	Coefiicient of Variation
Barmer	9.5	2.7	26.42
Bikaner	7.73	3.51	45.35
Ganga Nagar	6.34	2.4	37.81
Jaisaimer	14.08	4.22	29.99
Jodhpur	10.9	3.9	35.78
Phalodi	15.3	5.6	36.76
Ajmer	7.38	4.22	57.26
Jaipur	12.38	3.18	25.68
Jhalawar	5.83	3.05	52.3
Kota	4.83	2.75	56.91
Sikar	7.3	2.03	27.81
Udaipur	6.7	3.6	52.17

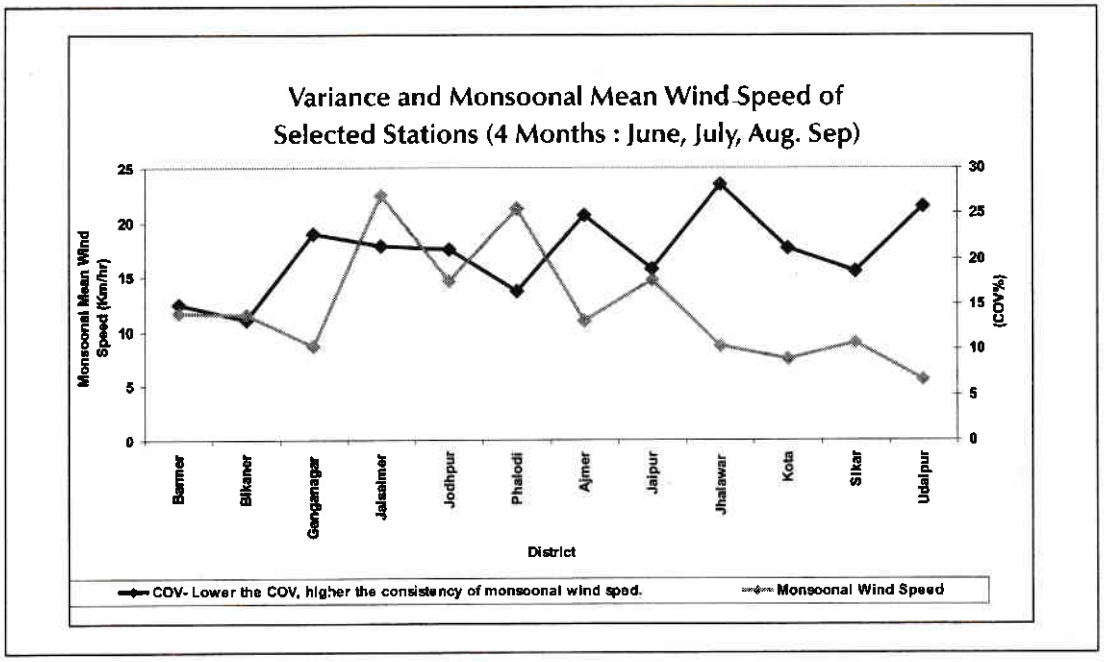


Fig. 6

Table 3
Monsoon Wind Speed

Districts	Average Speed	Standard Deviation	Coefiicient of Variation
Barmer	11.7	1.758	15.02
Bikaner	11.63	1.54	13.25
Ganga Nagar	8.63	1.96	22.73
Jaisaimer	22.45	4.79	21.36
Jodhpur	14.65	3.08	21.05
Phalodi	21.3	3.52	16.51
Ajmer	11.03	2.73	24.74
Jaipur	14.68	2.76	18.83
Jhalawar	8.68	2.44	28.13
Kota	7.43	1.57	21.13
Sikar	8.98	1.67	18.57
Udaipur	5.53	1.43	25.81

Range	Category	Region
Above 10	High Potential	Phalodi, Jaisalmer, Jodhpur
5 - 10	Medium Potential	Barmer, Bikaner, Ganganagar, Ajmer, Jhalawar, Sikar, Udaipur
Below 5	Low Potential	Kota

Rajasthan's commissioned wind plants are found located in Phalodi, Jaisalmer, Jodhpur, Sikar, and Barmer while Bikaner, Ganganagar and Udiapur seem to be good prospective sites. Selection of sites shows positive correlation with average annual wind speed.

Co-efficient of Variance of Wind Speed

This indicates the consistencies in the wind speed and this is an important aspect to be considered because wind energy generation has no back-up system; during the high wind speed, the surplus electricity, if not received by grid, goes waste while during low wind speed period lesser wind electricity is fed to the grid. The consistent wind speed areas are always better than high intermittent areas. This characteristic can be assessed by calculating the co-efficient of variation of wind speed and the following categories of wind potentials are obtained:

Range	Category	Region
Above 35	High Potential Range	Barmer, Jaisalmer, Jaipur, Sikar
35 - 50	Medium Potential Range	Sri Ganganagar, Jodhpur, Phalodi, Bikaner
Above 50	Low Potential Range	Ajmer, Jhalawar, Kota, Udaipur

Barmer, Jaisalmer and Sikar identified as high potential areas, have already been commissioned with plants but Jaipur though having high potential is left behind because of the other non positive factors such as non availability of wide and open space required for wind farm, and because of high land value. Ganganagar, Jodhpur, Phalodi and Bikaner with medium consistency range are considered as suitable sites because of high wind speed.

Monsoonal Wind Speed

As described earlier the climate of Rajasthan is hot and dry having monsoonal period from June to September when the wind speed is very high in the western and southwestern Rajasthan having almost south westerly direction. This is the time for obtaining high efficiency from wind harnessing machines. Table 3 gives the average speed and coefficient of variation in the monsoonal period. Fig. 6 represents it.

On the basis of monsoon wind speeds, three potential areas are identified.

Range	Category	Region
Above 20	High Potential	Jaisalmer and Phalodi
10 - 20	Medium Potential	Barmer, Jaipur, Jodhpur and Ajmer
Below 10	Low Potential	Ganganagar, Jhalawar, Kota, Sikar, and Udaipur

The high potential districts of Jaisalmer and Phalodi have already got wind mills established. However they lack high voltage grid lines. This factor is a big hurdle in obtaining the high efficiency of machines

Table 4

Total Analysis of Wind Power Potential in Rajasthan

Districts	Annual						Monsoonal						
	$\bar{X}a$	X_1	S.D	C of V	Y_1	$1-Y_1$	$\bar{X}m$	X_2	S.D	C of V	Y_2	$1-Y_2$	Z
Barmer	9.5	0.45	2.7	28.42	0.09	0.91	11.7	0.36	1.768	15.02	0.12	0.88	0.65
Bikaner	7.73	0.28	3.51	45.35	0.62	0.38	11.63	0.36	1.54	13.25	0.00	1.00	0.50
Ganganagar	6.34	0.14	2.4	37.81	0.38	0.62	0.63	0.18	1.96	22.73	0.64	0.36	0.33
Jaisaimer	14.08	0.88	4.22	29.99	0.14	0.86	22.45	1.00	4.79	21.36	0.55	0.45	0.80
Jodhpur	10.9	0.58	3.9	35.78	0.32	0.68	14.65	0.54	3.08	21.05	0.52	0.48	0.57
Philadi	15.3	1.00	5.6	36.6	0.35	0.65	21.3	0.93	3.52	16.51	0.22	0.78	0.84
Ajmer	7.38	0.24	4.22	57.26	1.00	0.00	11.03	0.33	2.73	26.74	0.77	0.23	0.20
Jaipur (Sanganer)	12.38	0.72	3.18	25.68	0.00	1.00	14.68	0.54	2.76	18.83	0.38	0.63	0.72
Jhalwar	5.83	0.10	3.05	52.3	0.84	0.16	0.68	0.19	2.44	28.13	1.00	0.00	0.11
Kota	4.83	0.00	2.75	56.91	0.99	0.01	7.43	0.11	1.57	21.13	0.53	0.47	0.15
Sikar	7.3	0.24	2.03	27.81	0.07	0.93	0.98	0.20	1.47	18.57	0.36	0.64	0.50

$\bar{X}a$ = Average Annual wind speed

$\bar{X}m$ = Average monsoonal wind speed

S.D. = Standard Deviation

C of V = Coefficient of variation

X_1 = Average wind speed

X_2 = Annual wind Speed

Y_1 = Coefficeint of variation (annual)

Y_2 = Coefficient of variation (monsson period)

Z = Power potential

during monsoon period. The medium range centers, Barmer, Bikaner, Ajmer, Jaipur and Jodhpur seem to be suitable; but except Jodhpur, other sites have some hurdles; Barmer has no high power grid line passing through; Bikaner has lesser power density; and Jaipur lacks wide and open space. Although Sikar comes in low potential range but its annual wind speed is consistent and has highest power density; and thus this district has been promoted.

Co- efficient of Variation during Monsoon Period

With reference to Table 3 and Fig. 6, three categories have been derived on the basis of co-efficient of variation during the monsoonal period.

Range	Category	Region
Below 15	High Potential	Bikaner
15 - 20	Medium Potential	Barmer, Phalodi, Jaipur and Sikar
Above 20	Low Potential	Jhalwar, Ganganagar, Jaisalmer, Jodhpur, Ajmer, Kota and Udaipur

Total Analysis

With reference to Table 4, a total analysis of wind power potential in Rajasthan has been done. The calculations have been done with the help of following equation and four categories have been derived which are shown in the following Table 5 and Fig. 7

$$Z = 1/4 \{X_1 + X_2 + (1 - Y_1) + (1 - Y_2)$$

where Z = Power Potential

$$X_1X_2 = \frac{\text{Actual Value } (\bar{x}_a, \bar{x}_m) \text{ -- Min. Value}(\bar{x}_a, \bar{x}_m)}{\text{Maximum Value } (\bar{x}_a, \bar{x}_m) \text{ -- Min. Value}(\bar{x}_a, \bar{x}_m)}$$

$$Y_1Y_2 = \frac{\text{Actual Value (C of V) -- Min. Value (C of V)}}{\text{Maximum Value (C of V)-- Min. Value (C of V)}}$$

Range	Category	Region
Above 0.75	High Potential	Jaisalmer, Phalodi
Above 0.50 - 0.75	Medium Potential	Barmer, Bikaner, Jodhpur, Sikar, Jaipur
0.50- 0.25	Low Potential	Ganganagar
Below 0.25	Very Low Potential	Ajmer, Jhalawar, Kota, Udaipur

Stations which come under High Power Density i.e. above 200 (W/m^2) are Harshnath (Sikar), Devgarh (Chittorgarh), Phalodi (Jodhpur), Mohangarh, Jaisalmer 1, Jaisalmer 2 (Jaisalmer), and Khodal (Barmer). Stations which come under Medium Power Density i.e. 150-200 (W/m^2) are Barli and Balesar (Jodhpur), Derasar and Bhadkha (Barmer), Kanod (Jaisalmer), Damotar (Chittorgarh), Bhagwanpur and Jaswantgarh (Udaipur).

Stations which come under Low Power Density i.e. below 150 (W/m^2) are 6RD Suratgarh (Sri Ganganagar), Bari Sadri, Kherueada, Naudli Ahada, Sisoda (Udaipur), Basi and Sawa (Chittorgarh), Bishengarh (Jalore), Bhissau (Jhunjhunu), Dadrewa (Churu), Gadoli (Tonk), Kathoti (Nagaur), Mandal (Bhilwara), Nahargarh (Jaipur), Pachpadra (Barmer), and Sheopura Ghat (Ajmer).

Wind Farm Development in Rajasthan

The first two wind farms were set up in 1999 by the state owned Rajasthan State Power Corporation Ltd., and after the success of these two megawatt projects private sector started investing in wind farm sector. The biggest three MW plant was set up at Barabagh by Endurance Transmission System Ltd., two years ago. The state owned Rajasthan Vidyut Prasar Nigam purchases the produced power from the private producers. But the Jaisalmer gird which is connected with 122 MW wind power stations has no capacity to carry the generated power and this has resulted in reducing the production capacity of the wind farms.

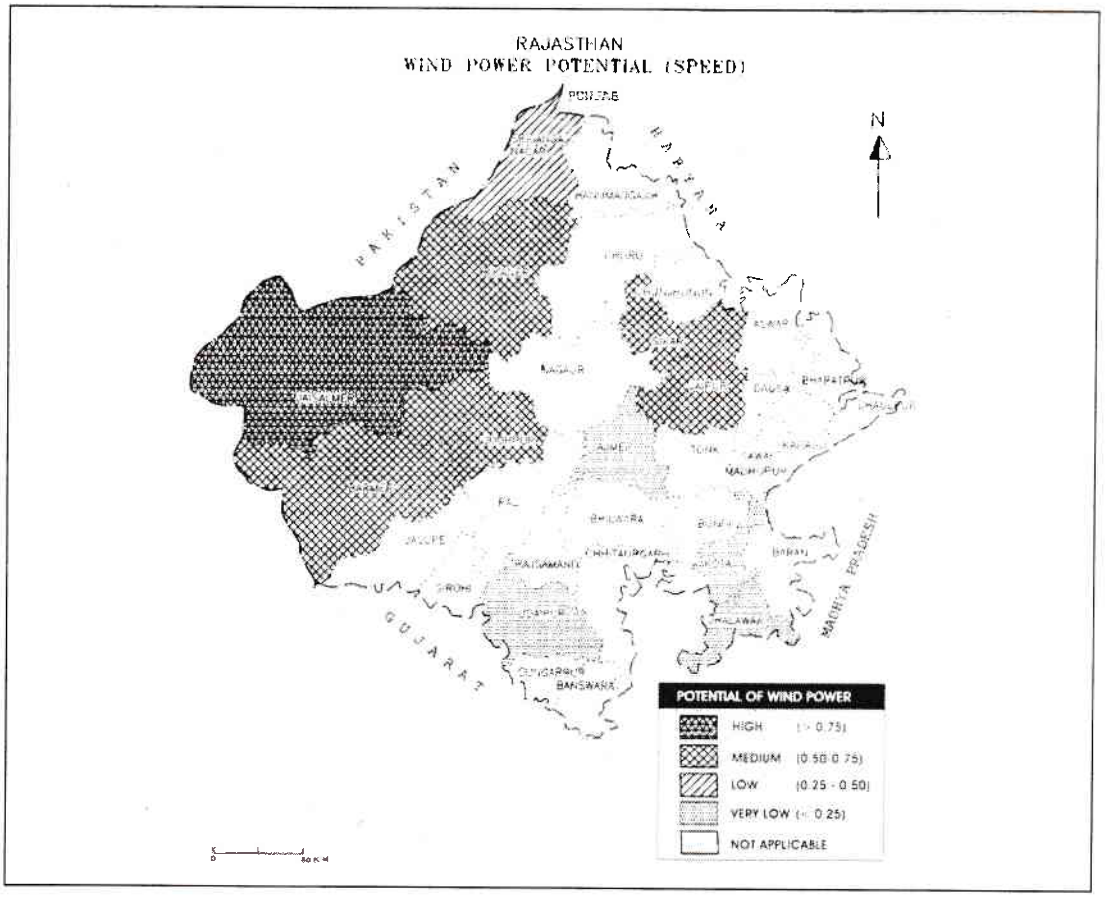
At present under the 132 KV system 100 percent of the generated wind power flows.

Table 6

Wind Mast Data of Rajasthan

S. No.	District	Stations	WPD extrapolated at 50m (W/m)
1.	Rajsmand	1.Bhagvanpur 2.Jaswanthgarh	169 166
2.	Udaipur	3.Kherwada 4.Nandi Ahada 5.Sisoda 6.Undari	073 119 072
3.	Jaisaimer	7.Jaisaimer (1) 8.Jaisaimer (2) 9.Kanod 10.Mohangarh	274 311 193 243
4.	Chittorgarh	11.Basi 12.Damotar 13.Devgarh 14.Sawa 15.Bari Sadra	114 189 281 146 142
5.	Barmer	16.Bhadka 17.Derasar 18.Khodal 19.Paxhpadra	185 195 229 124
6.	Jodhpur	20 Balesar 21.Barli 22.Phalodi	192 198 261
7.	Bikaner	23.Mahajan 24.Napasar 25.Gajner	112
8.	Sikar	26.Daubsi 27.Harshanth	206
9.	Jalore	28. Bishen Garh	148
10.	Jhunjhu	29. Bhissau	54
11.	Churu	30. Darewa	118
12.	Tonk	31. Gadoli	096
13.	Nagaur	32. Kathoti	096
14.	Bhilwara	33. Mandal	136
15.	Jaipur	34. Nahargarh	090
16.	Ajmer	35. Sheopara Ghat	149
17.	Sri Ganga Nagar	36. 6 RD (Surat Garh)	102

(Wind Power Potential on the basis of Power Density)



But such wind power farms which are connected to 33 KV systems are not equipped to carry the power, and there is a need to improve the grid to carry more power. According to an official report, the state government is making efforts to improve the grid system to enable it to carry far more load than is being carried presently. It is likely that

Table 7
Wind Power Installed Capacity (MW) of Rajasthan

Years	Installed Capacity
Up to 2001 -2002	16.1
2002 -2003	44.6
2003 -2004	117.8
2004 -2005	84.7
Total	263.2

Table 8
Wind Power Generation of Rajasthan (Kw/h)

Years	Installed Capacity
Up to 2001 -2002	24994198
2002 -2003	22394806
2003 -2004	17193349
2004 -2005	8721064
Total	7303417

Fig. 8

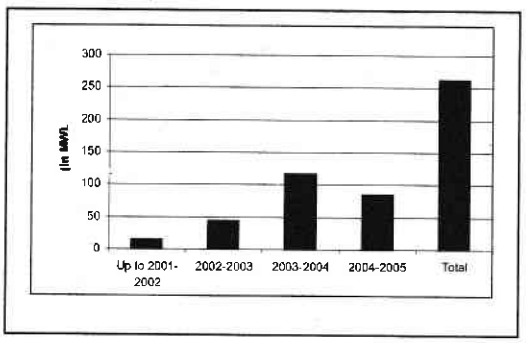


Fig. 9
Wind Power Installed Capacity (MW) of Rajasthan

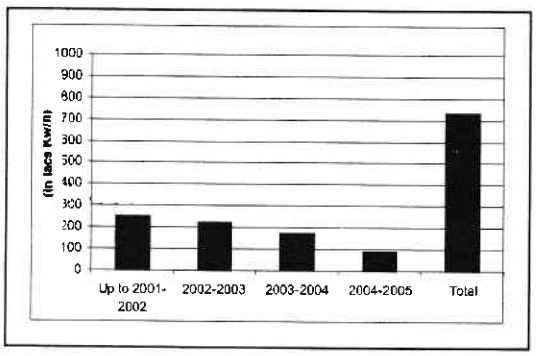


Fig 10
Wind Power Generation of Rajasthan (Kw/h)

the upgraded system will be ready by next year. Jaisalmer, which is a tourists paradise, has emerged in recent times as a major producer of wind energy. The state government has signed an agreement with private producers to produce 247.89 MW of wind power. There are 23 companies which are producing wind energy in Jaisalmer, Amarsagar, Barabagh, Baramsar, Mada, and Gorera.

Rajasthan's capacity and wind power Generation may be understood from the Tables 7 and 8 and Figs. 9 and 10.

Acknowledgement

This paper was written under the able guidance of our revered teacher Dr. (Mrs.) Preeti Mathur, who has recently passed away. Her untimely demise is a great loss to the academic fraternity. I fondly and thankfully remember her.

Select Bibliography

1. Cook, Earl,(1977). "Energy Sources for the Future," in William R. Burch J.R. (ed.). *Readings in Ecology, Energy and Human Society: Contemporary Perspectives*. New York: Harper and Row Publishers.
2. Dixit, Dhirendra Kumar (1987) "Harnessing Wind Power," *Yojana*, 31, (3). pp. 16-28.
3. Doughlas M. Considine (1977). *Energy Technology Handbook. New York:* Mcgraw Hill Book Company.
4.. Fresis, Leon (1992). "Inherit the Wind", *IEE Review*, 38 (4).
5.. Gupta O.P and Kulshrestha P (1983). "Power Threshing *Economical and Energy Saving Device," Energy Management*, 7(2).
6. Halacy D.S (1977). *``Earth, Water, Wind and Sun'': Our Energy Alternatives*. New York: Jr. Harper and Row Publishers.
7. IEE Conference (2001). *International Conference on renewable energy, 2001*. Publication No. 385, Clean Power.
8. Kusnur V.R (1982). "Top Priority for Energy," *Yojana*, 28.
9. Ministry of Non Conventional Energy Sources (2004). ``Renewable Energy in India''. (A Report).

Documents Consulted

1. "Financial Incentives for Renewable Energy Development", World Bank Discussion Paper, No. 391, 1997.
2. ``Renewable Energy and Energy Efficiency Financing Guidelines 2000. India Renewable Energy Development Agency, April 2000.
3. "Energy in India: India Energy Directory". Confederation of Indian Industry, September 1998.
4. "Power From Renewable Energy- An Industry Directory", CII, 1998.
5. Annual Reports of Ministry of Non -Conventional Energy Sources, Government of India.
6. Annual Reports of Indian Renewable Energy Development Agency (IREDA).
7. Annual Reports of the Ministry of Power, Government of India.

Oussudu Lake,Pondicherry, India:

A Survey on Socio-economic Interferences

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Oussudu Lake, spreading in about 700 ha in the Union Territory of Pondicherry, is one of the large expanses of fresh water in the Peninsular India. It is known for its biodiversity and migratory birds visiting the lake during winter months. The paper looks into the socio-economic impacts on the lake, using secondary data and field visits and interviews. There has been a steady environmental degradation in the lake due to encroachments and industrial pollution, and a decline of economic dependence of the villagers on the lake. In the recent years, recreational activities are being promoted, using the potentials of the lake, and this may bring about investment opportunities for revamping the lake on a sustainable scale.

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Oussudu lake, which is commonly called Ousteri (eri means 'lake' in Tamil), is situated about 110 km south-southwest of Chennai. The lake is identified with the Union Territory of Pondicherry even though close to half of the water-spread lies within the boundary of Tamil Nadu. Oussudu receives its water from monsoon rains. It also, at times, receives water from the Suthukenni check dam through a channel to the lake. When full, the lake spans about 700 ha with an average depth of one metre (5). The winter months find Oussudu abuzz with migratory birds. Indeed such is the richness and diversity of avifauna visiting Oussudu every year that the lake has come to be recognized as one of the most important host wetlands of peninsular India (6). The plankton and fisheries have a role to play in attracting the water fowl (7, 8).

In this paper, a socio-economic study of the impact of Oussudu on the people living in the Oussudu catchment has been presented in the context of the lake as a resource base. The study used the data collected both from the governmental and non-governmental sources. A wide cross-section of the population living around the lake, and the officials associated with the lake have also been interviewed to complete the socio-economic picture. Those interviewed include the local farmers who depend on the lake for irrigation, the officials of the Public Works Department , the Chief Wild Life Warden (Pondicherry) and the locals who make their livelihood from the various resources of Oussudu.

Utilization of Oussudu Watershed

Agriculture

Before 1990s, farmers of nearly 18 villages used to depend on Oussudu lake for irrigation. Now only 9 villages depend on it directly for irrigation: Koodapakkam, Agaram, Olavaikkal, Konerikuppam, Poraiyur, Sedanatham, Oussudu and Vazipettapalayam. The effective command area served by the

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Oussudu lake covers a mere 2000 acres of land, while the total area cultivated within the lake watershed is about 5000 acres. The remaining 3000 acres are irrigated not with the Oussudu water but with the help of bore-wells sunk within the lake watershed. Unfortunately, the heavy reliance on bore wells, rather than surface water bodies, for irrigation is a malaise afflicting the entire region (Table 1).

The farmers have been increasingly shifting to bore well-based irrigation for two reasons. Firstly, the government has been subsidizing the cost of sinking of bore wells and the electrical power used in drawing bore well water. Secondly, it is more convenient for the farmers to pump up water form their bore wells at will, instead of having to adjust their work to the convenience of government staff employed to operate sluices which release Oussudu water.

Cropping Pattern

The major crops grown around Oussudu lake are paddy (75%) and sugarcane (20%). The rest of the cultivation comprises of casuarina and other plantations, usually found along the banks of the lake and amidst the rice fields (5, 8).

Agricultural Inputs

It was a pleasant surprise to find that the farmers at Oussudu are using mostly dried cow dung, compost, azolla, phosphobacteria and azospirillum, instead of synthetic fertilizers. Farmers say that the practice of using cultured manure was prevalent during the French regime and is now regaining popularity after 50 years. Also the use of pesticides has been reduced by 60% in the past 5 years on the advice of the Agriculture Department, Pondicherry. Due to the efforts of the department, farmers have realized that it is in their larger interest to suffer some damage caused by the pests rather than risk the pests becoming resistant to pesticides.

Farmers do use pesticides, but more sparingly; Democran or Nuvan are used when the paddy crop is 20 to 30 days old; endosulphan and monocrotophos are used on when the crop is 30 to 45 days old crops.

Recharging of Aquifers

The geology of the Oussudu area reveals the presence of alluvium underlain by Cuddalore sandstone formations. Below this is the Manaveli formation and the aquifer contributes good deal to the ground water. According to the hydrogeology of the region, Oussudu lake recharges the acquifers of Vanur - Ramanathapuram sandstone formation. The farmers around the lake are aware that Oussudu lake plays a major role in recharging the ground water acquifers. During the period of 1967 till 1974, when the lake had dried up, there was a significant ground water depletion. Similarly during the period 1985- 89, the groundwater level had decreased drastically as the lake had dried up. Thus, Oussudu lake gains prominence as it recharges the ground water aquifers, more so now because the ground water remains the prime source of irrigation and drinking water for Pondicherry region. A special mention may be made of the fact that most of the Pondicherry town depends for its drinking water on the ground water aquifers of Muthirapalayam (4). The Muthirapalayam aquifer falls within the Vanur-Ramanathapuram aquifers which are directly fed by Oussudu lake.

Table 1
Area under Irrigation in Pondicherry over the Years

Year	Area under Canal Irrigation (ha)	Area under Tank Irrigation (ha)	Area under Tube Well Irrigation (ha)
1957	10780	5497	---
1958	11297	5430	2974
1959	11308	6103	3288
1960	11319	5883	4216
1961	11295	6229	4494
1962	11377	6355	4974
1963	11468	6034	7626
1964	11266	6328	7697
1965	11908	5825	8636
1966	11066	5464	8249
1967	11064	4770	9165
1968	11010	4894	8908
1969	10659	2742	11830
1970	10875	5046	9915
1971	11143	5516	9716
1972	11026	5490	9611
1973	11048	4835	10404
1974	10949	5048	10164
1975	10852	1548	13179
1976	10886	2954	11831
1977	10724	4498	10376
1978	10889	4902	10594
1979	11017	5368	10280
1980	11033	5191	10067
1981	15960	--	14897
1982	10872	2362	11064
1983	10696	100	13818
1984	10671	1241	12871
1985	10569	940	13721
1986	9254	1071	13639
1987	9587	234	14093
1988	8818	68	13804
1989	9586	56	13545
1990	9316	6	12520

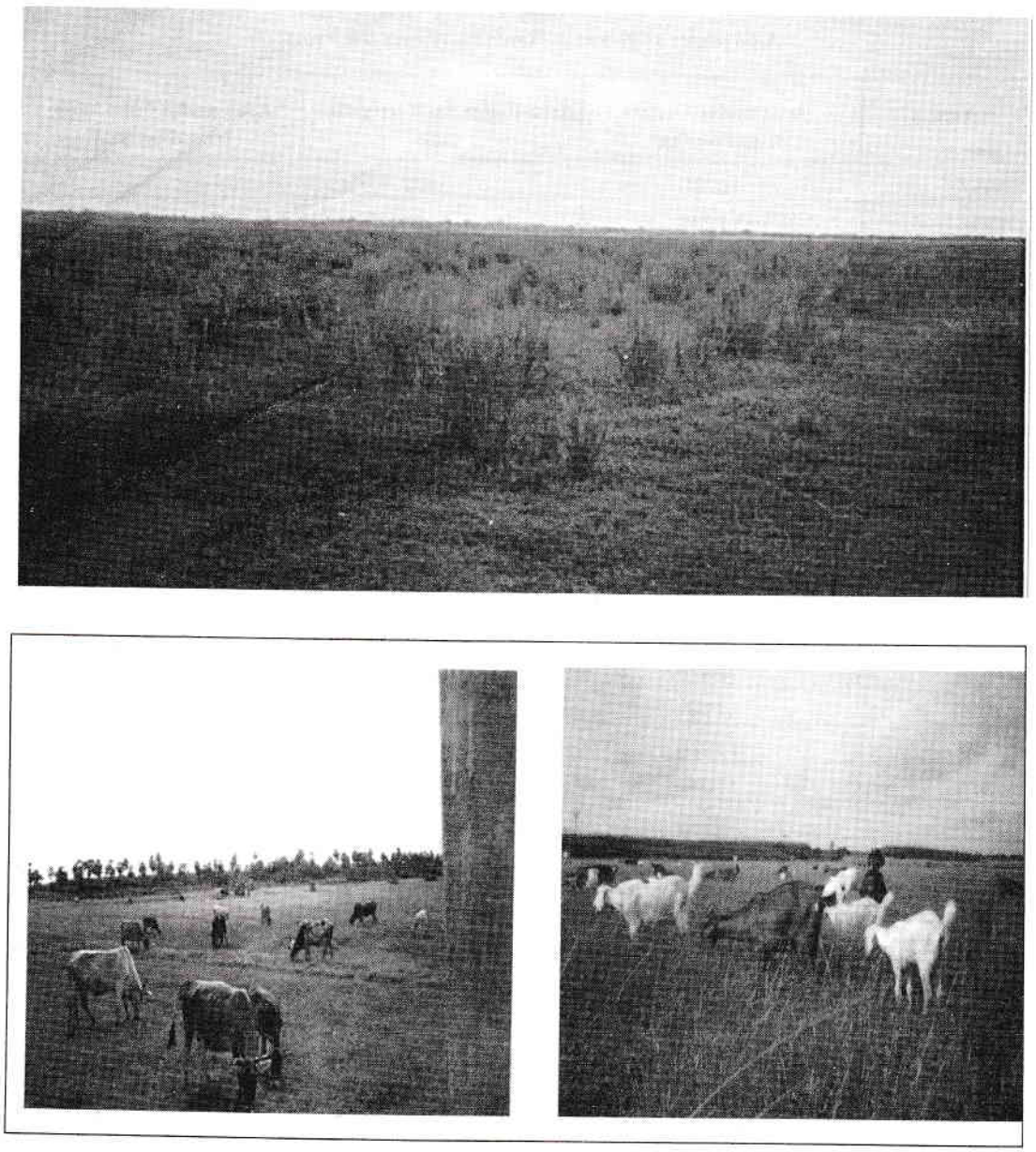

Plate 1 The Shallow Banks of the Lake sporting Various Types of Grasses

Plate 2 Ipomoea growing luxuriously inside the Lake, which is used for thatching of Huts, and Fencing

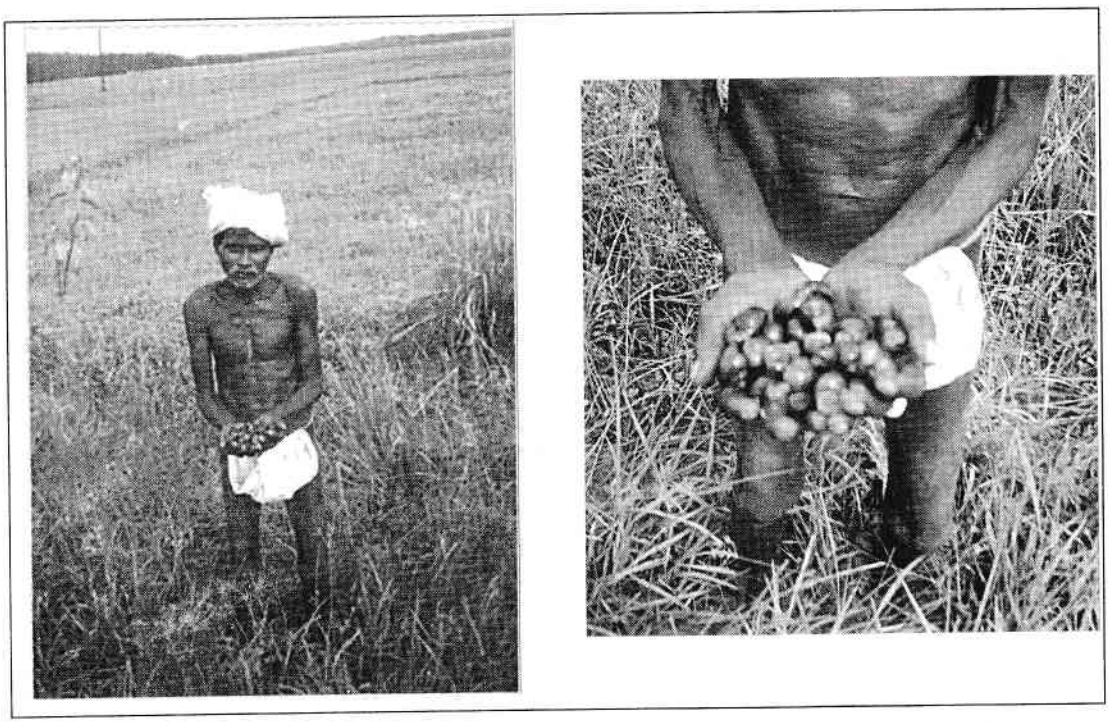

Plate 3 An Old Man Harvesting a handful of snails which are known to have Medicinal Value.

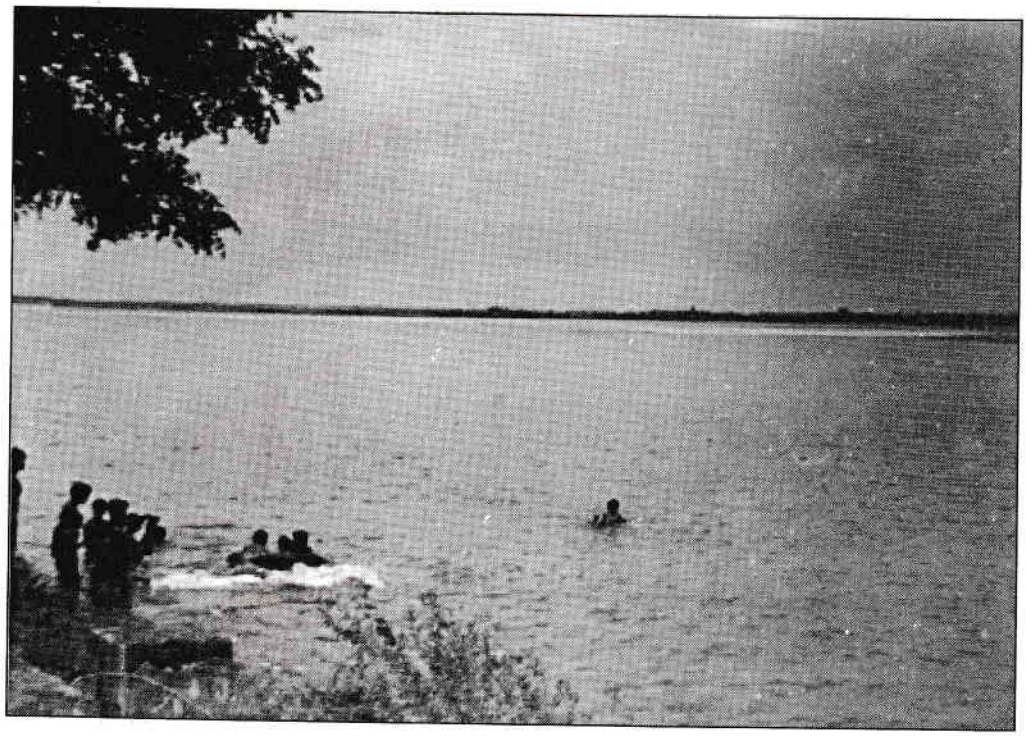

Plate 4 Oussudu Lake is now more a Recreation Centre than a Bird Sanctuary

Fisheries

Fishing is not the chief occupation of the people living around Oussudu lake, but it does provide a source of income to most. In the year 1988, the Oussudu lake was managed by the department of fisheries, Pondicherry, who introduced some commercial varieties of fish in the lake. From 1989 till 1997, it was under the control of Villianur Commune Panchayat. During this period, fishing rights were auctioned annually for Rs. 50,000 - 60,000. Since 1997, once the lake was declared a bird sanctuary, it came under the control of Department of Forestry and Wildlife, Pondicherry, and fishing has been totally prohibited. Over the years the pisean species diversity has declined (9).

Grazing of Live-stock, Reed Extraction, and Other Produce

The shallow banks of the lake sport rich and luxurious grasses (Plate 1). The local people feed their cattle on these grasses almost throughout the year. Also, they cut and use the reeds and grasses that grow in and around the lake for the purpose of thatching the huts. Ipomoea, which grows profusely in the lake, and is used for fencing the houses and agriculture fields (Plate 2). Other than fish, some people harvest the snails which thrive along the water supply channels and banks of the lake (Plate 3). These snails are known to have some medicinal value.

Recreation

Oussudu makes a pretty sight when it is full during the monsoons. It has a great potential for development as a picnic spot. Recently, there have been efforts from the Government of India and the Government of Pondicherry towards making Oussudu a centre for informal recreation. Restaurants, a boathouse, a water fountain, trekking facilities and other attractions are envisaged (Plate 4). These efforts may be helpful in securing the future of Oussudu by attracting investment, provided determined efforts are made to prevent recreational activities from becoming a source of pollution of the lake and disturbance of its wildlife. Indeed, the importance of lake quality and its ecosystem in attracting visitors should be built into the business plan of the centre.

The Potential Threats

Encroachment

The lake is deeper in its southeast portion and shallower towards northwest. It sports grasses and a variety of reeds towards north and hence is an ideal ground for the spawning of fish, and roosting of birds. Unfortunately, these shallow portions of the lake are the ones that are being encroached by the agricultural fields as soon as the water level in the lake recedes during the summer months (Plate 5).

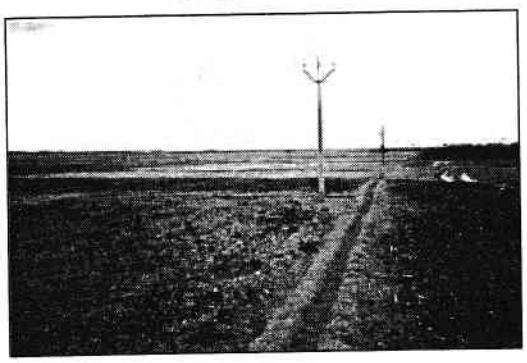

Plate 5 Encroachment of Agriculture Fields on the Shallow Parts of the Lake

The practice of agriculture inside the lake can contribute fertilizers and pesticides getting mixed with water body; this may be one of the factors responsible for the hyper-eutrophic condition of the lake (9, 10, 11). Agricultural encroachment may also be interfering with the habitat of migratory birds.

Industrial Pollution

Oussudu is now under great demographic and extractive pressure. The farmers of the region, encouraged by subsidies and loans, have taken to bore well irrigation in a big way, leaving the surface water sources under disuse, and over exploiting ground water (Table 1). With the decline of ground water table, there are reports of soil and water degradation (15, 16, 17). It was noticed that bore wells were sunk even within Oussudu lake for irrigating the crops (Plate 6). In the past few years,the rapid industrialisation and urbanisation over the years in Pondicherry has taken place in the vicinity of Oussudu (18, 19, 20), especially along Oussudu - Mettupalayam road in the east, and Thondamanatham in the northwest (Plate 7).

In the past, there were incidents of dumping of industrial effluents around and inside the lake. One such incident was reported by Mr. Prakash Patel of Sri Aurobindo Ashram who first noticed the presence of huge piles of obnoxious substance dumped at the periphery of Oussudu Lake during the summer of 1993 (1). The matter was brought to the notice of the Government of Pondicherry which could only promise to look into the matter but did not. Mr. Patel then approached INTECH, who in turn,

Plate 6 Bore Wells are sunk even inside the Lake for Irrigation

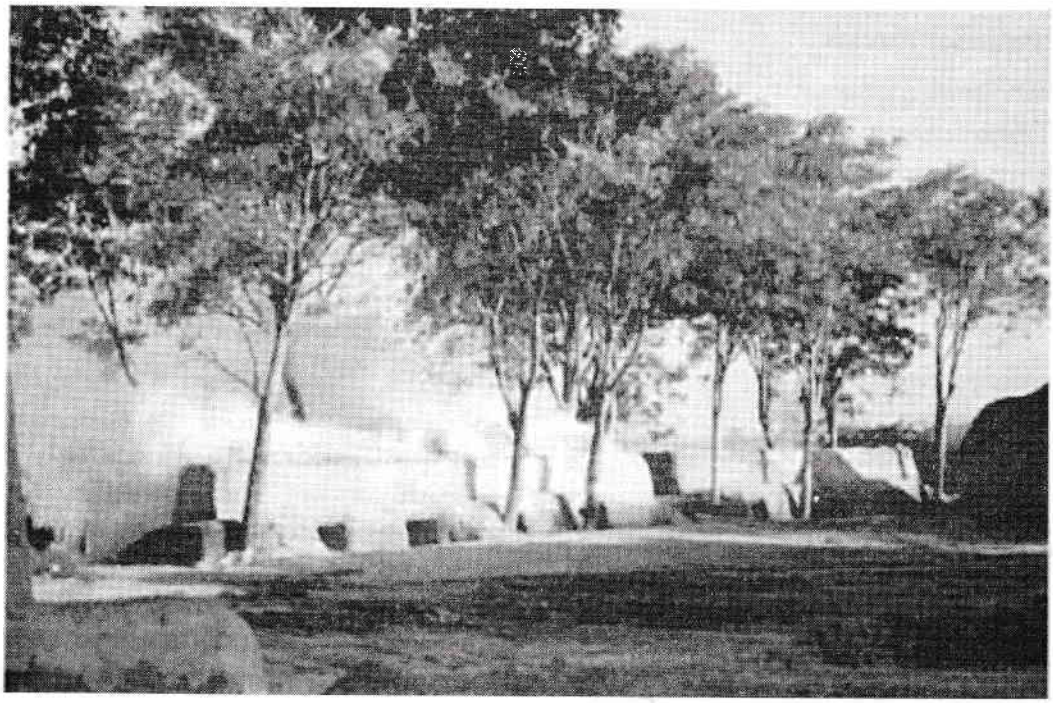

Plate 7 This Brick Kiln, located just a Few Metres away from the Lake, can cause serious Air Pollution and subsequently, the Water Pollution

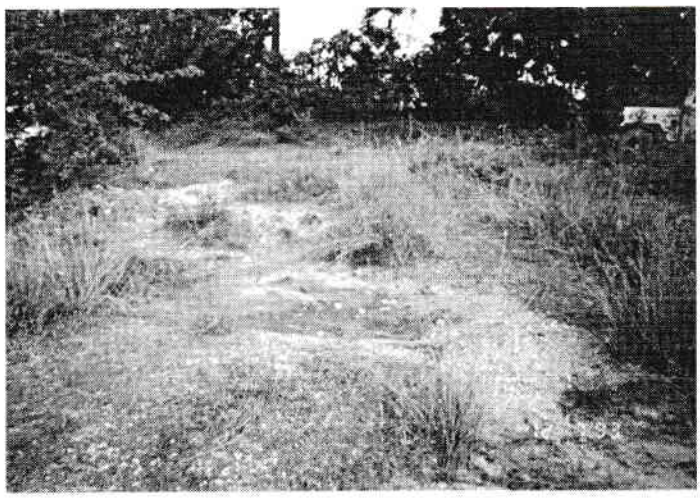

Plate 8 The Site where the Noxious Waste was dumped at Oussudu, devastating the Flora and Fauna that came in Contact

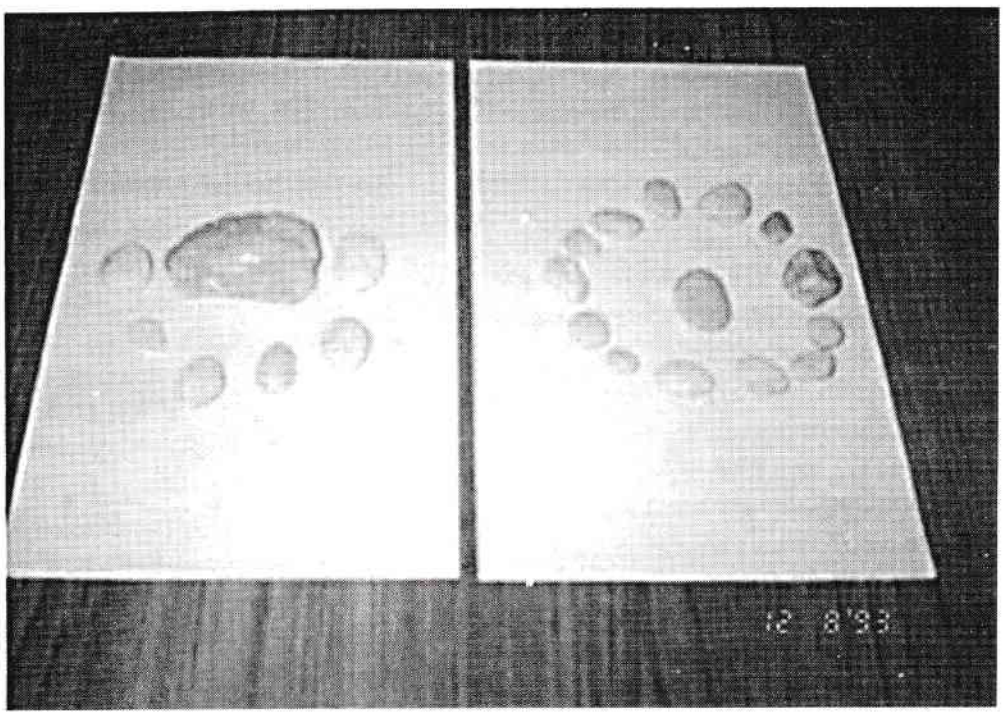

Plate 9 On Contact, the Acidic and Foul Smelling Waste discoloured the Pebbles (a) **and** *;the Normal Pebbles*(b).

in turn, referred samples of the waste to us for analysis. The foul smelling waste was highly acidic and toxic - it devastated the flora and fauna that came in contact with it, killing them instantly (Plate 8). The stones and pebbles on which the waste fell, lost their colour and texture (Plate 9).

In another incident, in June 1998, a sugar mill, dumped its effluent into the lake. The mill is located 20 - 25 km from Pathukannu in Mundiyapakkam. Death of a few birds was noticed. There was a public interest petition made to the Lieutenant Governor of Pondicherry, who in turn directed the issue to the Deputy Conservator of Forestry and Wildlife.

So far no light has been thrown on the incident. Now a 300-bed hospital and a medical college has come up right opposite to the southern flank of Oussudu. This has raised apprehensions that Oussudu may be exposed to highly hazardous hospital wastes – not to speak of other forms of pollutants (2,3).

As the Oussudu Lake has already become hyper-eutrophic due to the inflow of fertilizers and pesticides, it hardly has the resilience to survive the onslaught of industrial pollution. The increased vehicular traffic around Oussudu disturbs the birds and may also contribute to the atmospheric pollution. Though the Oussudu Lake has been declared a bird sanctuary, still illegal hunting of birds continues. Nets are placed across the lake to trap the wading ducks. The patrolling of the forest guards does help in curbing this illegal practice, but only to a limited extent.

Views of the Villagers on Oussudu

A large number of villagers living on the the Oussudu Lake catchment were contacted and their views sought on 15 specific questions. The questions, in italics, and the gist of the response against each question, is presented below.

1. ***How many villages depend on Ousteri (Oussudu Lake) for irrigation?***

   Earlier 18 villages (around 5000 acres) were dependent on Ousteri directly for irrigation. But now, only 8 villages depend on Ousteri water directly for irrigation. There are nearly 500-700 bore wells around Ousteri. Dug wells are few in number and they are not used for irrigation.

2. ***What are the crops grown around Ousteri?***

   Paddy is the major crop grown throughout the year in all seasons. It constitutes 75% of the crops grown. Sugarcane is the next crop grown which constitutes around 20%. The remaining 5% comprises of casuarina and other crops.

3. ***Are fertilizers and pesticides used?***

   Use of fertilizers has been reduced. Seventy per cent of the farmers use manure. Manure comprises mostly the compost, phosphobacteria, Azospirillum, and Azolla. The remaining 30% of the fertilizers comprise the complex, urea, potash, bactumpas, vijay complex, and DAP.

   Use of pesticides has been reduced by 60% from the past five years. It is used only when it is essential, such as, for paddy when it is 20-30 days old, democron or nuvon is used; and when it becomes 30-45 days old, endosulfon or monocrotophos is used.

4. ***Why this change from fertilizers to manure and less use of pesticides?***

The people from agricultural department, Pondicherry, has explained us how pests develop resistance when pesticides are used on long-term basis, and the hazards caused by the commercial fertilizers on a long-term basis. Once the pesticides are used, the number of pests increases, and therefore the cost to kill these pests also increases.

5. ***Is there any subsidy for electricity?***

   Yes, there is subsidy for electricity to small farmers; large farmers should pay Rs. 75/- per horse power (The distinction of small farmers and large farmers is determined by the Revenue Department).

6. ***Is ground water depletion felt when the lake dries?***

   From 1967, for 7 years when the lake had dried up, there was ground water depletion. Again the same happened from 1985-89. The level of ground water was very less during 1989-90; but now the ground water had increased because of consistent rains and water in the Lake.

7. ***Is there any co-operative society which helps the farmers?***

   For every village, there is a co-operative society for the welfare of the farmers.

8. ***Do you feel Ousteri is important ?***

   There were mixed reactions to this question:

   (a) Ousteri is very important for Pondicherry as such, because it is the source of drinking water of Pondicherry. Realising the importance of Ousteri, the World Bank, when approached by the state government had allotted a year back a sum of Rs. 13.8 million.

   b) No, Ousteri is of no use to us. We no more use the lake water for irrigation, and we depend only on the ground water.

9. ***In which way do you feel the Lake must be conserved?***

   The Lake must be deepened; should be cleaned; bridges and bunds to be built and taken care of.

10. ***Is there fish catch in the Lake? What types of fishes are found?***

    There is no fishing in the Lake. But there is some illegal fishing done.

11. ***Do they practice aquaculture or agriculture when the Lake dries?***

    No, such practice is not found.

12. ***How / what do you feel about Ousteri being declared as a bird sanctuary?***

    Ousteri has lots of birds. During November, many birds come from other places and stay here.

13. ***Is there any problem regarding Ousteri being partly in Tamil Nadu and partly in Pondicherry?***

    Till now no such problem has been experienced.

14. ***Is French type of agriculture practiced?***

    As such it is not practiced, but now use of compost is coming up after 50 years; this was so during the French period.

15. ***Were there any incidents of the industrial effluents and solid wastes being dumped nearby or inside the Oussudu Lake?***

    Two years back, we have seen containers, filled with effluents of industries, discharging the waste in the eastern side and south-eastern side of Ousteri. Previously we used to drink the water from Ousteri, but after this episode, we use the Ousteri water only for other purposes like washing clothes.

Summary and Conclusions

The studies reported in this paper, and some of the studies on the limnology of Oussudu reported by us earlier lead to the following conclusions:

(1) In the recent past, the farmers around Oussudu have been shifting to bore well-based irrigation rather than depending on the surface water resources. This would very soon lead to drastic loss of groundwater table.

(2) During the course of the study we spoke to a wide cross-section of villagers living close to the Lake. Most of them were aware of the likely benefits they derive from the Lake and the likely enhancement in the benefits if the Lake is managed better.

(3) There was an element of bitterness in the people's attitude towards Oussudu and a lack of a sense of belonging to the Lake. We believe that these feelings have their origin in the governmental initiatives to prohibit the villagers' traditional mode of interaction with Oussudu for fishing, wood, and occasional poaching of wildlife. The initiative was well meant but perhaps implemented in a bureaucratic, 'top down' fashion, without consulting the people or telling the people how best they (the people) can help in conserving the Lake, in general without taking them into confidence.

(4) The management plans for Oussudu should take into account the diverse uses made by villagers of this Lake. Traditional activities such as fishing, reed cutting, grazing, desilting, etc., if left under the care of the village cooperative, with periodic monitoring to safeguard against overuse, can cause little disturbance to the Lake. Indeed, ecosystems like Oussudu have adapted to moderate disturbances that humans have been causing over centuries, reaching a new equilibrium or stabilization (1).

(5) The ever-increasing pressure on groundwater for irrigation and industrial uses can have adverse effects on the hydrological regime of Oussudu, as is observed globally. For example, the Tablas de Daimal National Park (Spain) has an acute shortage of water caused largely by the use of groundwater for irrigation (1).

(6) Given the increasing awareness of people towards the long-term benefits of environmental conservation, it appears possible that a governmental initiative supported by people, or vice versa, may be effective in reversing the present trend of Oussudu. Such an initiative must aim at integrated watershed management. The present levels of pesticide and fertilizer use, which are often more than is essential (21), may be regulated or managed by informal agreement. Seasonal encroachment into shallow or dried areas of the Lake by farmers may be discouraged; instead, controlled fishing may be permitted. People's participation can also enable large masses of Ipomoea sp. and other weeds to be removed from the Lake and turned into compost / vermi-compost using recently- developed knowledge (12, 13, 14). A few areas of the Lake, such as those supporting stands of weed species, may be dredged to control their spread.

(7) The recent plans of making Oussudu a recreation centre should be treaded with caution. It would be in the long-term

interest of the Lake to promote eco-tourism.

Acknowledgement

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References

1. Abbasi S.A(1997). *Wetlands of India -Ecology and Threats: the Ecology and the Exploitation of Typical South Indian Wetlands.* New Delhi: Discovery Publications House.
2. Abbasi S.A and R. Soni, (1983). 'Stress-induced Enhancement of Reproduction in Earthworm Octochaetus pattoni exposed to chromium (VI) and Mercury (II) - implications in environmental management', *International Journal of Environmental Studies,* 22, pp 43-47.
3. Abbasi S.A and R. Soni (1984). 'Teratogenic Effects of Chromium (VI) in Environment as evidenced by the Impact on Larvae of Amphibian Rana tigrina: Implications in the Environmental Management of Chromium', *International Journal of Environmental Studies,* 23, pp. 131-137.
4. Bose S C (1998). 'Surface Water Management in Pondicherry Region'. A Paper presented at a Seminar on 'Water Resources'. Pondicherry: Public Works Department. (March 25th).
5. Chari K. B and S. A Abbasi, (2002). 'Environmental Conditions of Oussudu Watershed, Pondicherry, India', *The Indian Geographical Journal,* 75, pp. 81-94.
6. Chari K. B, S. A. Abbasi and S. Ganapathy (2003). 'Ecology, Habitat and Bird Community Structure at Oussudu Lake: Towards a Strategy for Conservation and Management', *Aquatic Conservation: Marine and Freshwater Ecosystems,* 13, pp. 373-386.
7. Chari K. B and S. A. Abbasi (2003). 'Assessment of Impact of Land Use Change on the Plankton Community of a Shallow Fresh Water Lake in South India by GIS and Remote Sensing', *Chemical and Environmental Research,* 12, pp. 93 – 112.
8. Chari K. B and S A Abbasi (2002). 'Application of GIS and Remote Sensing in the Environmental Assessment of Oussudu Watershed', *Hydrology Journal,* 25, pp. 13-30.
9. Chari K. B and S. A. Abbasi (2005). 'A Study on the Fish Fauna of Oussudu – A Rare Freshwater Lake of South India', *International Journal of Environmental Studies,* 62, pp. 137-145.
10. Chari K. B. and S. A. Abbasi (2006). 'A studies on the aquatic and amphibious weeds of Oussdu lake', *Hydrology Journal,* 28, pp 89 - 98.
11. Chari K. B and S. A. Abbasi (2006). 'Spatial and Temporal Patterns in the Water Quality of A Major Tropical Lake – Oussudu', *Hydrology Journal.* (in press).
12. Gajalakshmi S, E. V. Ramasamy and S. A Abbasi (2001). 'Screening of Four Species of Detritivorous (humus - former) Earthworms for Sustainable Vermi-composting of Paper Waste', *Environmental Technology,* 22, pp. 679-685.
13. Gajalakshmi S, E. V. Ramasamy and S. A Abbasi (2002). 'High-rate Composting-vermi-composting of Water Hyacinth (Eichhornia crassipes, Mart. Solms)', *Bioresource Technology,* 83, pp. 235-239.
14. Gajalakshmi S and S. A. Abbasi (2004). 'Neem Leaves as A Source of Fertilizer-cum-pesticide Vermi-compost', *Bioresource Technology,* 92, pp. 291-296.
15. Khan F. I and S. A Abbasi (1997). 'Risk Analysis of A Chloralkali Industry situated in a Populated Area using the Software Package MAXCRED-II', *Process Safety Progress,* 16, pp. 172-184.
16. Khan F. I and S. A Abbasi (1998). 'Multivariate Hazard Identification and Ranking System', *Process Safety Progress,* 17, pp. 157-170.
17. Khan F. I and S. A. Abbasi (1998). 'DOMIFFECT (DOMIno eFFECT): User-friendly Software for Domino Effect Analysis', *Environmental Modelling and Software,* 13, pp.163-177.
18. Khan F.I and S. A Abbasi, (1999). 'The World's Worst Industrial Accident of the 1990s: What

happened and What might have been - A Quantitative Study', *Process Safety Progress,* 18, pp.135-145.

19. Khan F.I and S. A. Abbasi (2000). 'Analytical Simulation and PROFAT II: A New Methodology and A Computer-automated Tool for Fault Tree Analysis in Chemical Process Industries', *Journal of Hazardous Materials,* 75, pp.1-27.
20. Khan F. I and S. A. Abbasi (1996). 'Simulation of Accidents in A Chemical Industry using the Software Package MAXCRED', *Indian Journal of Chemical Technology,* 3, pp. 338-344.
21. Kumar R. N (2000). *Applying Some GIS Concepts in the Environmental Management.* Pondicherry: Pondicherry University. (M.Phil Dissertation).

Short Communications

Poultry Litter and Energy Potentials in Namakkal Taluk, Tamil Nadu, India

Energy is the basic requirement for all the sectors of economy. Energy use in terms of fossil fuel is the major cause of air pollution and climatic change. Improving energy efficiency, developing alternative eco-friendly energy resources, and reducing the use of fossil fuel are the issues in the discussion of energy in these days (3). Ramachandra (4) explained biogas as a potential alternative fuel source, and attempted a study for Kolar district in Karnataka, using GIS. Batzias *et al.*(1) estimated that the wolrd may have a potential of 424 million cu.m of biogas for the year of 2010. Subhrabaran Das *et al.* (7) worked out the district-wise biomass residues generation and the potential for power generation from surplus biomass for the state of West Bengal State. Ramachandra *et al.* (5) developed a GIS-based methodology to map the potentials of solar and wind energy, bio-energy and small hydro-energy sources, based on taluk level information for the state of Karnataka. Another interesting study was made by El-Hadidi *et al.* (2) who investigated the possibilities of using poultry waste as an organic fertilizer and alternative energy source.

Study Area

The main objective of the present study was to make village-wise estimation of biogas energy potential and power generation from poultry droppings in Namakkal taluk, Tamil Nadu, India. Located at an mean altitude of about 300 m between 11° N and 11° 26′ N and 78° 02′E and 78° 28′ E, Namakkal taluk extends over an area of 1513 sq.km. Namakkal, the taluk headquarter, is the only town in the taluk which has 117 villages grouped under six development blocks. The taluk is known for egg production and sends the eggs to all over the country. Namakkal is known as Egg City or Poultry Town. It is also known for truck building industry. Hills are found on the northern and eastern parts of the taluk. Well-known Kolli hills, the garden of Namakkal taluk, spreads over an area of 371

□ The Indian Geographical Journal 83 (2) December 2008; published in June 2009

sq.km with peaks rising to 1300 m. Taluk has semi-arid climate, and Thirumanimutharu and Kaveri rivers pass through this taluk (6). The maximum temperature ranges from 28^0C to 40^0C and the minimum from 14^0C to 26^0C. Annual normal rainfall of the taluk is 784.10 mm. Paddy is the main crop, followed by *cholam,* maize, groundnut, cotton, sugarcane,

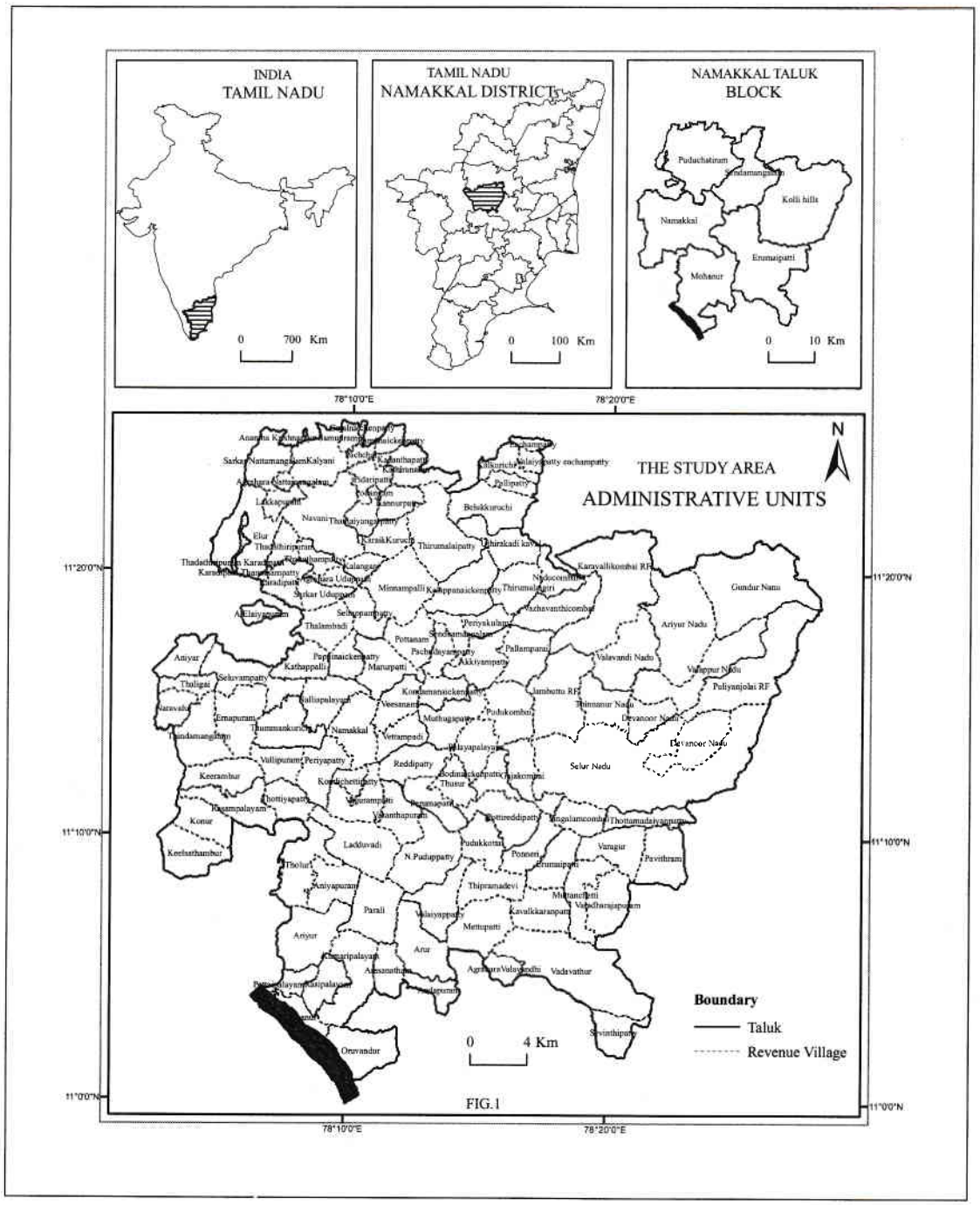


FIG.1

tapiaco, onion, turmuric and pulses. Total population as per 2001 Census of the taluk was 550000 with density being 332 per sq.km. About 52 per cent of working population is engaged in farming activities.

Material and Methodology

Biogas from poultry litter is an alternative energy source. Biogas energy potential assessment in the present study is based on compilation and computation of poultry litter

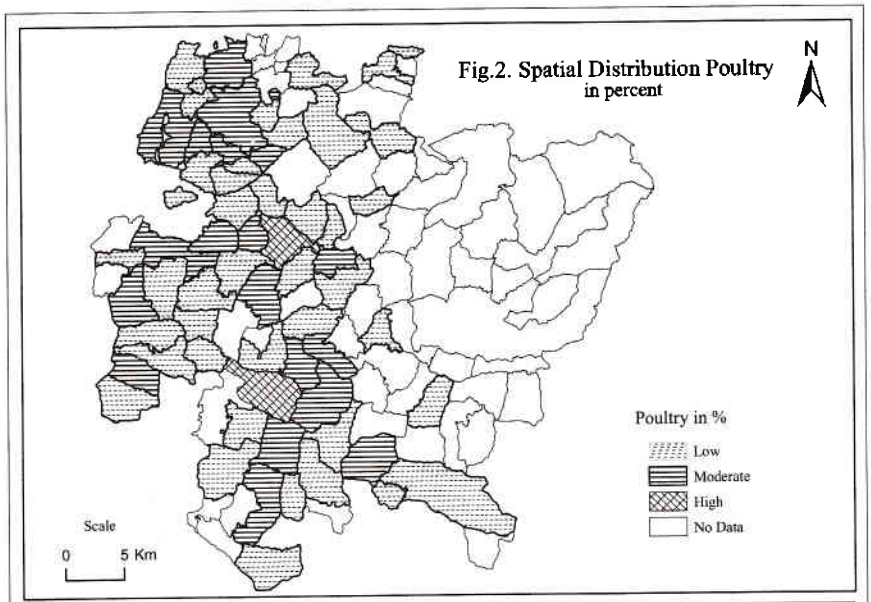


Fig.2. Spatial Distribution Poultry in percent

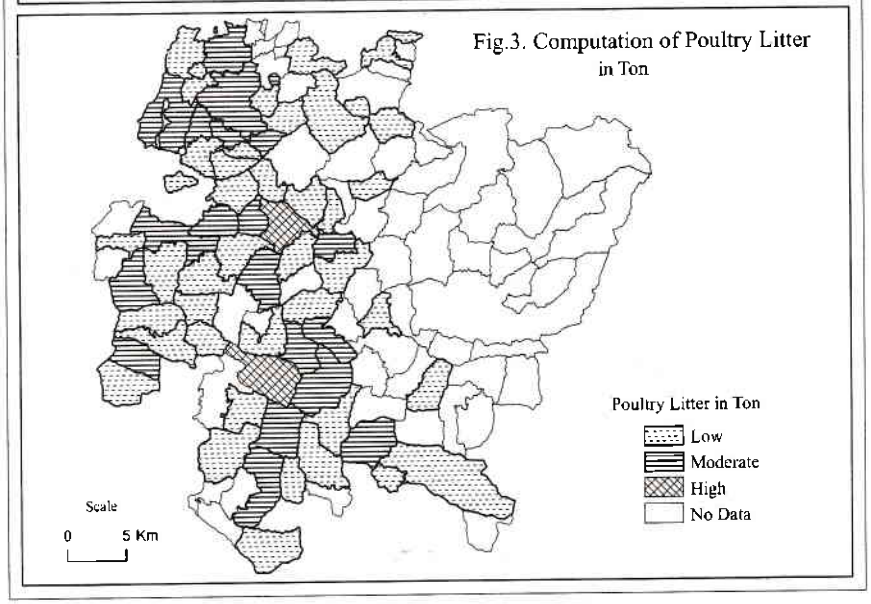
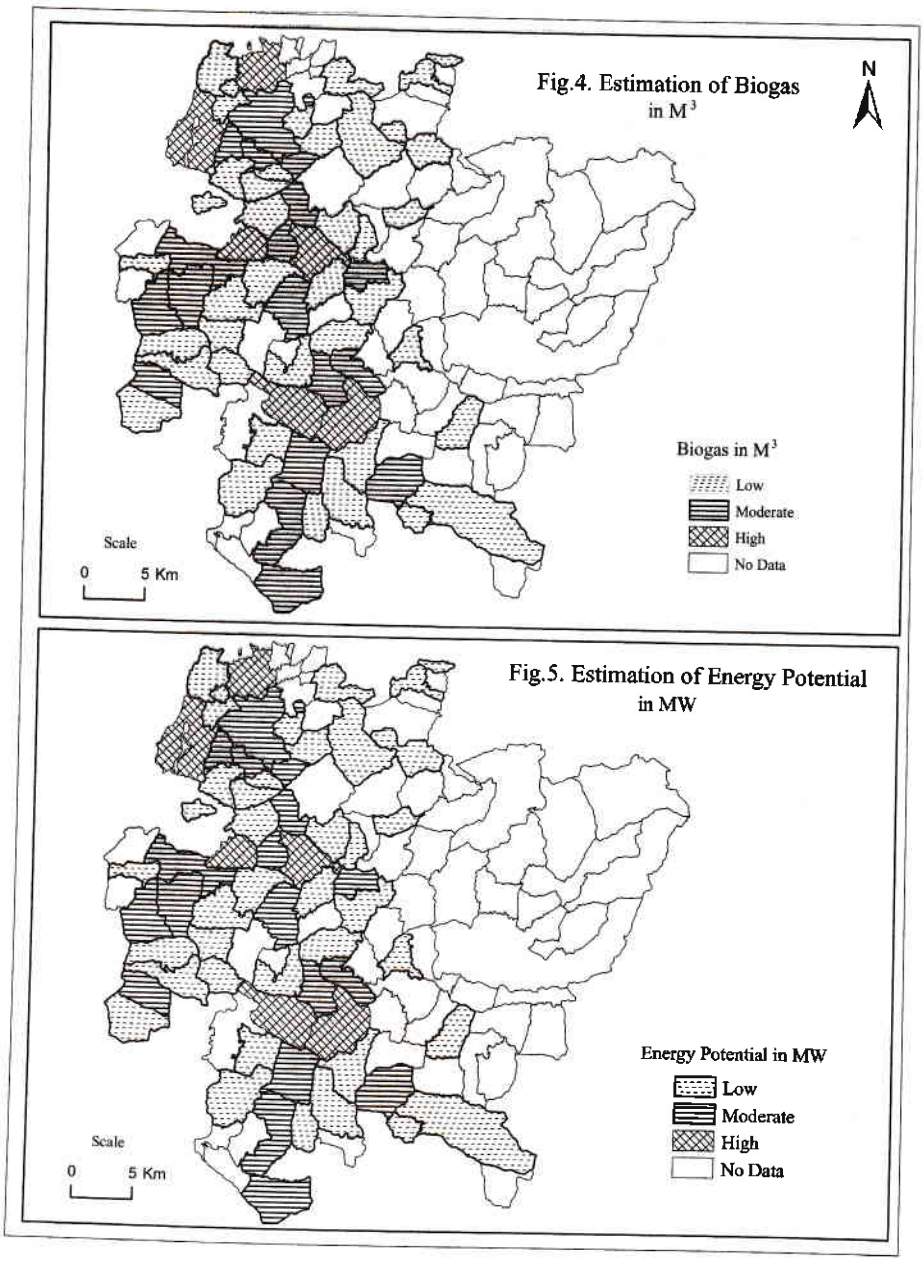


Fig.3. Computation of Poultry Litter in Ton

supply for the energy generation. The village-wise data for the year of 2007-08 required for this purpose were collected from the district agencies such as agriculture, poultry development and veterinary departments. District map with taluk boundaries and taluk map with village boundaries were digitized to generate base



layers using ARC/GIS 9.1, using Survey of India toposheets (1:50,000 scale) and the cadastral map of Namakkal taluk. The attribute data values were added to the map layers to generate maps of village-wise biogas energy potential. The theoretical potential is presented as a thematic map of the total amount of biogas energy available in each village.

Poultry Farms and Litter

Poultry is one of the fastest-growing segments of the agricultural sector in India, with an average growth rate of 8 to 10 per cent per annum. Now in Namakkal taluk, the total number of birds is 13,027,220. The study area included 64 villages, and in two villages, Marupatty and Ladduvadi, concentration of poultry farms is very high. Most of the poultry farms get located along the transportation lines for obvious reasons (Fig.2).

The quantity of poultry litter produced per day (Fig.3) was estimated at the village level by using the average amount of litter generated per bird. The average amount of litter generated by bird was assumed as 90 grams per day. Thus the total quantity of the poultry-generated in Namakkal taluk is about 1172 tonnes per day. Marupatty and Ladduvadi villages generated 98 tonnes and 72 tonnes per day. Forty two villages generate less than 20 tonnes of litter per day.

Biogas and Energy Potentials

Biogas is a product of anaerobic fermentation of organic matters and consists of around 60-70% Methene and 30-40% Carbon dioxide and traces of nitrogen, sulphur and moisture. Farm wastes locally available are used for extracting biogas from poultry litter. Assuming a production of 0.1 cu.m of biogas from one kilogram of poultry liter, it is estimated that Namakkal taluk can produce biogas of 117,145 cu.m per day (Fig.4). In six villages, biogas production can totally go more than 4200 cu.m per day, and in 20 villgaes, it may be less than 1746 cu.m per day. Assuming that one cu.m of biogas may produce two units of electricity, it is estimated that poultry litter generated in Namakkal taluk may produce about 235 MW of power per day. Again in six villages, it is about nine MW per day (Fig.5).

Conclusion

Biogas energy is a clean, pollution free and renewable source of energy. The method of generating electricity from biogas resources is one of the most effective ways to reduce global warming emissions. Poultry litter being generated continuously in Namakkal taluk may be profitably used, as it has a potential of generating about 235 MW of power per day

Referencess

1. Batzias F.A, D.K. Sidiras and E.K. Spyrou (2005). 'Evaluating Livestock Manures for Biogas Production: A GIS-based Method', *Renewable Energy*, 30, pp. 1161-1176.
2. El-Hadidi Y.M and A.I.Al-Turki (2007). 'Organic Fertilizer and Biogas Production from Poultry Wastes', *Journal of Food, Agriculture & Environment*, 5 (1), pp. 228-233.
3. Gupta K.R, Maria Anna Jankowska, Klaus Bosselmann, Prasenjit Maiti (2008). *Global Environment Problems and Policies*. Delhi: Atlantic Publishers & Distributors (P) Ltd.
4. Ramachandra T.V(2008). 'Geographical Information System Approach for Regional Biogas Potential Assessment', *Research Journal of Environmental Sciences*, 2 (3), pp. 170-184.
5. Ramachandra T.V and B.V.Shruthi (2007).

'Spatial Mapping of Renewable Energy Potential', *Renewable and Sustainable Energy Reviews*, 11, pp. 1460–1480.

6. *Soil Atlas, Namakkal District*. Coimbatore: Soil Survey & Land Use Organization., 1998.
7. Subhrabaran Das and TusharJash (2009). 'District-level Biomass Resource Assessment: A Case Study of An Indian State, West Bengal', *Biomass and Bioenergy*, 33 pp.137-143.

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Book Reviews

Geography of Water Resources by R. K. Gurjar and B.C. Jat (Jaipur:Rawat Publications, 2008; pp.448;glossary; Price:Indian Rs. 250/-)

Geography of Water Resources is a welcome addition to a few books on water written by geographers. The looming water crisis compounded by depletion of fresh water sources and disappearance of water bodies and rivers can only be tackled by informed citizens and this book serves this purpose very well. It is an informative book on various aspects of water distribution, its use, quality, water-induced hazard, water disputes and water management. The appended glossary is very useful for the students.

The distribution of water and trend in water use particularly in India are described in the initial chapters. A basic understanding on the circulation of water is provided in the chapters on hydrological cycle and ground water. While more attention is paid to the movement of water to soil, underground and plants, an important component in the hydrological cycle, the flow of water in the river, is given a cursory treatment in few sentences and that too with regards to soil erosion. There is detailed description with appropriate illustration on ground water recharge and artificial recharge techniques. The section on water balance assessment could have been avoided as it contains numerous errors. The chapters on water quality and river pollution give an account on the problem of salinity and alkalinity in the soil, sources of water pollution in the river and the status of pollution in Indian rivers, particularly in Ganges and Ganga action plan to control pollution.

On the use of water more attention is obviously paid to irrigation. Crop-water requirements and methods of irrigation are discussed in detail. The adverse effect of irrigation especially over-irrigation is appropriately stressed. The trend and issues in industrial water use and domestic water supply are highlighted. Community-based management of drinking water sources advocated for assuring equitable distribution of water.

A brief description on flood situation in different regions of India is followed by a discussion on flood control measures and management. That flood damages in India continue to increase in spite of enhanced allocation for flood control measures points out inadequacies in the current practices of following predominantly-structural control measures especially the embankments. This critical appraisal is not touched upon in the text. It is erroneous to cite exchange of economic activities as non structural method of flood control without mentioning methods such as relief, evacuation and regulation of land use. The drought scenario and drought management are discussed in detail. Improved

dry farming is suggested as the best way of managing drought. Traditional water conservation practices in different parts of India, especially in Rajasthan, are well documented with good number of illustrations.

Detailing various proposals on interlinking rivers of India in a chapter on integrated river basin planning without elaborating the concept and existing practices, gives a biased view on this topic especially in a book meant for students. On the other hand watershed management practices are well discussed with appropriate illustrations The section on water conservation through watershed development lists fourteen innovative activities for soil and water conservation. Each activity is lucidly explained and illustrated. Apart from discussing technical aspects this chapter elaborates the management, planning, implementation of and community participation in watershed development which is useful not only for students but also for anyone interested in development through watershed management. A cursory treatment is given to river water disputes in India. Application of remote sensing techniques In water management is highlighted in another chapter. The last chapter is on climate change and its potential effect on water resources.

The studies cited in the text are not included in the bibliography. Even the extensively quoted work of Dr. K.L. Rao is not mentioned in it. In the absence of references, further reading in the topic of interest is not possible. There are serious typographical errors in the statements and tables related to area and volume of water.

On the whole the book is a compilation of useful facts on various aspects of water resources and is reasonably priced. This book can be recommended as a supplementary reading in colleges and universities.

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Emerging New Industrial Spaces and Regional Development in India edited by Hidenori Okahashi (New Delhi: Manohar Publishers and Distributors, 2008; pp.197+xiii; Rs. 525).

This edited volume published as part of the Japanese Studies on South Asia is a collection of research papers on regional geography consists of four parts with nineteen chapters including an introduction and conclusion by the editors. All the contributors are from Japan and the editor's own research works form the bulk of this slim volume. Part I introduces the significance and role of industrial estates in regional development. Part II focuses on the developments in industrialization in India with an emphasis on automobile and related industries. Part III focuses on the changes that is brought about by industrial estate in the backward region. Part IV focuses on the impact of industrialization in the developed area. The work is an attempt to understand the comparative impact of industrial clustering on the regional development in a backward area and a relatively developed area. For this purpose a detailed study was conducted in the Pitambur Industrial Growth Centre in Madhya Pradesh and in the NOIDA district in Uttar Pradesh, bordering New Delhi.

India has made rapid strides in industrialization, particularly in the

automobile and software segments since the opening up of the economy in 1990, leading to a development of industrial hubs in these sectors. Much of the industries in the early phase of development had been concentrated in cities and their fringes, and the rural and backward regions remained laggards for many years. The concept of industrialization through clusters has been promoted by UNIDO since 1970s and it has been progressively adopted by India in its industrial development. Many industrial estates were established in backward areas; while the aim of such industrial estate development is to provide infrastructural facilities to the industries to be located in these areas, little attention has been paid to the displacement effects of such large scale operations as well as the impact these industrial estates on the surrounding areas and the region in which they are located. Industrial estates have been largely occupied by large and small firms, and the secondary impacts in terms of forward and backward linkages they generate become the primary movers of the region's overall development.

Many argue that such pattern of industrial clustering has produced unbalanced regional development in India. In fact, the emergence of IT and communication firms has led to the establishment of Software Technology Parks and Special Economic Zones in urban spaces leading to polarization of economic activities. While many studies look into the pattern of industrialization and its impact on economic development, a serious research on the dimensions of regional changes, particularly on the social and economic changes in the industrial spaces and the surrounding areas has been lacking. In this respect the present study is a welcome addition to the regional development literature. The approach is also unique as the study does not follow the conventional approach of studying the industrial units. Rather, the focus is on the impact these industrial spaces have on the region, studying the firm locations, employment and the socio-economic background of the workers in these industrial locations. The study also brings out the impact these industrial spaces have on the nearby regions, and their agricultural and social transformations, and the dynamic changes that are happening there.

Chapter 2 of the book sets the background for the study with a brief account of the significance and role of industrial estate development, and outlines the research framework. The research work uses the tradition of geographical unit, the district with zones and subdivisions with infrastructure facilities, to define industrial estate. Chapter 3 presents a comparative picture of the Indian and Japanese industrial estate development and regional policy. The chapter traces the policy through the Five Year Plans and the growth of number of districts and number of industries and the nature of classifications in industrial estate development in India. Chapter 4 is devoted to narrate the growth of industrial structure in India, emphasizing its regional character. Chapter 5 is an exclusive focus on the growth of automobile industry in India, highlighting on development under the control, and partial and full liberalization economic scenarios. By studying the location of automobile sites and the automobile market, the chapter comes closer to the modern New Economic Geography version of Paul Krugman's trade and home market effects, without explicitly referring to it.

Chapter 6 takes up the agglomeration effects in large cities by tracing the growth of India's much acclaimed success story, the software industry along with its regional distribution and the accompanying changes.

The development of the Pithampur Industrial Growth Centre is described in chapter 7, particularly its site and situations in a backward area, while chapter 8 outlines the promotional efforts by the Madhya Pradesh Industrial Centre Development Corporation to develop the Pithampur Centre in 1980s and its infrastructural facilities. Chapter 9 deals with the structure of industrial agglomeration in Pithampur. As this Growth Centre has emerged as an automobile hub, with automobile giants like Hindustan Motors, Kinetic Honda, Eicher Motors and Bajaj Tempo locating their factories, and the development of their allied industries; and the chapter discusses the production and trade relations among them. A noteworthy contribution of the book is its analyses on the labour market characteristics in this Centre, elaborately presented in chapter 10. Taking up two industries - Kinetic Honda and Eicher Motors - as case studies, the study analyses the labour force characteristics in this backward area. The lifestyles of the workers and the residential qualities in housing colonies are considered in chapter 11. The impact of this industrial estate on the development of the village Pithampur to an urban centre is analyzed in chapter 12, highlighting the agglomeration of central functions. The spillover effect of urban agglomeration on the village is examined by studying a neighbouring village in chapter 13. Detailed account of how the non-agricultural employment, agrarian and social structures have changed especially due to the influx of newcomers in a quite village economy is presented. Overall the research shows the compounding effects of industrialization in a backward region.

Turning to the analysis of the impact of industrial space in a developed region, chapter 14 presents an overview of NOIDA's growth in the National Capital Region. The NOIDA Centre has a high concentration of various industries which necessitated the expansion in many phases and the development of Greater NOIDA. Chapter 15 discusses the process of industrial agglomeration and their characteristics. Again this chapter takes up the examination of automobile and related industries as this industrial area houses Escorts Yamaha Motors, Honda Siel Cars India, Daewoo Motors and a host of accessory-producing units. After describing their location and linkages among these industries, a brief account of the differences in industrial agglomeration between NOIDA, Greater NOIDA and Pithampur is presented. Like the earlier approach in Pithampur, chapter 16 presents the housing and characteristics of labour, and chapter 18 looks in the transformation of the neighbouring village. Here the emphasis is on urban characteristics as the study region is close to Delhi. The true sense of urban agglomeration is analyzed in the innovative chapter 17, which looks this industrial centre as a commercial centre. With commercialization of rural settlements and planned central areas in this industrial centre, shops and offices spiraled, and accordingly the worker characteristics are different from the Pithampur centre.

Over all, the book is a neat attempt to bring

new dimensions on the industrial estate development and its impact. However, notable gaps exist. Though the agglomeration concept is widely used, its full meaning, nature, dimension, measurement and impact, as understood in the literature, and its relation to regional development have not been captured closely and clearly. One is not sure whether the very word 'Emerging New Industrial Spaces' is appropriate as the industrial estate concept is neither new nor emerging. Further, the book could have been more comprehensive and useful for non-geographers also had it attempted to give an overall Indian scenario of industrial estates and a comparative picture of the industrial estates and special economic zones. Throughout the book, much of the works cited are of Japanese origin, available either in Japanese language or in Japanese publications. Barring the NASSCOM sources and a few official documents published in India, the book has not exploited the voluminous research literature produced by either the government or the researchers in India at large. This is understandable as the aim is not to provide an exhaustive review on industrial estates but to study only two industrial estates. The chapter on software industry seems to be a misfit as the book does not follow its analyses in the subsequent chapters. The book, though published in 2008, has rather dated materials and data of 1990s. Hence, the modern concepts of agglomeration effects could not be effectively explored. In this respect the recent World Bank publication, World Development Report 2009, which deals with the New Economic Geography and its relevance for regional development is much relevant. The book may be more helpful to beginners, and will encourage geographers to look at the industrial spaces and agglomeration issues with an interdisciplinary perspective.

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Globalisation: Issues and Challenges for India edited by Nanda Kumar Sawant, Sulochana Shekar, Jayamala Diddee and Suresh Jog (Pune: Institute of Indian Geographerss, University of Pune, and Margoa, Goa: Department of Geography, Smt.Parvatibai Ghowgule College, 2009; Pages: 225; Price: Rs.250/-).

The book is a compilation of 15 papers presented at the seminar on "Globalisation, Consequences in the Indian Context" held in Margoa, Goa in October, 2007.The various facets of globalisation are classified into five sections. The introduction by Prof.R.P.Misra is elaborate and comprehensive though it suffers from serious editorial errors in spelling, language, misuse of capital letters, repetition of paragraphs etc.

The first section on "Overview of Globalisation" has two papers. The first paper, "Globalisation: Implications for India" by Prof. R.P. Misra, explores globalization through economic development and trade as seen in migration, Direct Capital Investment and Research and Development. Globalization has been a boon only for a limited section of

people. It has created a divide at a regional, sectoral and global levels, leaving the development of agriculture, employment, education, and poverty reduction in lurch. The chapter by Ms. Alka Pande, " Globalisation : Balance Sheet after Two Decades" analyses the good and the negative aspects of globalization. She points out that there has been an increased exports from India with a rapid growth in IT, industrial and service sectors, bringing a good flow of foreign exchange, and at the same time there has been an increase in unemployment and inequality in income distribution.

The second section, "Globalization: Regional and Sectoral Development" has five papers. Prof.Hanuman Singh in his paper "Foreign Direct Investment and Spatial Configuration in Indian Economy under Globalisation" examines the temporal, spatial and sectoral structure of FDI, relation between FDI and socio economic component, and spatial configuration of the Indian Economy due to inflow of FDI. Paper on "Globalisation, Sectoral Change and Child Work in India" by Dr. Neera Ramachandran attempts to assess the impact of globalisation and child labour especially in the unregistered sectors of manufacturing, agricultural, construction and services for a decade. Globalization has shown regional variations in all the sectors. In the paper on "Regional Development and Disparity in Post-reforms India", Dr.Suryakant tries to explore economic reforms of the post SAP programme and its spatial implications. The paper shows how existing regional inequalities have been widening under the impact of new investments, and industrial and trade policies. Poverty seems to be declining and is concentrated regionally. Christina de Souza in her paper on "Globalisation and the Unorganised Sector in India: Social Security Investments" notes that though 86% of the employment is in the unorganized sector and 64% in agriculture with seasonal, casual and contractual labour, there is an absence of social security against health, accidents, death and old age. Expanding social security requires a multi level, multi dimensional and well-integrated and efficiently-delivered system backed by legislation with involvement of NGO's and individuals. The paper on "Globalisation and Trade Unions" by Blacnche Fernandes analyses the impact on globalization on trade unions. Globalization has increased employment, reduced the organized sector, and increased the informal sector with insecurity and deprivation. There seems to be change in the role of trade unions with greater responsibilities in training workers and improving productivity.

The third section focuses on agriculture with two papers. The first article " Food Crises expose Failings of Indian Agricultural Reforms" by Afsar Jafri express that in the post reform period India was forced by the World Bank to import wheat through global wheat corporations. The government lost confidence in the neo liberal agricultural reforms and felt that food security in India is best left in the hands of small farmers. The chapter on "Globalisation and Indian Horticulture- A Study on Special Emphasis on Marketing of Table Grapes" by Sanjay Gaikwad *et al.*, examines the post-liberalization period where a shift from cereals to horticulture was possible due to technologies in cold storage and co-operatives to export fruits and vegetables.

The fourth section has two papers on the

impact of globalization on urban development. Sulochana Shekar *et al.*, in "Globalising Indian Cities- Special Reference to Pune", explains the benefits and negative impacts of globalization. They say that the city has much more to offer than ever, and its growth and development has made Pune a "global City". Daksha C. Barai *et al.*,in "Globalising India and Changing Urban Structure: A Study of Bangalore City", explains how a change in the outward growth of Bangalore has influenced the restructuring of spatial, social and economic situations, affecting social values, life styles, purchasing power, changing land values etc., and thereby creating a dualism between the earlier- and later- built areas-making.

The fifth section on "Globalisation: Social and Environmental Impact" includes five papers. The paper on "Developmental Consequences of Globalisation: Andhra Pradesh Experience", by S. Simhadari traces Andhra Pradesh's roots from colonization to modernization, and explains benefits of globalization being enjoyed only by certain power groups, caste groups and communities. K. M. Kulkarni in his paper on "Globalisation and its Impact on Indian Society", describes the change in society with opportunities in agriculture, industry and service sectors due to globalization, and reduction in trade and tariff barriers that enhanced mobility of people to give a global feeling. Nandkumar Sawant *et al.*, in "Beach Tourism, Globalisation and Socio-Economic Transformation: A Case Study of Palolem Beach Community- Goa" observes a shift in occupation of people with infrastructural development, and change in life-style and cultural values. The paper, "Global Warming: The Indian Response to International Initiatives" by Gita Kewalramani discuses the Kyoto Protocol on combating climate change. Discussing carbon emissions, extreme rainfall and drought the author emphasizes on the use of renewable energy especially from new sources like Jatropha.

The chapters in the book reviewed looks into different situations and impacts of globalization. Content of these chapters is very much multidisciplinary in approach and enters into the borders of Sociology, Tourism, Economics, Urbanisation and the like. As such, the book may be quite valuable for scholars across disciplines

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Water First: Issues and Challenges for Nation and Communities in South Asia Edited by Kuntala Lahiri-Dutt & Robert J. Wasson (New Delhi: Sage Publications, 2008; pp.435 plus 50; Rs. 850/-; ISBN 978-0-7619-3625-1(HB).

Composed of three independent yet related sections, this babushka doll-like edited collection is wide ranging in topic and interdisciplinary in approach. There is a ready acknowledgement that water fulfils many roles, from economic resource to collective good to sacred entity and the articles are linked by an understanding, be it implicit or explicit, that it is the control of, rather than access to, water that affords real power.

As the outer doll, the first section, "The Regional Politics of Water in South Asia", appropriately provides an overview of the

water management histories of each of the South Asian nation-states. Including chapters on the regional politics of shared waterways (Chapter Four), international agreements and conventions covering South Asia's international rivers (Chapter Five), and the impact of colonial water management priorities in India (Chapter Three), this section provides the backdrop to the detail of the dolls yet to come.

The second section, "Regional Issues, Challenges and Approaches", bridges the big picture to the fine detail of the innermost doll by investigating water quality and management issues from national and intra-national perspectives. For example, chapters investigating arsenic contaminated groundwater in Bangladesh (Chapter Eight) and India (Chapter Nine) not only highlight the importance of having a solid understanding of a resource base prior to exploitation but also the public policy complexities of changing entrenched water practices. Chapter Seven applies the well-known, if contested, Environmental Kuznets Curve (EKC) to investigate the implications of economic development on Indian riverine water quality. Integrated water resource management (IWRM) is thoroughly investigated: a gender/community perspective (Chapter 10); an assessment of IWRM's application in four Indian states (Chapter 11); and the reality of community participation in Indian IWRM with the ideal (Chapter 12). To some extent Chapter Thirteen's review of Indian watershed development programs reinforce the findings of the preceding chapter.

The last babushka doll not only draws the collection together, it exemplifies the collection's standard with its attention to detail. Similarly, section three, "Interpreting Community Roles and Initiatives", elegantly connects the sections to become a unified collection with its detailed focus on local and community involvement in water management. It fills the space below the nation-state priorities and regional water management decisions with the day-to-day realities of the application of those theories and decisions to local landscapes.

Chapter 14, for example, quickly dispels any notion that all at the local level unquestionably accept the priorities as decided at broader scales. Indeed, the conflicts that arise can lead to individual and group identity being changed, questioned or compromised. Chapter 15 shows how all these challenges faced the *adavisi* during a long campaign against the relocation of their village for dam building. They now find themselves in the unenviable position of having their status as an "authentic" tribe questioned, and their perspectives and behaviours, individually and collectively, charged as "corrupt" (p. 305).

The detail of the third section is easy, indeed enjoyable, to absorb. This is in no small part due to the previous sections. Without them, and the solid background they provide, this third section's local scale and detail would not be as easily accessible. By the time you come to the final chapter, Bolitho's sensitive "cultural interpretation" (p. 389) of the river Ganga (the Ganges), even the most 'scientifically rational' person would accept that "we could learn from the cultural bank of that river" (p. 404) as much as from the physical bank. The collective, inter-disciplinary image this collection finishes on is

simply a magnification of that presented at the beginning; in much the same way as the detail of the third babushka doll highlights the relative crudeness of the outer dolls.

The editors aspired to a collection that, among other aims, challenged some longstanding myths and misunderstandings about South Asian water. One of the biggest misunderstandings dealt with is the expectation that water models and management approaches are readily transportable from one geographical environment to another. A number of articles highlight the flaws in using one hydrological environment, and associated water management priorities and systems, to assess other hydrological environments or water management systems. This important hydrological warning appears in several chapters, including Chapters 17, Six, Three and Two. A key myth actively debunked is the that notion there are no systemic water understandings or management practices in communities being 'developed'. Barensein (Chapter 17) demonstrates the "fallac[ies] 'of participation in water development projects" using a rural Bengalese community as a case study to show that there are "far more locally organized collective actions...than generally assumed." (p. 350). My research on Thailand's "local wisdom" (1) is in line with these experiences.

Having been afforded the rare luxury of reading this book in chapter order, I was struck by the care taken in defining the sections and ordering the chapters. It seems akin to the passion required to create quality babushka dolls. Generally a well edited collection I did, however, find the use of feminine pronouns for nation states in Chapter Five disconcerting to read. Further, while realizing the editors chose to have a limited emphasis on physical descriptions of water (although some geomorphological aspects of monsoon rivers are discussed in Chapter Two), a table outlining basic water statistics for the nation-states could have been provided without compromising non-physical representations of the complexity of the South Asian water world. In a similar vein, the geographical range was such that a two page map of the region outlining nation-states, their provinces and significant rivers and catchments, particularly those referred to in the text, tucked in the front or back cover would have been useful. These minor points aside, this collection undoubtedly fulfils the ambitious goal of bringing together scholarship challenging statist approaches to water resources and their management in South Asia (p. xxxiii). Not only does it provide a comprehensive overview of important regional water issues, the collection provides a compelling examination of the complexity of water representations and management. A complexity not limited to South Asia and, as such, I commend this book to all water researchers and policy makers willing to grapple with the conflicts in water understandings and practices in an equitable and open manner, regardless of geographical area of expertise.

Reference

1. Harriden K (2008). 'Stormwater in Thailand: A Potted History', *Water*, 32 (2) pp. 129 – 131.

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4004: On Disasters in India by Anu Kapur (New Delhi: Cambridge University Press, 2009; pp. 397; price: Rs.895/-)

Humanity has faced natural disasters throughout its evolution but the scientific study of natural disaster is of much recent origin. There are several infirmities in the process as well. Some natural disasters such as earthquakes and cyclones, received disproportionate attention as the neglect of the others; the research remained confined to certain accessible regions or extreme events; and social scientists made only a marginal contribution to the theme. Such considerations, in addition to fragmented and dispersed research on disasters in India is what perhaps intrigued the author Anu Kapur, to dig out a gold mine of any available literature on the theme. 'Research on Research' is an innovative idea to be pursued by a scholar. A meticulous collection of 4004 references drawn from 191 journals, 134 books, 427 reports, 113 doctorate thesis among others form the foundation of this intensive effort.

A perceptive view of the evolution of research identifies three phases (i) Colonial (1830-1947) - when all the research credit goes to the British. This phase has an exceptionally large presence of catalogues, records, notes and news; (ii) post-independence (1947-1990) – when the small number of research units available represents Indifference to the reality of disasters; and (iii) the globalisation (1990-2006) – when the occurrence of three successive major disasters of Orissa cyclone (1999), the Bhuj earthquake (2001) and the tsunami in 2004 were traumatic enough to gain recognition. The author believes that though the trajectory of research on natural disasters has covered the successive phases of awareness (1830-1947); Indifference (1947-1990) and recognition (1990-2006). Yet, a phase of realization of the grim situation is yet to usher in.

The book has several pioneering features- it offers a methodology for conducting research on research, follows an evolutionary approach, identifies disparities in adoption of regions or areas for research, gives an idea of research unit's vis-à-vis research publications and evolves new typologies for natural disasters. It introduces the concept of research units by giving a weight of 4 to a book, 3 to a research report or a thesis and one to a research article to evolve a comparative view on natural disasters.

All of them were subjected to a study of their Basics, Occurrences, Characteristics, Causes, Impacts, Responses, Forecasting and Management. The major focus of the thematic classification was on cyclones, droughts, earthquakes, floods, heat and cold waves, heavy rains, landslides, storms, tsunami's and other assorted disasters. A comprehensive view of the spatial coverage of studies has also been identified with the Coastal Plains claiming 32 per cent of the research units, the Northern Mountains 27 per cent, Deccan Plateau 23 per cent and Great Plains 18 per cent.

The author attempts to relate to varying audience with appropriate messages for each - how to do research for students; the need to get sensitized to the theme for the social scientists; how to address the issues for policy makers; how to implement things for the administration; and how to envision for everyone. The future of 4004 has been envisioned to create willingness to invest in

people, in research on disasters, and in creation of more of 4004s but of a different kind. The use of simple and direct communication with its readers further lends it another star. The flawless printing with the title page reflecting 4004 on the background and 'On Disasters in India' on the foreground is most creatively put forth. A must read book irrespective of the discipline barricade.

Natural disasters are sudden unpredictable and uncontrollable. They bring about destruction, disruption, fear, distress and apprehension. This is also the irony of research on disasters as it limits it to the study of events after they have occurred. Developing an insight towards identifying, coping, rebuilding and recovery are the key words floated thereafter, and research on disasters can take a new dimension.

Reading 'On Disasters in India' is captivating and emotionally stirring up. One empathizes with the trauma of the disasters and connects with the author's emotions, elated at acquiring new information, subtle remarks and tears on articles that promised too much but deliver little. A future hope on the part of the author is that research would be less plump and more meaningful.

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Seminars & Conferences

National Seminar on
Trends and Prospects of Geoinformatics in Spatial Planning
March 12-13, 2009

The Department of Geography at Osmania University, Hyderabad organized a National Seminar on *"Trends and Prospects of Geoinformatics in Spatial Planning"* during March 12-13, 2009 under the aegis of UGC-ASIST Programme. The Seminar was inaugurated by Prof.T.Tirupati Rao, Vice Chancellor, Osmania University. Prof. Mohd. Iqubal Ali, Vice-Chancellor, Sathavahana University, Karimnagar, Andhra Pradesh gave an inspiring Guest Lecture on Regional Development in the Current Century. Prof.S.Subbiah, Editor of the Indian Geographical Journal, presented a key note address on Space, GIS and Spatial Planning. The Department of Geography at Osmania University planned to bring out a bi-annual journal, *Spatial Science* to promote and support the current technological

development and its application in Geography, under UGC Special Assistance Programme (SAP), and the first volume was released by Prof. T. Tirupati Rao at the Inaugural Function of the Seminar.

Paper presentation was organized in five sessions, three in the first day and two in the second day. Session I had discussion on Application of Geospatial Technologies. Papers presented in this Session looked into issues from urban, metropolitan and rural domains. There was a paper by an Arab geographer, and its subject matter was the climate change, environment and tourism development in Yemen. Session Two concentrated more specifically on the discussion of GIS and Remote Sensing technologies in managing the resources and regional development. Session Three had papers more on land use/land cover studies.

Day Two of the Seminar began with a Lead Talk by Prof.A.Anji Reddy of Jawaharlal Nehru Technological University, who illustrated his practical experiences on preparing a Village Information System with GIS (GIS for VIS), quoting extensively from his on-going Project on Cadastral Studies supported by the State Government of Andhra Pradesh. Session Four had papers on resource evaluation studies, and spatial and development planning, using GIS and remote sensing. Papers of the last Session highlighted the applications of GIS, GPS and Decision Support System.

Totally 38 papers were presented in the sessions, and scholars had a very fruitful exchange of thoughts and interactions. Senior geographers reminded the young scholars to have a serious outlook and a priority on the logics and content of the subject matter of geography and research, and to improve their

cartographic and presentation skills.

The Seminar was concluded with a Valedictory Function with Prof. Y.C.Venudher, Registrar of the Osmania University, as Chief Guest, and Prof. Venkatachalam, Registrar of Palamuru University, Mahboobnagar, as Guest of Honour. Prof. A. Kamalarkar Reddy proposed a Vote of Thanks to all the participants, guests, fellow-faculty members, students, and scholars. Prof.Vijaya Bhole and Prof. A. Kamalakar Reddy were quite successful in organizing this national seminar.

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National Seminar on Climatic Change and Emerging Diseases

December 12-13, 2008

The School of Earth and Atmospheric Sciences, Madurai Kamaraj University, Madurai in association with the Indian Geographical Society and the Indian Society for Environmental Health, organized a National Seminar on *Climatic Change and Emerging Diseases* during December 12-13, 2008, as a part of the activities of the UGC-SAP-DRS I Phase. The Seminar was inaugurated on the morning of 12th December, 2008 with Dr. K. Kannan, Retired Professor of Endocrinology, Madurai Medical College, in Chair. Prof. N. Krishnan of the Department of Environmental Remote Sensing and Cartography, Madurai Kamaraj Univeristy welcomed the guests and the participants. Dr. B. K. Tyagi of the Centre for Research in Medical Entomology, ICMR, Madurai


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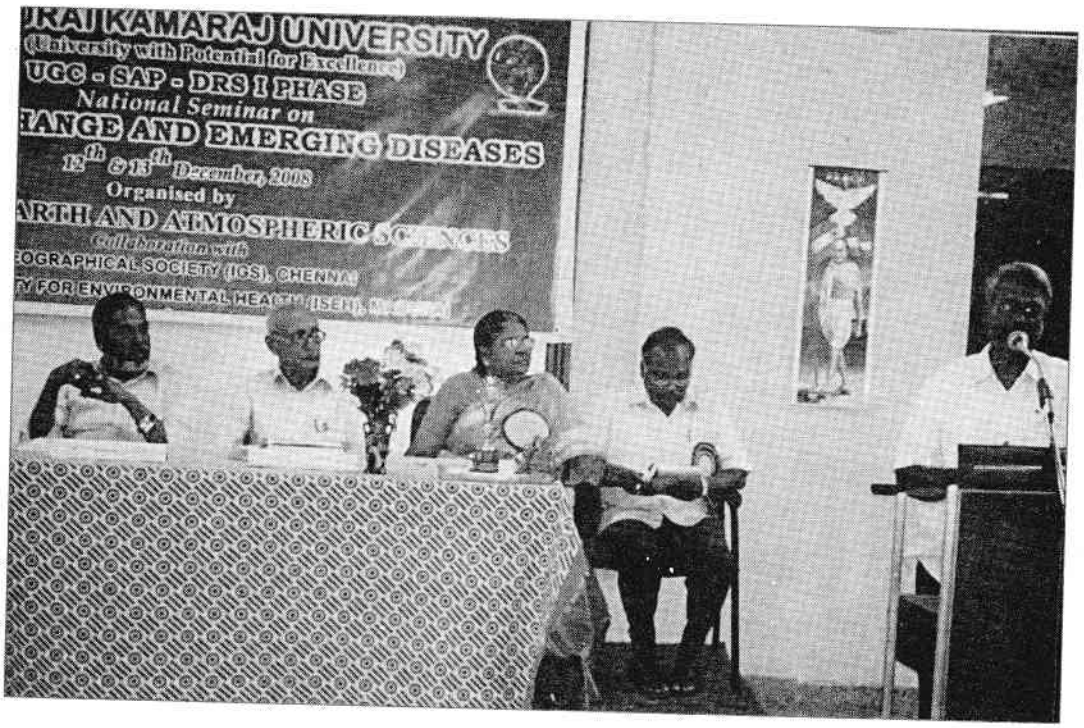
delivered the Key Note Address. Prof. S. Jayachandran, Retired Professor of Geography, Madurai Kamaraj University, Madurai, unveiled the portrait of Late Professor A.R.Irawathy, former Principal of Queen Mary's College, Chennai, beloved



teacher of Geography, and the Founder-Director of the Department of Geography at Madurai Kamaraj University, and gave a Felicitation Address. Prof. K. Lakshmi of the Department of Geography, Madurai Kamaraj University proposed a Vote of Thanks.

Presentation of Papers was organized in five sessions and totally 31 papers were presented. First Session had papers mostly on incidence of diseases and their spatial pattern. Second Session took up the issues of the role of climate and environment on human health. Case studies on climate and some select diseases are the subject matter of discussion during the Third Session. Papers discussing gender-specific case studies, alternative medicines and children's health were presented in Fourth Session. Last Session debated on the pattern of health care delivery system and the use of geo-spatial technology in health care planning. The Seminar concluded with a Valedictory Function chaired by Prof. S. Jayachandran. Welcome Address was given by Prof. G. R. Parthasarathy, Coordinator of the UGC-SAP-DRS I Phase. Prof. T. Vasanthakumaran of the University of Madras delivered the Valedictory Address. Prof. P. Ilangovan of the Department of Environmental Remote Sensing and Cartography proposed a Vote of Thanks.

A Handbook on *Rural Health Care Access: A Case Study of Madurai District* by Prof. K.Lakshmi was also released during this Seminar. It brings out the results of a research project funded by the University Grants Commission, New Delhi. Using GIS technology, it made use of secondary and field data to map and analyze the accessibility and efficiency of Primary Health Care Delivery System in the rural areas of Madurai district.

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Madurai

Information to Authors

The Indian Geographical Journal is published half-yearly in June and December by The Indian Geographical Society, Chennai. It invites manuscripts of original research on any geographical subject providing information of importance to geography and related disciplines with an analytical approach. The article should be submitted in duplicate (the original typescript and a copy) typed in double space of one side of 22 x 28 cm (or quarto) paper with a left hand margin of 4 cm and should not exceed 5000 words. However, an e-mail submission of the paper is preferred, and please e-mail the article to the editor (shanmugampillai.subbiah@gmail.com). The article should start with an abstract of 150 words typed in single spacing.

References should be listed in alphabetical order and serially numbered at the end of the paper and cited in the text as a bracketed number. Footnotes should appear at the bottom of the respective page, typed in single space and the foot note number placed a little above the line, should run consecutively throughout the text. Reference details and the placement of the citation numbers etc., should follow the style adopted in the present issue.

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Author's name and affiliation should appear in a separate title page and should not appear anywhere in the text so that the article could be impartially assesed by a referee.

All manuscripts submitted for publication should be addressed to : The Editor, Indian Geographical Journal, Department of Geography, University of Madras, Chennai - 600 005, India or they may be submitted to any one of the members of the Editorial Board geographically near to the author.

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