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Cover photo: *Sat Crit, Brașov county (Antonio Del Negro)*

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- Keywords (not more than 5-6 words);
- Acknowledgments (if any);
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- Tables must be numbered with Arabic numbers and should not repeat data available elsewhere in the text.
- References must be indicated in the text, between brackets and they must include the author's name and the date of the publication (Popescu, 2000). When three or more authors are referred, they will appear in the text as follows: (Popescu et al., 1997). References must be listed in alphabetical order at the end of the text.

The following style sheet is recommended:

- for journals:

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- for books:

Bran, F.,Marin, D., & Simion, T. (1997). Turismul rural. Modelul european, Editura Economică, București

- for papers from conference proceedings:

Deci, E. L., Ryan, R. M., (1991), A motivational approach to self: Integration in personality. In R. Dienstbier (Ed.), *Nebraska Symposium on Motivation: Vol. 38. Perspectives on motivations* (pp. 237-288). Lincoln: University of Nebraska Press.

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All the manuscripts received by the editors undergo an anonymous peer review process, necessary for assessing the quality of scientific information, the relevance to the field, the appropriateness of scientific writing style, the compliance with the style and technical requirements of our journal, etc. The referees are selected from the national and international members of the editorial and scientific board, as well as from other scholarly or professional experts in the field. The referees assess the article drafts, commenting and making recommendations. This process leads either to acceptation, recommendation for revision, or rejection of the assessed article. Editors reserve the right to make minor editorial changes to the submitted articles, including changes to grammar, punctuation and spelling, as well as article format, but no major alterations will be carried out without the author's approval. Before being published, the author is sent the proof of the manuscript adjusted by editors. If major revisions are necessary, articles are returned to the author so that he should make the proper changes. Authors are notified by email about the status of the submitted.

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In Memoriam Professor Vasile Pleniceanu – life and activity

Oana MITITELU-IONUȘ[1,*], Liliana POPESCU[1]

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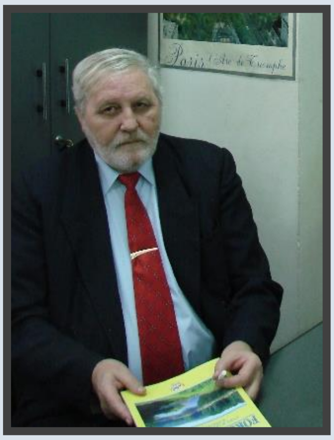
"Un Om ales și de ispravă
cum alții nu-s în rostul lor.
S-a dus pandurul, fără zarvă,
spre vadul fără vis și dor.

Acolo unde Jiul plânge
cu lacrimă de rouă lină
alura lui se va răsfrânge
precum o jerbă de lumină".

(Prof. univ. dr. Pompei Cocean, Aprilie 2020)



Vasile Pleniceanu was born on January, 2nd, 1942 în Cetate village, Dolj county. During the 1953-1956, he attended Cetate Gymnasium and în 1960 he graduated from Cetate Theoretical Highschool. Between 1960 and 1965 he was a student at the University of Bucharest, Faculty of Geology-Geography, specializing în Geography-Biology. în the following decades, he also enrolled în post-tertiary education focusing on hydrology, hydro-geology, water quality and environment protection, two of them abroad:

- Moscow, în the former USSR, *Lomonosov* University, în May-July 1971 – post-university training within the *International course of high hydrology studies*, focusing on underground waters, organized by UNESCO, having as advisers Prof.dr. B.I. Vartazarov, Moscow, USSR and Dr. G. Castani, from Paris, France.
- Madrid, Spain, January – June 1979 – *International course of general and applied hydrology,* also held under UNESCO auspices, scientific coordinator Prof.dr R.H. Rodrigues, Spain.

In 1985, he presented his PhD thesis titled *The Oltenia Plain between the Ji and the Danube – hydrologic study, focusing on underground waters,* PhD. Coordinator Prof.d.r Ioan Pișota, from the University of Bucharest, Faculty of Geology-Geography.

Vasile Pleniceanu s-a născut la 02 ianuarie 1942 în Comuna Cetate, judetul Dolj. în perioada 1953-1956 a fost elev la *Școala generală Cetate*, iar în anul 1960 a absolvit *Liceul Teoretic Cetate, Secția Reală.* Începând cu 1960 și până în 1965 a fost student al *Universității din București, Facultatea de Geologie-Geografie, Specializarea Geografie-Biologie*. A urmat apoi specializări postuniversitare în domeniul hidrologiei, hidrogeologiei, protecţiei calităţii apelor şi mediului înconjurător, dintre care doua în străinătate:

- Moscova, Universitatea "V.I. LOMONOSOV", 1971, Mai – Iulie, stagiu de specializare postuniversitară în cadrul "Cursului internaţional de înalte studii hidrologice", specializarea ape subterane, sub egida U.N.E.S.C.O.. Îndrumători ştiinţifici: prof. univ. dr. doc. B.I. Vartazarov, Moscova, U.R.S.S. şi G. Castani – dr. în ştiinţe, Paris, Franţa.
- Madrid, Spania, 1979, Ianuarie – Iunie, stagiu de specializare postuniversitară "Cursul internaţional de hidrologie generală şi aplicată", desfăşurat sub egida U.N.E.S.C.O. Îndrumător ştiinţific: prof. univ. dr. R. H. Rodrigues – Spania.

Formarea profesionala a culminat în iunie 1985 prin teza de doctorat cu titlul "Câmpia Olteniei dintre Dunăre și Jiu – Studiu hidrologic, cu privire specială asupra apelor subterane", sub coordonarea științifică a Prof.dr. Ioan Pișota, Universitatea din Bucureşti, Facultatea de Geologie – Geografie.

Later on, his PhD thesis was published under the title *Waters within the Oltenia Plain* (1999) at Universitaria Publishing House, Craiova.

He began his career în 1965 teaching at Cetate Theoretic Highscool, which he attended as a pupil, until 1968. He later transferred to the National Institute of Meteorology and Hydrology Bucharest, where he was named Chief of Underground Water Department for Oltenia Branch (1969-1975).

Later, between 1976 and 1988, Vasile Pleaniceanu was the manager of Dolj Water Management Directory, part of the National Council of Waters, Bucharest.

Beginning with 1990, until 1998, he was Chief inspector of the Agency of Environment Protection Craiova, which was part of the Ministry of Waters, Forests and Environment Protection.

For the last two decades of his professional career, Vasile Pleniceanu taught at the University of Craiova, being Assistant Professor at the Department of Geography, Faculty of History-Philosophy-Geography, and, beginning with 1998 until he retired Head of Geography Department. While at the University of Craiova, he was also Editor-in-chief of the two scientific journals edited by the Department of Geography: *Annals of the University of Craiova*, Series Geography, beginning with 1999, and *Forum Geografic*, since 2001.

During his more than 40 years long career, he had the opportunity to work în various scientific fields, also carrying on a pioneer activity to some extent for a geographer.

Thus, în the domain of underground waters în Romania, Vasile Pleniceanu was the first to insist on the need for hydro-geological drills for the phreatic and underground water structures în order to gather more detailed information about underground hydrology, the regime and chemical composition of underground waters în Oltenia.

When working for the Qualitative and Quantitative Management of Waters, he promoted and supported various programmes for the protection of water quality, waste-water treatment, as well as planning works for protection against floods.

In the domain of Environment protection, his main target was to bring solutions for diminishing and limiting the negative effects of pollution sources spread throughout the entire Dolj county.

Apart from great organisational skills, he was a very prolific researcher, publishing 6 books, 112 scientific papers în national and international journals with referees and attending numerous conferences. He published the following books (in Romanian):

1. Pleniceanu, V., (1999), Waters within Oltenia Plain, Universitaria, Craiova;

Teza de doctorat a fost publicată ulterior (1999), sub titlul *Apele din Câmpia Olteniei* la Editura Universitaria, Craiova.

Experiența profesională a început în anul 1965 în cadrul *Liceului Teoretic Cetate* unde Pleniceanu Vasile a fost profesor titular până în 1968. În perioada 1969-1975 a deținut funcția de Șef serviciu ape subterane – Oltenia, Sectorul Teritorial de Meteorologie şi Hidrologie – Filiala Craiova a Institutului Naţional de Meteorologie şi Hidrologie Bucureşti.

Ulterior, 1976 – 1988, Vasile Pleniceanu a fost directorul Oficiului de Gospodărire a Apelor Dolj – Consiliului Naţional al Apelor Bucureşti.

Începând cu anul 1990 și până în 1997, a deținut funcția de inspector-șef al Agenţiei de Protecţie a Mediului Craiova, din structura organizatorică a Ministerului Apelor, Pădurilor şi Protecţiei Mediului.

Incepând cu anul 1999 și până la iesirea la pensie în 2010, Pleniceanu Vasile a fost cadru didactic la Universitatea din Craiova, fiind conferentiar universitar la Facultatea de Istorie, Filosofie, Geografie, Specializarea Geografie și Șeful Departamentului de Geografie din 1998 până în 2010. În toată această perioadă, a fost Redactor şef al Revistei ,,Analele Universităţii din Craiova" – Seria Geografie (din 1999) și Redactor şef al Revistei de specialitate ,,Forum Geografic", ce apare sub egida Universităţii din Craiova din anul 2001.

În activitatea sa ştiinţifică şi cariera profesională desfăşurată de-a lungul a peste 40 ani, Pleniceanu Vasile a avut şansa să lucreze în domenii de activitate în care pentru un geograf au fost ca un pionierat.

În *domeniul apelor subterane*, Pleniceanu Vasile a promovat, pentru prima dată, realizarea de foraje hidrogeologice pentru structurile acvifere freatice şi de adâncime în scopul cunoaşterii caracteristice hidrologiei subterane, a regimului şi chimismului apelor din Oltenia.

În domeniul *Gospodăririi Calitative și Cantitative a Apelor* a promovat şi susţinut programe privind protecţia calităţii apelor, epurarea apelor uzate, precum şi realizarea de lucrări pentru apărarea împotriva inundaţiilor.

În domeniul *protecţiei mediului*, preocuparea primordială a fost aceea a modului de soluţionare, în sensul diminuării şi limitării efectelor negative ale surselor de poluare „distribuite" în judetul Dolj.

Concomitent cu activitatea de pregătire profesională şi de cercetare ştiinţifică Pleniceanu Vasile publicat 6 carti, 112 articole în reviste de specialitate naționale și internationale recunoscute CNCSIS şi a susţinut numeroase comunicări la manifestări ştiinţifice naţionale şi internaţionale.

Cărți:

1. Pleniceanu, V., (1999), Apele din Câmpia Olteniei, Editura Universitaria, Craiova;

2. Pleniceanu, V., (2000), Hydrology, (Vol. I), SITECH, Craiova;
3. Pleniceanu, V. (2003), Lakes and wet lands,
4. Pleniceanu, V., Ionuş, O., (2007), Geography of continental waters, Universitaria, Craiova;
5. Pleniceanu, V., Ionuş, Oana, Marinescu, Ioan, (2008), Geography of water resources on the Earth, Universitaria, Craiova;
6. Pleniceanu, V., Ionuş, Oana, (2009), Course of General Hydrology , Universitaria, Craiova.

He also wrote more than 100 papers, published în peer-reveiwed journal, some of the most important of them being:

1. Maria Pleniceanu, Pleniceanu, V., (2000), *Radioactivity of environment factors within the southern part of Oltenia. Radio-protection measures,* Annals of the University of Craiova, Biology Series, TPPA., vol. IV (XL)/1999;
2. Pleniceanu, V., (2000), *Information about underground water discharge within Oltenia Plain,* Annals of the University of Craiova, Biology Series, TPPA., vol. IV (XL), 316-321;
3. Pleniceanu, V., Petrişor, I, (2001), *Integrated monitoring system for establishing the state and the evolution of the air quality in the area of Craiova city,* Volume ,,IV Yugoslav Symposium – Chemistry and Environment, pag. 133-135, Zrenjanin, Serbia;
4. Pleniceanu, V., (2001), *New perspectives on the ecological education în Romania,* Journal of Environmental Protection and Ecology, Balkan Environmental Association (B.EN.A.), vol. 2, nr. 3, pag 643-652;
5. Pleniceanu, V., S. Boengiu, (2002), *Impact of human activities on the evolution of the Jiu water quality, în* Global environment changes, A.S.E;
6. Pleniceanu, V., S., Boengiu, (2003), *RWater resources and their quality within Oltenia Plain,* Annals of Valahia University, Series Geogrphy, III
7. Pleniceanu, V., (2004), New perspective on the ecological education în Romania, Journal of Environmental protection and ecology, Vol. 2, No 3, 643-651;
8. Pleniceanu, V., (2006) *Modifications of the atmosphericnatural quality within the industrial area of Işalniţa – Craiova,* Journal of Environmental Protection and Ecology*,* Vol. 2;
9. Pleniceanu, V.– co-author (2006), *The Rehabilitation of the Danube Floodplain on Rast - Corabia Sector*, Annals of the University of Craiova, Geography Series, Vol. IX, Universitaria Publishing House, Craiova, 43 – 52;
10. Pleniceanu V., Ionuş O**.**, Licurici M. (2008), *Extreme hydrological phenomena în the hydrographical basin of the Danube. The floods from the spring of 2006 along the Oltenian sector of the river*, Annals of the University of Craiova, series Geography, XI: 37-47.

3. Pleniceanu, V., (2003), Lacuri şi zone umede, Editura Universitaria, Craiova;
4. Pleniceanu, V., Ionuş, Oana, (2007), Geografia apelor continentale, Universitaria, Craiova;
5. Pleniceanu, V., Ionuş, Oana, Marinescu, Ioan, (2008), Geografia resurselor de apă ale Terrei, Editura Universitaria, Craiova;
6. Pleniceanu, V., Ionuş, Oana, (2009), Hidrologie generală – curs universitar, Editura Universitaria, Craiova.

Dintre lucrările reprezentative, publicate în reviste cotate CNCSIS, amintim:

1. Maria Pleniceanu, Pleniceanu, V., (2000), *Starea radioactivităţii factorilor de mediu în zona de sud a Olteniei. Măsuri de radioprotecţie*, Analele Universităţii din Craiova, Seria Biologie, Horticultură, TPPA., vol. IV (XL)/1999, 310-315;
2. Pleniceanu, V., (2000), *Contribuţii la cunoaşterea scurgerii apelor subterane în Câmpia Olteniei. Implicaţii asupra culturilor agricole*, Analele Universităţii din Craiova, Seria Biologie,
3. Pleniceanu, V., I. Petrişor, (2001), *Integrated monitoring system for establishing the state and the evolution of the air quality în the area of Craiova city,* ,IV Yugoslav Symposium – Chemistry and Environment, pag. 133-135, Zrenjanin, Serbia;
4. Pleniceanu, V., (2001), *New perspectives on the ecological education în Romania,* Journal of Environmental Protection and Ecology, Balkan Environmental Association (B.EN.A.), vol. 2, nr. 3, pag 643-652, Bulgaria;
5. Pleniceanu, V., S. Boengiu, (2002), *Impactul activităţilor antropice în evoluţia calităţii apelor Jiului,* „Modificări globale ale mediului". Contribuţii ştiinţifice româneşti. Editura A.S.E, pag. 153-161;
6. Pleniceanu, V., S., Boengiu, (2003), *Resursele de apă şi calitatea acestora în Câmpia Olteniei,* Analele Universităţii Valahia –Târgovişte, Seria Geografie, Tomul III/2003, 134-138;
7. Pleniceanu, V., (2004), New perspectives on the ecological education în Romania, Journal of Environmental protection and ecology, Vol. 2
8. Pleniceanu, V., (2006) *Modifications of the atmosphericnatural quality within the industrial area of Işalniţa – Craiova,* Journal of Environmental Protection and Ecology*,* Vol. 2
9. Pleniceanu, V.– co-author (2006), *The Rehabilitation of the Danube Floodplain on Rast - Corabia Sector*, Annals of the University of Craiova, Geography Series, Vol. IX, 43 – 52;
10. Pleniceanu V., Ionuş O**.**, Licurici M. (2008), *Extreme hydrological phenomena în the hydrographical basin of the Danube. The floods from the spring of 2006 along the Oltenian sector of the river*, Analele Universităţii din Craiova, Seria Geografie, XI:37 – 47.

Vasile Pleniceanu was part of twelve research grants, either as manager or researcher, involving young researchers, such as:

- Monitoring pollution along the rivers from southern Romania. Monitoring water quality along the Jiu river – international grant, cooperation between the University of Craiova and Luton University, England (1997-2001).
- Strategy of environment protection în Dolj county on short, medium and long term (2000-2010);
- Health Environment status within Oltenia South-Western Development Region (Dolj, Gorj, Olt, Mehedinți, Vâlcea counties) (2000-2002);
- Waste Management în Craiova city. Administration and elimination of waste, especially toxic and dangerous waste – a collaboration between the University of Craiova and the Balkan Environmental Association (2001-2002).
- Strategy for sustainable development of Craiova, phase 1.

Pleniceanu Vasile kept connections to various colleagues not only from other institutions în Craiova – collegues from „Romanian Waters" National Administration and Environment Management System; but also throughout the country – "Spiru Haret" University, Romanian Academy Geography Institute, universities of Bucharest, Cluj-Napoca, Timișoara, Târgoviște and Iași, acting as co-chair during numerous conferences.

His prodigeous activity was recognised at national and international level, being a member of important scientific and professional societies, such as:

- The Romanian Committee for the International Hydrological Decade, Bucharest;
- Romanian Geographical Society;
- Association of Geomorphologists from Romania;
- National Society of Hydro-Geology;
- Balkan Environmental Association, Bulgaria;
- National Geographic Society, Washington DC;
- International Association for Danube research.

He was also the:

- Founding member of the NGO *Romanian Ecological Action,* Craiova;
- Vicepresident of the International Office of the Environmental Education Association, University of Craiova;
- Director of the Centre for Environment Research and Sustainable capitalization of resources.

Pleniceanu Vasile a fost membru sau chiar a coordonat echipe de tineri geografi în cadrul a 12 contracte/granturi de cercetare, dintre care:

- Grant/Contract Internaţional (Universitatea din Craiova în colaborare cu Universitatea LUTON, Anglia), ,,Monitorizarea poluării apelor râurilor din Sudul României. Monitorizarea calităţii apelor râului Jiu" (1997-2001).
- Proiect de Cercetare - Dezvoltare - ,,Strategia de Protecţie a Mediului în Judeţul Dolj, Pe Termen Scurt, Mediuși Lung" (2000-2010);
- Grant/Contract ,,Starea Mediului în Regiunea de Dezvoltare Sud-Vest Oltenia (Jud. Dolj, Gorj, Olt, Mehedinţi Şi Vâlcea)" (2000-2002);
- ,,Waste Management în Craiova City. Administration and elimination of wastes Especially Of The Toxic And Dangerous ones - Balkan Environmental Association (B.EN.A) şi Universitatea din Craiova (2001-2002);
- Strategia de dezvoltare a municipiului Craiova, etapa I.

Pleniceanu Vasile a păstrat mereu legătura cu colegi de la diverse institutii din Craiova – colegii de la Administrația Națională Apele Române și Adminsitrația apelor bazinale Jiu, Agenția de protecție a mediului, dar și din Romania – Institutul de Geografie al Academiei Române, Universitățile din bucurești, Iași, Cluj-Napoca, Târgoviște, și Universitatea Spiru Haret.

Activitatea la nivel national și internațional a fost recunoscută și prin apartenența la societăți științifice și profesionale, precum:

- Comitetul Român Pentru Deceniul Hidrologic Internaţional, Bucureşti;
- Societatea de Geografie din România;
- Asociaţia Geomorfologilor din România;
- Societatea Naţională de Hidrogeologie;
- Membru Fondator al Organizaţiei Nonguvernamentale „Acţiunea Ecologică Română", Craiova;
- Membru Al „Balkan Environmental Association" (B.En.A.) Sofia, Bulgaria;
- Membru al „National Geographic Society" Washington D.C..;
- Vicepreşedinte al "International Office Of Environmental Education" – Of The Balkan Environmental Association, Universitatea din Craiova;
- Membru al "International Association For Danube Research";
- Director Al Centrului De Cercetare A Mediului Şi Valorificare Durabilă A Resurselor (CCMVDR).

Recunoasterea activitatii profesorului Pleniceanu Vasile s-a confirmat prin:

- Diploma de Merit în Domeniul Gospodăririi Apelor, Consiliul Naţional Al Apelor, Bucureşti, 1986;
-

His fellow peers recognized his important contribution to the geographical research in Romania, granting him several honorific titles and diplomas:

- Certificate of Merit for Water Management, National Council of Waters, Bucharest 1986;

- Diploma and votive medal, celebrating 75 years since the establishment of Natural Museum of Craiova and 70 years of existence as part of the Oltenia Museum (1998);

- Diploma and votive medal, celebrating *A century of geographic education at the University of Bucharest* (1900-2000), Bucharest, 2000;

- Diploma and votive medal, celebrating *125 years since the establishment of Romanian Society of Geography* (1875-2000), Bucharest, 2001.

Vasile Pleniceanu was and will be one of the pillars of Craiova school of Geography, as under its direct supervision and unconditional support, a young, strong and passionate team was formed, all of our first career steps being taken due to his advice and constructive criticism (Teodorescu Camelia, Curcan Gheorghe, Boengiu Sandu, Marinescu Emil, Marinescu Ioan, Vlăduț Alina, Popescu Liliana, Ionuș Oana). Professor Pleniceanu left his mark on numerous generations of students and young fellows, always letting us on his personal and professional experience, with great patience and especially humour, while teaching us to pursue our career with passion and devotion and offer unconditional support to our peers.

On April, 11th, 2020, Professor Pleniceanu passed away. All the persons that met, respected and loved him owe him not only to have high expectations from ourselves, but also to be kind and supportive with our fellows.

- Director Al Centrului De Cercetare A Mediului Şi Valorificare Durabilă A Resurselor (CCMVDR).

Recunoasterea activitatii profesorului Pleniceanu Vasile s-a confirmat prin:

- Diploma de Merit în Domeniul Gospodăririi Apelor, Consiliul Naţional Al Apelor, Bucureşti, 1986;

- Diploma și Medalia Jubiliară cu prilejul împlinirii a 75 ani de la înfiinţarea Muzeului de Istorie Naturală al Craiovei și a 70 de ani de la funcţionarea sa ca Secţie a Muzeului Olteniei, Craiova, 1998;

- Diploma de Onoare și Medalia Jubiliară "Un Secol de Învăţământ Geografic la Universitatea din Bucureşti (1900-2000)", Bucureşti 2000;

- Diploma de onoare și Medalia Jubiliară "125 de Ani de la Înființarea Societăţii de Geografie din România (1875-2000)", Bucureşti 2001.

Vasile Pleniceanu a fost și va rămâne unul din pilonii reprezentativi ai geografiei craiovene, căci sub coordonarea și sprijinul său necondiționat s-a creat un colectiv tânăr, puternic și unit, care a făcut primii pasi în cariera universitară și în cercetarea științifică avându-l drept critic și sfătuitor (Teodorescu Camelia, Curcan Gheorghe, Boengiu Sandu, Marinescu Emil, Marinescu Ioan, Vlăduț Alina, Popescu Liliana, Ionuș Oana).

Profesorul Pleniceanu și-a lăsat amprenta asupra multor generații de studenți și tineri colegi, cărora le-a împărtășit cu răbdare, și întotdeauna cu umor, din experiența profesională și personală, învățându-ne, în același timp, să dăm dovadă de dăruire și devotement în cariera didactică și de sprijin necondiționat față de colegi.

În data de 11 Aprilie 2020, mult îndrăgitul profesor Pleniceanu Vasile a trecut în lumea celor drepti. Noi toți care l-am cunoscut, respectat și iubit, suntem datori cu înalte năzuințe profesionale și întoarcea către semeni a cel puțin o faptă bună.

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Climate aridity in southern Bulgaria for the period 1961-2015

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Abstract

The climate change on a global, regional and local scale is one of the largest problems indicated by the 21st century studies. Some of the major climate changes on the Balkan Peninsula, and in particular in Bulgaria, are related to rising temperatures and decreasing precipitation, which leads to drought and climate aridity. The present study focuses on the investigation of the climate aridity in the non-mountainous part of Southern Bulgaria in order to assess the aridity condition in temporal and spatial scale. The main investigated period is 1961-2015 and the reference periods are 1961-1990 and 1986-2015. The aridity is analysed on the basis of monthly data for air temperatures and precipitation from eight meteorological stations by calculation of De Martonne aridity index and Emberger Index. The survey shows that in all the analysed meteorological stations in Southern Bulgaria there are periods which display characteristics of the semiarid or arid climate. The aridity is well-expressed in the southwest part of Bulgaria (station Sandanski) and the western part of the Thracian lowland (station Plovdiv). Despite the aridity conditions established in the investigated region the tendencies in multiannual variability of De Martonne and Emberger indices show decreasing of aridity during the last 30 years (1986-2015) of the investigated period.

Keywords: *aridity, climate change, Southern Bulgaria, De Martonne Aridity Index, Emberger Index*

Rezumat. Ariditatea climatică în sudul Bulgariei în perioada 1961-2015

Schimbările climatice la scară globală, regională și locală sunt una dintre cele mai mari probleme indicate de studiile secolului XXI. Unele dintre schimbările climatice majore din Peninsula Balcanică, în special în Bulgaria, sunt legate de creșterea temperaturilor și scăderea precipitațiilor, ceea ce duce la secetă și ariditate climatică. Studiul de față se concentrează pe investigarea aridității climatice din partea non-muntoasă a sudului Bulgariei pentru a evalua starea de ariditate la scară temporală și spațială. Principala perioadă investigată este 1961-2015, iar perioadele de referință sunt 1961-1990 și 1986-2015. Ariditatea este analizată pe baza datelor lunare de temperatură a aerului și de precipitații la opt stații meteorologice prin calculul indicelui de ariditate De Martonne și al indicelui Emberger. Studiul arată că la toate stațiile meteorologice analizate din sudul Bulgariei există perioade care sunt caracteristice climatului semiarid sau arid. Ariditatea este bine exprimată în partea de sud-vest a Bulgariei (stația Sandanski) și în partea de vest a podișului tracic (stația Plovdiv). În ciuda condițiilor de ariditate stabilite în regiunea investigată, tendințele variabilității multianuale ale indicilor De Martonne și Emberger arată scăderea aridității în ultimii 30 de ani (1986-2015) din perioada investigată.

Cuvinte-cheie: *ariditate, schimbare climatică, Bulgaria de Sud, indicele de ariditate De Martonne, indicele Emberger*

Introduction

The study of the climate aridity could give important information about the condition for natural vegetation and agricultural plants. Aridity and drought are not equal concepts. Aridity, in contrast to drought, is a constant feature of the climate in a given area with low rainfall, resulting in a number of problems such as water scarcity. The aridity is a result of large-scale sustainable atmospheric and oceanic circulations or regional geographic features of the topography (Maliva and Missimer, 2012). The study of the aridity is based in large periods (at least 30 years), while the study of the drought is performed in small periods, which is a consequence of its occasional character. According to Maliva and Missimer (2012) there are four basic reasons for the existence of the arid climate: constant anticyclones with a combination of trade winds; continental air masses with low humidity; orographic shadow and cold ocean currents.

The existing publications show that the aridity has been investigated by various complex climatic indices. One of the most common indices for aridity research is the Thornthwaite climate index (moisture index). According to this index, aridity is shown in several tropical and subtropical areas of the world, being represented in Europe only in small parts of the south and southeast of the Iberian Peninsula (Feddema, 2005). In the last years, many studies revealed the existence of aridity and water scarcity in many areas of the Mediterranean and the Balkan Peninsula: Nastos et al. (2013), Rego and Rocha (2014), Andrade and Corte-Real (2016), Chendeș (2010), Vlăduț et al. (2017). According to Topliisky (2006) the aridity is characteristic for almost 2/3 of the plains of Bulgaria and can be observed well in the period June - October. Nikolova and Mochurova (2012) point out the tendency to arid climate during late summer and beginning of autumn in many region of Bulgaria. The De Martonne and Thornthwaite indices are used by Mitkov and

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Topliiski (2018) who have determined the tendencies to arid or semi-humid climate in Bulgaria.

The aim of present paper is to analyse spatial and temporal variability of aridity condition in South Bulgaria. In order to achieve this aim two climatic indices (De Martonne aridity index and Emberger index) are calculated and the years with the extreme values of the indices are determined. The tendency in temporal variability in both indices is reveal.

Studied area, data and methods

In order to assess the aridity condition in temporal and spatial scale the present study focuses on the investigation of the climate aridity in non-mountainous part of Southern Bulgaria (Fig. 1) which is one of the main agricultural areas in the country. The main investigated period is 1961-2015 and the reference periods are 1961-1990 and 1986-2015. The aridity is analysed on the basis of monthly data for air temperatures and precipitation from eight meteorological stations (Table 1) by calculation of the De Martonne aridity index and Emberger Index.

The selection of the stations and the duration of the investigated period are determined by the availability of monthly precipitation data. The sources of monthly data are the Meteorological yearbooks (National Institute of Meteorology and Hydrology, Bulgaria) and the Statistical yearbooks (National Statistical Institute, Bulgaria).

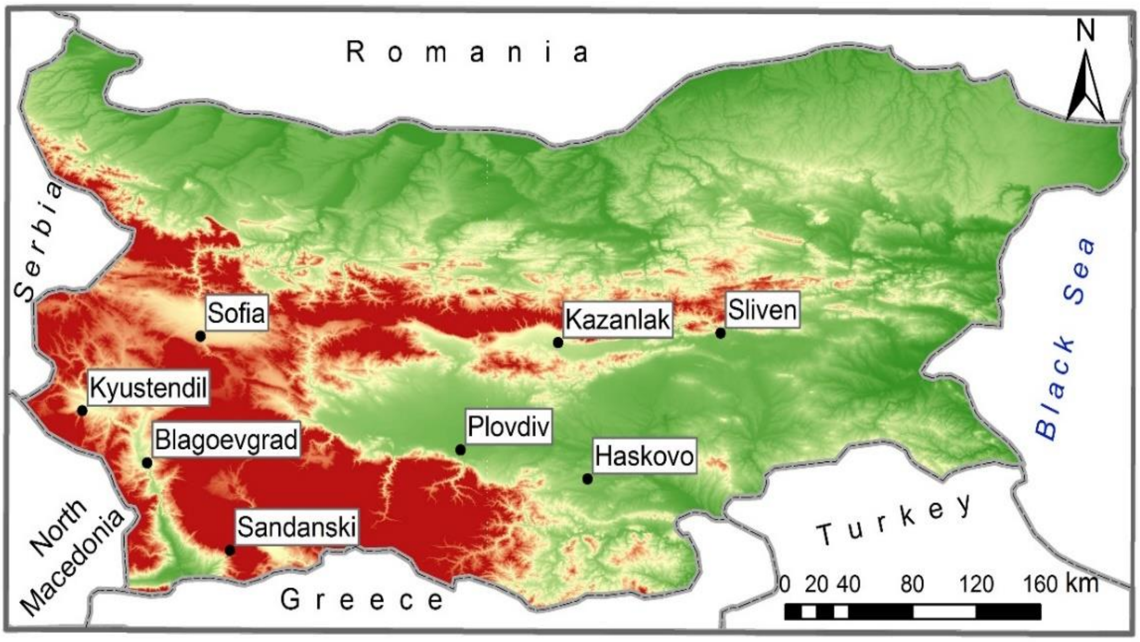


Fig. 1: Location of the studied meteorological stations *(Base map SRTM digital elevation model, NASA JPL, 2013)*

Table 1 List of meteorological stations used in the survey

Meteorological station	Latitude	Longitude	Altitude /m/
Sandanski	41º33′	23º16′	296
Blagoevgrad	42º00′	23º05′	410
Kyustendil	42º16′	22º43′	560
Sofia	42º39′	23º23′	500
Kazanlak	42º37′	25º24′	407
Plovdiv	42º04′	24º51′	164
Haskovo	41º55′	25º34′	203
Sliven	42º40′	26º19′	243

The analyses have been made using empirical and statistical methods. The De Martonne aridity index is one of the first indices used to assess aridity. The index was created by the French geographer Emmanuel de Martonne in 1926. In recent years there are many publications, based on De Martonne's aridity index in Greece (Mavrakis and Papavasileiou, 2013), Bulgaria (Mitkov and Topliiski, 2018), Romania (Vlăduț et al., 2017), Turkey (Chendeș, 2010), etc.

The annual values of the De Martonne index (Ia) are calculated using the following formula:

$$Ia = \frac{P}{T + 10}$$

where:

P - the annual precipitation totals

T - the average annual air temperature

10 - coefficient used to acquire positive values

The acquired results can be related to the following climate types, according to the De Martonne index (Table 2).

Table 2 Climate types according to DeMartonne aridity index

Climate types	De Martonne index values
Arid	< 10
Semi-arid	10 – 20
Mediterranean	20 – 24
Semi-humid	24 – 28
Humid	28 – 35
Very humid a	35 – 55
Very humid b	> 55

Source: Baltas (2007), Nikolova (2018)

The Emberger index is based on data from rainfall sums and average monthly air temperatures of the coldest month and warmest month (Emberger, 1930). Emberger used this index to classify phytoclimatic regions. That is why some scientists investigate the dissemination of vegetation according to the Emberger index (Gavilán, 2005 in Spain; Savo et al., 2012 in Italy). The Emberger Index (IE) is calculated using the following formula:

$$IE = \frac{100.P}{M^2 - m^2}$$

where:

P - the annual sum of rainfall

M - the monthly average temperature of the warmest month

m - the average monthly air temperature of the coldest month

The climate types according to the Emberger index are the following (Table 3):

Table 3 Climate types according to Emberger index

Climate areas	Emberger index values
Arid	< 30
Semi-arid	30 – 50
Semi-humid	51 – 90
Humid	> 90

Source: Nikolova (2018)

The temporal variability of aridity is analysed by application of linear regression model ($y=b_0+b_1*x$) of the time-series of both investigated indices (De Martonne aridity index and Emberger index). The statistical significance of the trend is determined by T-test using AnClim software (Štěpánek, 2008). Also, to obtain more information about the aridity in Southern Bulgaria and in particular about the causes of this climate characteristic, a correlation was made between the data for the De Martonne and Emberger indices and the North Atlantic Oscillation (NAO) and the Western Mediterranean oscillation (WeMOI).

The impact of NAO and MOI on the climate of Europe, including Bulgaria, are active throughout the year, but are best expressed in the cold half of the year (Hurrell, 2000; Martin-Vide and Lopez-Bustins, 2006). The NAO represents the difference in sea level atmospheric pressure between Iceland and the Azores. When NAOI is positive western winds are stronger and the winter in southern Europe are a colder and drier. The negative NAOI determine wet and warmer winters in southern Europe. The WeMOI is determined as an air pressure difference between Padua and Cadiz. The positive WeMOI is related to the anticyclone over the Azores and low-pressures in the Liguria Gulf. The negative phase coincides with the anticyclone located over the central Europe (Martin-Vide and Lopez-Bustins, 2006). The NAOI are taken from Hurrell Station-Based dataset[1] and WeMOI are from Climate Research Unit[2].

Results and discussion

Aridity indices – average and extreme values

The present study of aridity in South Bulgaria is based on calculations of the De Martonne aridity index and Emberger Index. According to the De Martonne index the average values for three investigated periods 1961-2015, 1961-1990 and 1986-2015 show humid and semi-humid climate while for the meteorological stations in Sandanksi and Plovdiv the indices are constantly associated with the Mediterranean climate (Table 4). This fact can be also interpreted as a geographical expansion to the north of the Mediterranean climate. In most of the investigated stations the average values of the Emberger index show humid climate (Table 5) while De Martonne index indicates semi-humid climate. The difference between the two types of indices is biggest for stations Sandanski where the De Martonne index shows Mediterranean climate and according the Emberger index the climate is

[1] https://climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-nao-index-station-based

[2] https://crudata.uea.ac.uk/cru/data/moi/

semi-arid. The second station with different results is Plovdiv–De Martonne index indicates Mediterranean climate while Emberger index shows humid and semi-humid climate. Despite different 30-years periods Nikolova and Voisilova (2013) have found similar results for De Martonne aridity index in South Bulgaria, which indicate slight changes in the multi-annual course of the indices.

Table 4 Climate types during various periods based on the De Martonne aridity index

Meteorological station	1961-2015	1961-1990	1986-2015	Lowest values	Year of lowest values
Sofia	29,00	27,7	29,02	12,47	1990
				14,14	2000
Kazanlak	26,98	26,58	26,18	14,77	2000
Sliven	27,44	25,46	28,25	16,90	2008
Kyustendil	27,58	27,93	26,90	14,3	2000
Blagoevgrad	24,08	24,79	23,12	9,79	2000
Plovdiv	23,67	23,28	22,92	11,00	2001
Sandanski	20,67	20,33	20,45	9,52	2000
				9.59	1993
Haskovo	29,25	29,62	27,99	16,03	2008

Climate types

Arid	Semi-arid	Mediterranean	Semi-humid	Humid

The average values of the De Martonne index indicate mainly semi-humid and Mediterranean climate during different periods (Table 4). Semi-humid climate is established also by Vlăduț et al. (2017) for the period 1961-2015 in the lowlands and plains in the north part of Bulgaria and south of Romania. On the other side, annual values of the index show that in some of the stations located in south-west part of the study area the aridity conditions have been observed in 22 to 45 % of the investigated years. These are stations which show a Mediterranean type climate according to the 30-years average values: Blagoevgrad (22% of the years with arid or semi-arid conditions), Plovdiv (35 %) and Sandanski (45 %). Based on potential evapotranspiration Nastos et al. (2013) show the tendency to sub-humid and semi-arid climate in many areas, mainly in eastern Greece.

The index values for the 90^{-es} and the beginning of the 21st century are the lowest and in some cases are equivalent to arid climate (Blagoevgrad and Sandanski according to the De Martonne index; Sandanski, Blagoevgrad, Plovdiv and Kyustendil according to the Emberger index), Tables 4 and 5. The peculiarity of the results is that both indices (De Martonne index and the Emberger index) indicate as the most arid year the year 2000 for which the lowest values of the indices are obtained (Tables 4 and 5).

Table 5 Climate types during various periods based on Emberger index

Meteorological station	1961-2015	1961-1990	1986-2015	Lowest values	Year of lowest values
Sofia	124,65	126,56	118,52	39,67	2000
Kazanlak	115,45	120,93	105,21	42,08	2000
Sliven	105,9	110,38	102,92	59.22	2013
Kyustendil	117,8	124,69	107,77	26,72	2000
Blagoevgrad	95,87	104,29	85,52	22,57	2000
Plovdiv	90,89	94,12	83,11	22,36	2001
Sandanski	69,89	74,71	64,51	28,03	2000
				28.23	1993
Haskovo	111,84	119,67	108,44	48,24	2000

Climate types

Arid	Semi-arid	Semi-humid	Humid

The De Martonne Index characterizes climate aridity but is also applied to assess the suitability of the climate for the development of natural vegetation. According to Satmari (2010), the Mediterranean and semi-humid climates with the De Martonne indices 20-25 and 25-30 are favourable for steppe vegetation. According to the results obtained in the present study, the stations are grouped into two groups: 1) with index 25-30 and 2) with index 20-25. In the first group are the territories with semi-humid climate, which are favourable for high grass steppes. This group of stations includes the stations located mainly in central Bulgaria (the Sub-Balkans valleys) and Haskovo station located in south-eastern Bulgaria in the lower part of the Eastern Rhodope Mountains.

The second group of stations, according to the De Martonne Index, is characterized by a Mediterranean climate and favours the development of grass or woody plants with hollow stems and long narrow leaves. These conditions are observed in the middle and lower Struma River valley (southwestern Bulgaria) and in the central parts of southern Bulgaria (station Plovdiv in the Upper Thracian valley).

Trend of aridity indices

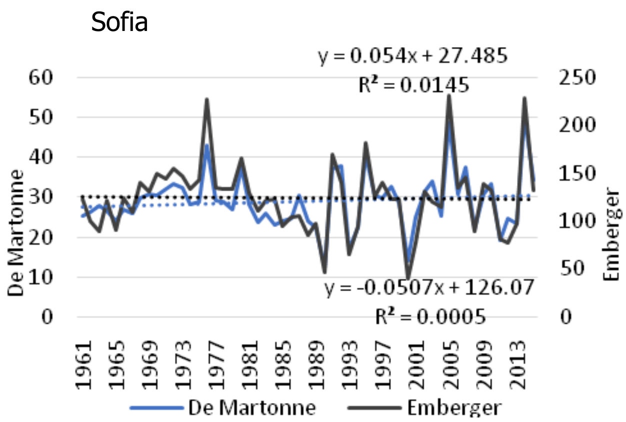
In order to study multiannual variability of aridity conditions the linear regression was applied to the time series of the De Martonne and Emberger aridity indices for two periods: 1961-2015 and 1986-2015. For the period 1961-2015 the trend of Emberger index is negative and the similar tendency show four meteorological stations (Blagoevgrad, Kyustendil, Kazanlak and Haskovo) for de Martonne index. The negative trend is statistically significant only for Emberger index at station Haskovo. The multiannual courses show quite good synchronicity between the De Martonne and Emberger indices (Fig. 2.). Mitkov and Topliiski (2018) have established the negative trend of the De Martonne index for the period 1900–2016 in selected stations from the non-mountainous part of Bulgaria. The decreasing trend in the aridity index could be explained by increasing of air temperature and decreasing of precipitation (Tabari et. al., 2014; Chenkova and Nikolova, 2015).

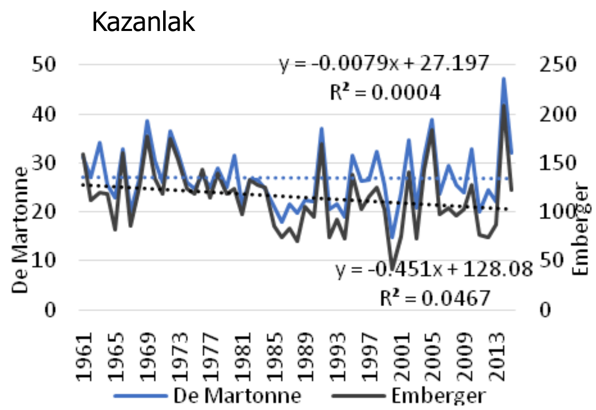
In the last 30 years (1986-2015) the tendency of aridity indices has changed and the trend for both indices in all of the investigated stations is positive (Table 6). Four stations, situated mainly in the western part of the studied area (Blagoevgrad, Kyustendil, Sandanski and Plovdiv) show statistically significant trend. The positive trend indicates the decreasing of aridity during the period 1986-2015. On the other side Cheval et al. (2017) indicate significant tendency towards more arid climate in the eastern part of Balkan Peninsula, including Bulgaria for the period 2021-2050 in comparison to 1961-1990.

Table 6 Trend of aridity indices for the period 1986-2015

	Blagoevgrad	Kazanlak	Kyustendil	Plovdiv	Sandanski	Sofia	Sliven	Haskovo
De Martonne	-0.05	-0.08	-0.24	0.24	0.38	0.54	0.91	-0.35
Emberger	**3.85**	**3.06**	1.35	**3.82**	**2.76**	2.51	2.41	2.26

Values marked in Bold are statistically significant at p=0.05





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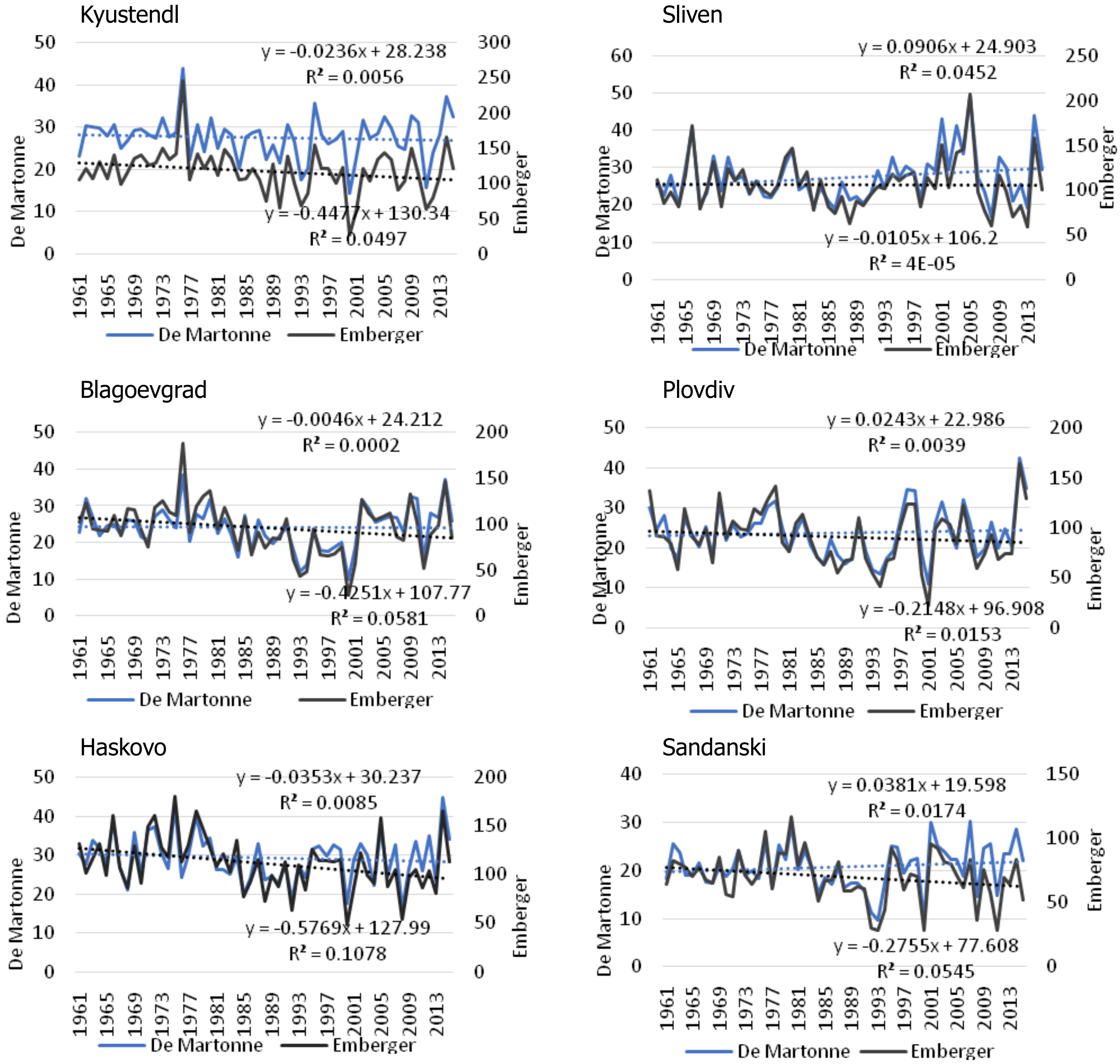

Fig. 2: Multi-annual variability of aridity indices

Impact of atmospheric circulation on aridity conditions

In order to analyse the impact of atmospheric circulation on aridity conditions the correlation coefficients between aridity indices and annual values of two circulation indices (NAOI and WeMOI) are calculated. The results show negative and statistically non-significant correlation. The correlation coefficients between NAOI and De Martonne aridity indices are higher than the coefficients for the Emberger indices (Table 7).

Compared to the period 1961-2015, a slight increase in the correlation coefficients between the aridity indices and the circulation indices is observed during the period 1986-2015. The relationship between WeMOI and aridity indices is better determined for the last 30 years (1986-2015) of the investigated period and mainly for the stations in the Upper Thracian valley and in the western Sub-Balkans valleys.

Table 7 Correlation between aridity indices and annual values of NAO and WeMOI

	Sofia	Kazalak	Sliven	Kyustendil	Blagoevgrad	Plovdiv	Sadanski	Haskovo
De Martonne Aridity Index ()								
1961-2015								
NAO	-0.17	-0.15	-0.21	-0.21	-0.25	0.04	-0.26	-0.21
WeMOI	-0.17	-0.07	-0.08	-0.03	0.08	-0.09	0.00	0.03
1986-2015								
NAO	-0.23	-0.13	-0.27	-0.23	-0.24	0.07	**-0.37**	-0.28
WeMOI	-0.22	-0.23	-0.06	-0.21	**-0.40**	-0.29	-0.14	-0.29
Emberger Aridity Index								
1961-2015								
NAO	-0.10	-0.09	-0.21	-0.09	-0.20	0.06	**-0.31**	-0.12
WeMOI	-0.08	0.03	0.07	0.05	0.10	0.01	0.27	0.18
1986-2015								
NAO	-0.16	-0.06	-0.23	-0.10	-0.15	0.12	**-0.37**	-0.17
WeMOI	-0.27	-0.25	-0.06	-0.28	**-0.38**	-0.32	0.04	-0.28

According to T-statistic the values in Bold are statistically significant at p=0.05

The statistical significance of the correlation is confirmed only in two stations (Blagoevgrad and Sandanski), located at the Struma river valley in the south-western part of Bulgaria.

The different correlation between atmospheric circulation indices and aridity indices can be explained by the relationship between parameters used for the calculation of aridity indices and also by the fact that annual values of air temperature and precipitation are used for the calculation of the De Martonne index while the Emberger index is based on the monthly air temperature for the warmest and the coldest months. We have selected the annual values of the atmospheric circulation indices for the study of the correlation with Emberger indices in order to have comparability with the results of the analysis of the correlation between De Martonne aridity index and atmospheric circulation. On the other hand, Emberger's formula also includes annual values - for precipitation totals. The results of the present study show that future investigation of the relationship between Emberger index and NAOI and WeMOI have to be directed to the analysis on monthly level.

Conclusion

The present study analyses the aridity conditions in non-mountainous part of south Bulgaria where the climate is transitional between moderate continental and Mediterranean. Based on the calculation of De Martonne aridity index and Emberger index for the period 1961-2015 and two 30-years periods (1961-1990 and 1986-2015) the following conclusion can be drawn:

- For all investigated periods the Emberger index shows mainly humid climate while according to the De Martonne index the climate in the investigated area is mainly semi-humid and, in some stations, – Mediterranean. The Mediterranean climate is characteristic for the south-western part of Bulgaria but also expanding to the north, occupying the middle part of the Struma river valley and central part of southern Bulgaria (Upper Thracian plain, station Plovdiv).
- The year 2000 makes impression with arid or semi-arid conditions in all of the investigated stations. On the background of general positive trend of aridity indices, the occurrence of the years with arid or semi-arid climate during the last decades increases.
- Despite the slight positive trend of aridity indices during the last 30 years (1986-2015) of the investigated period the aridity is a feature in many parts of the investigated area: the region of the middle and low Struma valley (Blagoevgrad and Sandanski) and Upper Thracian plain (Plovdiv) which will suffer from the consequences of aridity.

The relation between aridity indices and atmospheric circulation is better determined for the De Martonne index than for the Emberger index. However, the correlation coefficients are not statistically significant which require to direct future study to other factors that impact the aridity conditions e.g. solar radiation, topography, land use etc.

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The occurrence of the armored mud balls during the flash flood phases of the streams from the Meledic Plateau – the Curvature Subcarpathians, Romania

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Abstract

Armored mud balls that form in fluvial environments were observed on the river bed of two small streams from South-East Subcarpathians Bend, in the area of Miocene deposits with salt dia-pirs. Pieces of well-rounded clay mate-rial but with coarse surface were found on the gravel banks as well as partially submerged into stream channel and embedded in soft sediments of stream banks. The surfaces of mud balls, nearly spherical and ranging from 5 cm to 17 cm in diameter, were studded with sand grains and gravel that collected during flash floods as a result of bedload transport. The main source material of the armored mud balls consists of dark clay material detached from the cap rock of the salt massif that is crossed by the two streams. The newly formed armored mud balls, which were found among the gravels on the stream bed following the summer flash flood event from June 2019, supports the fact that these particular sedimentary features form during exceptional floods when pieces of clay material are rolled by the high-energy water flow, which results in acquiring of their spherical shape and the pebble shell. This paper represents the first report on the occurrence of modern armored mud balls formed in a fluvial environment, located in the Curvature Subcarpathians, Romania.

Keywords: *armored mud balls, Meledic Plateau, salt diapire, ephemeral fluvial flood, temperate climate*

Rezumat. Formarea ”bilelor de argilă ghintu-ite”(”amored mud balls”) în condiții de scurgere torențială a pâraielor din Platoul Meledic - Subcarpații de Curbură, România

În lungul a două văi cu caracter torențial, formate în depozitele Mio-cene de sare din cadrul pânzei subcar-patice de Sud-Est, au fost identificate formațiuni geologice descrise în litera-tura geologică și geomorfologică inter-națională sub numele de armored mud balls (bile de argilă armate/ghintuite). Formațiunile argiloase rotunjite, dar cu suprafața rugoasă, care au fost identifi-cate în albia pâraielor, erau parțial sub-merse, ori prinse într-o matrice de sed-imente fine. Suprafața bilelor de argilă, cu diametrul cuprins între 5 și 17 cm, era armată cu nisip grosier, pietriș și fragmente angulare de rocă, colectatate în timpul scurgerii turbulente care apare doar la debitele extraordinare cauzate de ploi torențiale. Sursa pri-mară a materialului din care sunt for-mate bilele de argilă este cuvertura sedimentară a masivului de sare, frag-mentat de văile în care s-au format acestea. Bilele de argilă care au fost identificate în albia unei văi, imediat după inundația din iunie 2019, con-firmă faptul că aceste structuri sedi-mentare particulare se formează exclu-siv în timpul debitelor extraordinare ale unor cursuri mici de apă. Atunci când bucățile angulare de argilă, de dimensi-uni caracteristice, ajung în albia râului, ele sunt preluate ca parte a debiuluit solid de scurgerea turbulentă a apei, timp în care sunt rulate și rotunjite, asigurînd totodată și aderarea fragmen-telor de rocă și nisip la suprafața plas-tică a acestora din care rezultă din care se formează armura. Această lucrare semnalează pentru prima dată for-marea bilelor de argilă armate în mediu fluvial actual aflat în Subcarpații de Curbură, România.

Cuvinte-cheie: *bile de argilă armate, Platoul Meledic, cută di-apiră, curgere torențială, climă temperat continentală*

Introduction

An armored mud ball is described as an rounded, unusual clastic sedimentary structure, consisting of piece of clay material eroded from a muddy bank or detached from a streambed and rolled along the river bottom, shore bed, sea bed by the strong currents or waves and coated with sand grains and pebbles of different origins, even organic debris (Bell, 1940; Picard & High Jr., 1973; Tanner, 1996; Goudie, 2013; Gutierrez & Gutierrez, 2016).

The term armored mud balls (AMBs) was coined by Bell (1940) and since then it is widely used in geological literature, both for fossil and modern specimens. In his seminal paper and comprehensive study, Bell pleaded for his proposed term as being "truly descriptive" one for the highly spherical mass-es of clay studded with pebbles. In earlier papers these geological structures were referred to as "clay galls" (Jones & King, 1875). "Pudding balls", "mud pebbles", and "mud cobbles" are other synonymous terms (Little, 1982), but Prokopovich & Isom (1985) suggest

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that "armored clay balls" is preferable to the widely used term AMBs.

AMBs are commonly formed during bedload transport of floods events in small streams, temporary streams, torrents, and gullies from semiarid and arid climate regions (Bell, 1940; Karcz, 1969; Karcz, 1972; Prokopovich & Isom, 1985; Martin Penela & Barragan, 1993; Sholokhov & Tiunov, 2002; Mather, Stokes, Pirrie, & Hartley, 2008; Desir & Marín, 2008; Desir & Marín, 2009; Marín & Desir, 2010). Also, fluvial contemporary AMBs have been identified and described in streams from temperate regions (Bescós Roy, 1991), including within Outer Carpathian flysch from Poland (Baluk & Radwanski, 1962; Glazek & Radwanski, 1962; Jońca, 1981; Krzyszton, 1984; Gebica & Sokolowski, 2001) and Slovakia (Bóna, Kováčik, & Kobulský, 2005). Recently they have been document-ed in humid climate regions that record tremendous floods have (Bachmann, 2014).

Besides, the occurrence of AMBs has also been reported on the shorelines of the lacustrine environments (Haas, 1927; Dickas & Lunking, 1968), on marine beaches (Tanner, 1996; Baptista Neto & Martins da Silva, 2001; Martins, Martins, & Tabajara, 2003; Ghandour, Al-Washmi, & Haredy, 2003), barrier islands (Hall & Fritz, 1984), intertidal environments (Stanley, 1969; Jindrich, 1969; van Diggelen, 1983), and in the deep marine environment within sandy turbidity currents (Stanley, 1964; Hizzet, Summer, Cartigny, & Clare, 2020). Although it is generally assumed that AMBs have a transitory existence, they are common features in many sedimentary rocks that developed in various environments, including salt deposits (Lang, 1963), ranging in age from the Late Pre-Cambrian until the Holocene (Leney & Leney, 1957; Bull, 1964; Dickas & Lunking, 1968; Wayne, 1981; Little, 1982; Diffendal, 1984; Sen & Sit, 1998; Felix et al., 2009; Rybar et al., 2015; Mleczak & Pisarska-Jamroży, 2019). However, the armoring process of the mud balls is not a sine qua non to assure their fossilization, but their occurrence within stratigraphic sequences record high hydro energetic conditions in any particular environment as well as the suitable sources of pieces of clay material (Unrug, 1963).

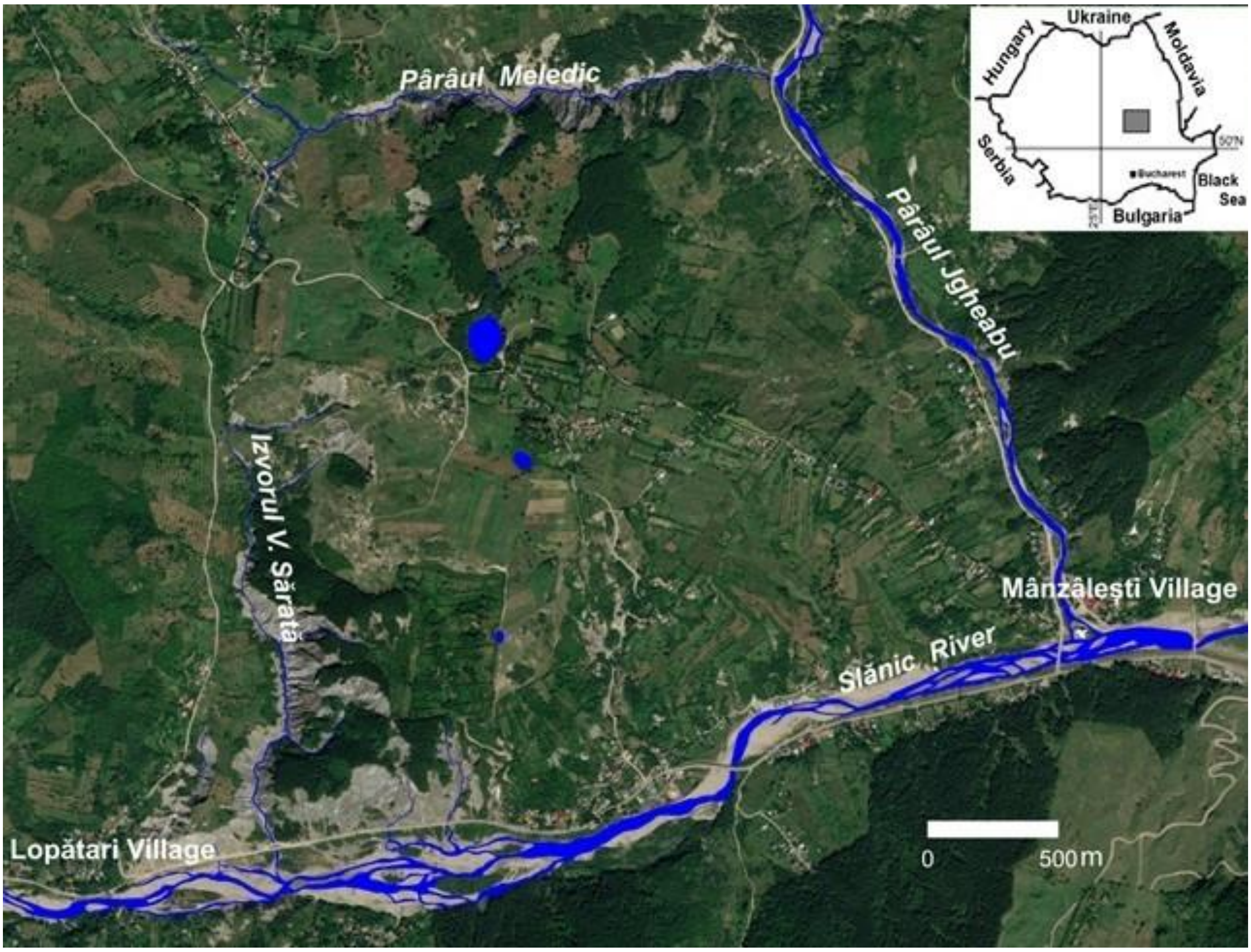

Fig. 1: Location of the Meledic Plateau in Romania

The formation of AMBs in the fluvial environ-ments is a physical process due to high energy de-veloped during flood events. Their occurrence is related to the discharge characteristics of river, and their shape and size reveal the competence of the rivers. They form when large pieces of hard and dry clay material or mud fell into a stream from slopes and river banks (Bell, 1940). Then, during the flood events, as a result of bedload transport within fluvial river systems, the angular pieces of rock tumble in the fast water currents (Bell, 1940; Mather, Stokes, Pirrie, & Hartley, 2008). Consequently, these angular pieces of rock become rounded as well as sufficiently soft and sticky on the outside for embedding of the streambed pebbles and coarse grains sand in their soft exterior. In this way, the armor of the mud balls is formed. The armor defines the final size of the mud balls. Soon after the energy of the flash runoff decreases, the AMBs remain scattered along the transport path. Further, the newly created AMBs might be preserved and recorded as sedimentary evidence only if they are buried and sealed by fine sediments during the flood events. Within temper-ate climate areas AMBs occur during summer floods that are caused by torrential rains; they were not found after winter floods induced by thawing (Krzyszton, 1984).

After Bell (1940) performed a thorough study of clay ball genesis in a ravine subject to strong flooding, several experiments were undertaken to investigate the origin and morphological development of these kinds of mud aggregates (Smith, 1972; Mather, Stokes, Pirrie, & Hartley, 2008). The sphericity and roundness are the main criteria for the morphological description of AMBs (Bell, 1940; Mather, Stokes, Pirrie, & Hartley, 2008; Li, Shengli, Shan, Gong, & Yu, 2017) and as well as parameters that may be used to estimate the length of clay clasts and the velocity of streams which transported them (Bell, 1940; Diffendal, 1984; Faimon & Nehyba, 2004). However, regardless of the environment in which they are formed, common to AMBs is that they are made by two distinct materials (a rounded clay core, and debris elements that compose the armor) and are shaped by turbulent water currents and waves.

In this paper we report the occurrence of AMBs along two stream valleys that drain a salt massif located in southeastern Subcarpathians Bend, Vrancea Hills, Romania. Morphological and morphometric characteristics of AMBs as well as the environment conducive to their genesis are discussed based on successive field observations.

Methods

The study area - Geological and geomorphological setting

The two salt streams with low-flow regime, Meledic and Izvorul Sărat, wherein have been formed the armored mud balls, belong to the Subcarpathians section of the Slănicul de Buzău River drainage basin, Vrancea Subcarpathians hilly region. The area corresponds to the anticline structure that has developed in Miocene deposits of the Sub Carpathian Nappe (Săndulescu, 1984). Both streams drain an Aquitanian buried salt dome diapir that belongs to Mânzălești salt formation (Dumitrescu, Săndulescu, Bandrabur, & Săndulescu, 1970).

The sedimentary cover of diapir consists of Aquitanian salt breccia (reddish and grey clays, silty interbeds, clasts of green schist, fragments of marl and sandstone up to cobbles, and boulders) and Burdigalian age deposits that consist in grey marls, calcareous sandstones, an discontinuous gypsum strata (Dumitrescu, Săndulescu, Bandrabur, & Săndulescu, 1970). The salt breccia deposits are the main source of the heterogeneous stream bed material.

The sedimentary succession on top of the salt massive is near horizontal, but the contact plane with the salt rock is corrugated, both due to recent local folding caused by diapir (Stoica, Andrășanu, Palcu, & Popa, 2017) and sub erosion processes. The sub erosion of the salt massif at the contact with its cap rock, driven by the infiltrated meteoric water, leads to the subsidence of overlying sediments and continuous readjustment of the topographic surface. Sub erosion processes in the upper part of the salt diapir are marked by a darker residual layer of cap rock.

Fig. 2: General view of the Pârâul Meledic valley

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The physiographic expression of this salt massif is a plateau landform, the Meledic Plateau, resembling a trapezium which is delineated by river valleys (fig. 1) and a thrust fault on the west side. It is located between 45°29′3″ and 45°30′13 North latitude, and 26°36′25″and 26°32′19″ East longitude, covering an area of 3.12 km2 with an average altitude of around 500 m. The Meledic Plateau is sharply confined by steep slopes and escarpments where salt rock outcrops, both as a result of faulting process and fluvial erosion. Numerous karst features like dolines and sinkholes, are scattered on its surface (Strat, 2016; Móga et al. 2018). Some former dolines have evolved into doline valleys, gullies and ravines.

According to Köppen classification, the region has a humid continental climate, warm summer subtype. Based on the 1961-2000 data period, the yearly mean air temperature is around 8.7 °C. The multiannual average precipitations amount is around 650 mm, unevenly distributed throughout the year. Nearly two thirds of annual precipitations fall during the warm semester, May-July recording the annual pluvial maximum and heavy rains events. Precipitations amount recorded in June 2019 was 140 mm, of which about 80 mm were recorded in the first four days of the month and 37 mm fell on June 4th 2019, which caused a flash flood in the area.

Due to its geological, geomorphological and biodiversity value, most of the Meledic Plateau, including the above-mentioned two salty streams, it was designed natural protected area and also it belongs to Buzău Land Geopark (Anonymous, 2000, 2008; Andrășanu, 2010).

Field survey and data gathering

Fig. 3: General view of the Izvorul Sărat stream valley in the lower course, upstream to its debouche in the Slănic River. Picture taken on June 7th 2019, after the flash flood event

During a field trip carried out in August 2014 several well rounded, rougly spheroidal mud clasts coated by various size mineral debris were found partial immersed in water as well as stranded on the river bank along the Pârâul Meledic valley (Meledic Stream) located in the Meledic Pateau that belongs to Subcarpathians section of the Slănicul de Buzău River drainage basin. These unusual fluvial sedi-mentary features, never seen before, were identified as armored mud balls. In the following years, exten-sive surveys of the stream valleys from Meledic Pateau allowed to discover more AMBs specimens, to identify the sediment supply (suitable aggregates as mud ball seeds), the mud ball factory zone of stream valleys.

Also, geomorphology of the stream valleys was exanimated. Taking advantage of the flood event from 4th June 2019, the stream valleys were explored on 7th June 2019. Newly formed armored mud balls were found and exanimated on the river bed of the second stream, Izvorul Sărat, also. Along the two stream valleys that have been subject of our observations, AMBs were randomly collected in order to examine their clay core material, size, shape, roundness, type of armor, and degree of preservation. To find if our findings are supported by other pub-lished studies, the literature review on AMBs subject was made.

Results and Discussions

The stream valleys – the environment of formation of AMB

The Pârâul Meledic delineates northern side of the Meledic Plateau (Fig. 1). This stream flows in eastern directions along around 1.5 km and debouches into Jhiabului River that is the left-bank tributary of the Slănic River as well as the eastern boundary of the Meledic Plateau. The valley of Pârâul Meledic is fairly straight, deep and narrow "V-shaped", with unstable steep sides, over 45°, where the salt rock outcrops. The upper part of slopes exhibit badland features as a result of erosion of friable and loose sedimentary material (Fig. 2). Superficial landslides and mudflows are mobilized on springs when the clay material reaches its plastic limit and can slide due to heavy rains. During dry periods, because of sodium chloride, this material is affected by desic-cation cracks and popcorn structures.

On the salt outcrops surface runoff shapes sharp rillen-karren patterns that then evolve into planar solution surfaces. The remaining residue of rock salt is carried downslope by runoff and deposited on sub-horizontal portions of the slopes which, accord-ing to its thickness and areal distribution, become a protective layer of salt from further dissolution. Due to a sandstone sequence in the eastern part of the salt dome, close to its confluence with Jhiabului River, the Meledic valley has a short a gorge section with knick point and waterfall, where the valley does not exceed 2 meter wide.

The main tributary of the Pârâul Meledic drains a doline and salt cave system from Meledic Plateau, which includes one of the longest salt caves in the world (Giurgiu, 1987). Several other brine springs that drain salt massif feed the stream on the right-bank.

Izvorul Sărat, which is almost a 2 km long stream, has developed its catchment in the western part of the Meledic Plateau (Fig. 1). It flows in north-south direction and is a left-bank tributary of the Slănic River. The Izvorul Sărat valley is a relatively straight channel, deeply incised into salt diapir, with very steep slopes, especially in the midle and lower course section that is named „Salt Canyon" (Fig. 3) where it overlaps on a thrust fault (Ponta, 2019).

Fig. 4: Salt outcrop and earth pyramids formed in cap rock material on the steep slopes of the Izvorul Sărat stream valley

The evolution of the salt escarpments delineated by streams is controlled by runoff, dissolution and gravitational mass-movement. Over time, the erosion has been disintegrated slopes and generated peculiar features as a result of the overlap of two different geological materials: salt rock and its cap rock. In the cover material, with stone blocks and enough large sandstone and mudstone debris, formations resembling something between the classic earth pyramids and tulin are formed, while in the more homogenous material only ravines and ridges are shaped. When the salt rock outcrops, water rain dissolves the exposed salt, detaching salt columns with more or less pyramidal breccia material cover (Fig. 4).

The span life of these salt pyramids is shorter than that of classical earth pyramids and most probably weathering processes are involved in their evolution. It is not uncommon for the columns of salt to break off and collapse under the weight of their covering material. Materials derived from sed-imentary cover of salt rock are the source of the talus cones as well as of the river bed pavement. The stream Izvorul Sărat is fed by many small salty springs that emerge from both sides of the valley. These springs play a critical role in the salt content of the stream during dry period times.

Both streams, Pârâul Meledic and Izvorul Sărat, are very shallow. Their water discharges show monthly variability, being directly linked to rainfall regime. Toward the end of the summer the water discharge is very low and streams are affected by drying up processes. Drought periods lead to evaporation of high mineralized water from streams and their hyporheic zones and efflorescence of sodium chloride that results in the white crusts on the river bed sediments (Fig. 5). Thus, the stream bed becomes partially covered by salt crust and halite crystals, resembling frozen water and hoarfrost. Clay materials on the steep slopes of both stream valleys alternately desiccate/crack and erode during hot dry and rainy seasons.

Armored mud balls – morphology, genesis and deposition

Along two stream valleys, which are deeply incised in a salt Miocene formation from southeastern Subcarpathians, Romania, have been found particular rounded sedimentary structures whose already enshrined name is armored mud balls. Their distribution along the valleys was irregular, being preponderantly in the middle course of Pârâul Meledic and in the lower course of Izvorul Sărat stream, which, morphologically, mainly corresponds to its canyon-like valley section, just before of its debouche.

The density of AMBs along the Pârâul Meledic ranged from 0.6 to 1.4 per m2 across the area in which they occurred. They were lying in the stream channel, partial immersed, as well as on the stream bank, and among rock debris (Fig. 6, 7). Also, AMBs were identified embedded in sediments of stream bed that were exposed by fluvial erosion (Fig. 7). Few AMBs, only partially embedded in a loose sandy loam matrix, were thoroughly coated by white halite crystals. Several of AMBs that were completely subaerial exposed were partially disintegrated, most probably due to desiccation and weathering, which means that they are never preserved unless completely covered at the time of the flood by soft alluvium (Bell, 1940; Mather, Stokes, Pirrie, & Hartley, 2008).

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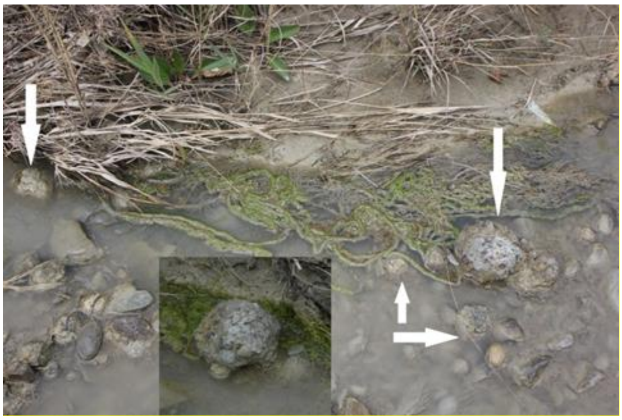

Fig. 5: AMBs immersed in water stream in a low velocity section of the Pârâul Meledic channel and surrounded by Enteromor-pha intestinalis thali. The size of AMB may be noted in comparison to the alga thallus, which range from 0.5 to 1.5 cm wide. In insert, a close up of an AMB spec-imen. Noteworthy is the heterogeneous armor of the mud ball, whitish appear-ance of its subaerial exposed part caused by salts precipitations, and thalli of ma-rine alga Enteromorpha, which is an un-common species in rivers but whose its occurrence is supported by the high salin-ity of stream water

Fig. 6: AMBs immersed in water stream in a low velocity section of the Pârâul Meledic channel and surrounded by Enteromor-pha intestinalis thali. The size of AMB may be noted in comparison to the alga thallus, which range from 0.5 to 1.5 cm wide. In insert, a close up of an AMB spec-imen. Noteworthy is the heterogeneous armor of the mud ball, whitish appear-ance of its subaerial exposed part caused by salts precipitations, and thalli of marine alga Enteromorpha, which is an uncommon species in rivers but whose its occurrence is supported by the high salin-ity of stream water.

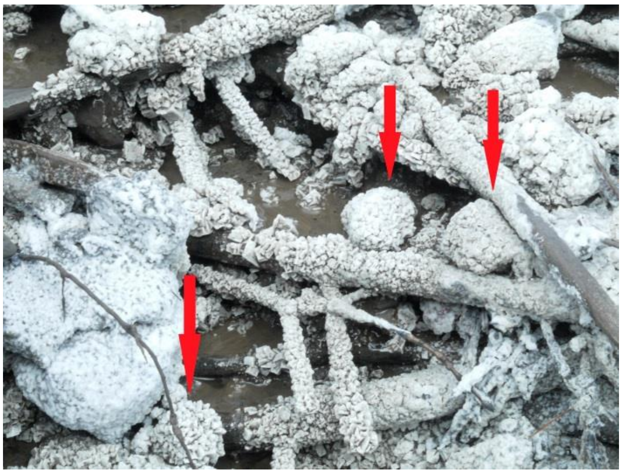

Fig. 7: AMBs immersed in water stream in a low velocity section of the Pârâul Meledic channel and surrounded by Enteromorpha intestinalis thali. The size of AMB may be noted in comparison to the alga thallus, which range from 0.5 to 1.5 cm wide. A close up of an AMB specimen. Noteworthy is the heterogeneous armor of the mud ball, whitish appearance of its subaerial exposed part caused by salts precipita-tions, and thalli of marine alga Entero-morpha, which is an uncommon species in rivers but whose its occurrence is support-ed by the high salinity of stream water

Based on measurements of 57 specimens ran-domly sampled the AMBs ranged in size from 5 to 17 cm in diameter, with an average diameter of 9 cm, but few specimens which was not part of the sam-ple, were larger. The AMBs were dark grey and brownish yellow, nearly perfect spheres in shape (Fig. 6, 7, 8). They were generally uniformly armored and the armor was variable in composition and size, ranging from coarse grains sand to pebble. The peb-bles were firmly inserted into clay and well pressed in, so the surfaces of AMBs were fairly smooth (Fig. 7, 8). AMBs specimens that have collected from the Izvorul Sărat stream soon after the flood event were soft, malleable and sticky but with a dry core.

The armored nature of the mud balls that were found was confirmed by slicing several open. The interior of each mud ball consisted of clay material with few small pebbles and the exterior was coated by a layer of coarse sand grains to pebble – size clasts, more diverse as origin (sandstone, marl, green schist, limestone), up to 30-35 mm in diame-ter. Clasts were irregular, with varying degrees of rounding, from unrounded to well-rounded. Some of AMBs were well rounded and spherical but incomplete varnished by armor.

The core material of AMBs that have been found in the study area has two sources. The main source consists of clay material that composes the cap rock of salt massif that has evolved in badland slopes. It is about by detached blocks from the upper part of slopes as a result of rock falling, which break up and reach the river channel, pieces of clay material detached by cracking from slopes affected by mass movement, popcorn structures, as well the colluvi-um material that produced talus slopes. The second source core of AMBs is the fine mud material deposited along the stream bed and then exposed. The desiccation cracking process that is enhanced by the crust of sodium chloride generates irregular clasts of cohesive clay material. From the resulted mass of unsorted pieces of clay material by various sizes, some of them suitable aggregates to become AMBs. S-o called mud ball 'seeds", if the energy of currents during time of floods is strong enough, are transported as bedload or lifted in the water column, being suitable to be rounded by turbulence flow. Then, if they are enough soft and sticky, the armor is added to the core as the sand and gravel grains press into soft exterior while they are rolling downstream.

Fig. 8: Close up of AMBs specimens collected from the Izvorul Sărat valley following the flash flood event fom June 4th 2019

However, based on observations carried on the two valleys it was noticed a larger number and a higher frequency of occurrence of AMBs along the Pârâul Meledic than in the Izvorul Sărat valley, althought the lithology and climate are identical in both cathments. The diffrence in their ability to generate mudballs consists in topographic configu-ration of the valleys and extension of the salt out-crops within the slopes in relation to clay material cover of the salt rock. Althought in the most of the previous reported cases of AMBs in fluvial alluvial systems there is a direct and strong connection be-tween steep slopes that supply the source of suitable aggragates and generation of AMBs, the Izvorul Sărat reveals a weak connection in this regard com-pared to the other stream. The slopes of the Pârâul Meledic are less steep than those of the Izvorul Sărat, but they are covered by bare clay material, seasonaly affected by active mass movements and runoff. Besides the salt soluble content of this mate-rial enhances desiccation cracking and popcorn stucture formation. Consequently, these slopes are constant, direct and suitable source of mud ball seeds to the stream.

Fig. 9: Mud clasts produced by mud craking are the second source of the 'seeds' of AMBs. The dessication craking process is inten-sified by the sodium chloride content of clay material

The slopes of Izvorul Sărat valley, even though they are very steep, they are rather point sources of clay into stream. Most part of slopes consists of exposed salt rock and clayey material comes from their upper part, mainly as large blocks of material which fall at the foot slope, building the talus. Then,

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subsequently these blocks might become source aggregates for the mudballs by wethering and fluvial erosion (Fig. 3,4,10) evolving in suitable mud ball seeds in term of size or might be disintegrated by rains.

The AMBs that were found on the Izvorul Sărat valley were close to the mouth of stream, where the valley has a wide and flat floor, paved with gravels, cobbles, and even erratic boulders. The density of AMBs (ranging in size from 6 cm to 11 cm) in the area was 0.2 per m2, but they had a high degree of roundness and sphericity. These findings are in accord-ance to Bell (1940) who pointed out that size of balls record facts about the stream which made them; in a stream with bed composed mainly of stones, if the pieces of clay that reach stream bed are not large enough, then they would be crushed and smashed to bits by the heavier elements of the load during high water and hight velocities. The high degree of roundness and sphericity of AMBs, may sugests another interpretation, sensu Bell (1940): the AMBs increass in sphericity and armoring shell with the distance from source material, which is upstream to „Salt Canyon" area, the place where they occured.

Fig. 10: Cayley blocks in the stream bed rounded by flow of stream, source of mud ball "seeds"

As opposed to Pârâul Meledic valley, where AMBs were present in considerable numbers, including embedded in riverbank sediments (Fig. 11) there is the possibility that the Izvorul Sărat stream does not produce commonly AMBs during the flash floods. Rounded mud clasts with various sizes as well as some disintegrated specimen of AMBs were noticed in the river bed during the surveys of valley, well-defined AMBs was spotted only once, immediately after the flood event from June 2019. However, the possibility of their genesis in similar circumstances cannot be excluded. Taking into account AMBs have poor preservation potential, even though they are produced because remain exposed on the stream bank and gravel bars, then they are disaggregated in the meantime. Perhaps the most important explanation of the scarce occurrence of AMBs on Izvorul Sărat valley may be that there are not suitable clay pieces or mud ball "seeds" (Mather et al., 2008) in the "mudball "factory" (Bell 1940) for production of AMBs during each flood event, the optimum condi-tions for mud balls generation are not met regularly. Also, it may be speculated that the scantiness of AMBs along this valley is that they are delivered to the mainstem as a sediment load because before of it confluence there is not enough flow decrease to cause their deposition.

Fig. 11: AMBs embedded in the layered Pârâul Meledic stream bank of the Pârâul Meledic. The erosive section of the stream bank shows successive fluvial deposits that preserve AMBs formed during previous flood events. Some of the mud balls, rested on the current river bed, both armored and unarmored, may have been exhumed from their matrix by ero-sion during high waters and reintroduced into active river system as bedload. Also, the lightly armored balls found in the water may have been new, unfinished mud balls, formed during the most recent flood event, or older AMBs that were peeled off by corrosion

Fluvial erosive sections through several point bars of the Pârâul Meledic have revealed buried AMBs formed during discrete flood events that were preserved in the subsurface (Fig. 11). This fact support idea that in similar valleys nearby study site and other salt areas from Subcarpathians AMBs may be occurring, but not necessarily. However, if they are not covered by a thick layer of gravel, sand or clay, almost certainly they will be disintegrated and washed out by the next flood, as it was stated and experimentally confirmed (Haas, 1927; Bell, 1940; Mather et al., 2008).

The occurrence of AMBs in the area of the Meledic Plateau represent a new natural element that enhances the already its known scientific (geo-logical, geomorphological) and educational value (Giurgiu, 1995; Mărunțeanu & Ioane, 2010; An-drășanu, 2010; Strat, 2016; Stoica, Andrășanu, Palcu, & Popa, 2017; Melinte-Dobrinescu, et al., 2017; Moga et al., 2018). Taking into account that AMBs, as geo-logical formations, have not been documented in the Romanian geological or geographical literature, and neither in vernacular language, we suggest two Romanian versions of the accepted term by the international scientific community. The first one is "bilă de argilă armată", and it is the literal transla-tion without any change of meaning of the English term "armored mud ball". The other one,"bilă de lut ghintuită", is closer to normally spoken Romanian language, informally.

Conclusions

Modern fluvial armored mud balls developed in the salt Miocene formations that belong to South-East Subcarpathians, Romania, are reported for the first time. The geological, climatic and hydrogeomorphologic conditions are suitable for genesis of AMBs along two small stream valleys that are deeply incised in a salt diapire formations over which overlaps the geomorphological unit called the Meledic Plateau.

The occurrence of centimeter-sized mud aggregates coated by sand grains and various pebbles and rock clasts is associated with high energy of water during flash floods episodes following dry period times. The badland catchments and the steep slopes of the stream valleys supply the weathered blocks of clay material to the stream bed that are the main mud ball seeds within the "mud ball factory". The second source of AMBs consists in more homoge-nous pieces of polygonal shape of clay detached from stream banks as a result of mud cracking and erosion. The AMBs that were found along the stream valleys from the Meledic Plateau, Vrancea Subcarpa-thians, are nearly spherical, with an average diame-ter of 9 cm.

The observations made from this study show that these streams represent an exceptional opportunity to study contemporary fluvial AMBs formed in a hilly region with temperate climate. The occurrence of these particular sedimentary structures represent a physical proof of extreme floods episodes caused by summer heavy rain episodes following a dry long period time, similar to semi-arid regions when AMBs were initially studied, but more detailed stud-ies are needed. In addition, AMBs can be regarded as a new natural element that enhances the scientific and educational value of the Meledic Plateau, which was designed as natural protected area and part of the Buzău Land Geopark.

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Author contribution

Both authors contributed equally to this manuscript.

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Gross chemical analysis of the turf and podzolic soils on glacial deposits, laid by dense carbonate rocks

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Abstract

Gross analysis allows us to reveal issues concerning the genesis of soils and to identify the peculiarities of elementary soil processes. The article summarizes the results of the study of gross chemical analysis of the turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks. Features and relationships of oxides content in soils and soil-forming rocks are considered, that will make possible to justify important issues of the nature of these soils and to study the dependence of their natural properties with dense carbonate rocks.

It is established that oxides of silicon, ferum, aluminum and calcium form the basis of gross chemical composition of the turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks. The maximum content of the first component is observed in the upper humus-eluvial horizon (90–94%), aluminum and ferum oxides – in iluvial accumulative horizons, where their content in total is 7–15%. Calcium oxide content in soil profile of studied soils, naturally increases from 0.36% in the upper horizons to 0.95% in the transitional, and in the laid carbonate rocks its content can reach up to 35%. This confirms the fact that laid carbonate rocks have a significant influence on the flow of all soil elementary processes, and gross analysis confirmed the presence of carbonates in the entire soil profile, which could not be determined during field or macromorphological studies. Oxides of alkaline-earth metals are mainly accumulated in the upper humus horizons of all soils, their content decreases down the profile. Potassium and phosphorus oxides, although pliable to washing, however are delayed in the soil and included in the biological cycle and partially fixed in secondary minerals. The content of biologically important components such as P_2O_5, MnO, S, N in the upper horizons of the studied soils is closely related to the accumulation of humus.

Keywords: *gross chemical analysis, gross chemical composition, oxides, chemical elements, soil formation, turf and podzolic soils on glacial deposits, laid by dense carbonate rocks*

Rezumat. Analiza chimică brută a solurilor podzolice dezvoltate pe depozite glaciare, depuse pe roci carbonatice dense

Analiza brută ne permite să dezvăluim probleme referitoare la geneza solurilor și să identificăm particularitățile proceselor pedogenetice. Articolul rezumă rezultatele studiului analizei chimice brute a solurilor podzolice pe depozite aluviale și glaciare, formate pe roci carbonatice dense. Sunt luate în considerare caracteristicile și relațiile conținutului de oxizi din soluri și rocile din substrat, ceea ce va face posibilă justificarea problemelor importante ale naturii acestor soluri și studierea dependenței caracteristicilor lor naturale de stratului de roci carbonatice.

S-a stabilit că oxizii de siliciu, fer, aluminiu și calciu se află la baza compoziției chimice brute a solurilor podzolice dezvoltate pe depozitele glaciare, deasupra rocilor carbonatice dense. Conținutul maxim al primei componente este observat în humusul orizontului eluvial superior (90-94%), aluminiu și oxizi de fier în orizonturile de acumulare iluviale, unde conținutul lor total este de 7-15%. Conținutul de oxid de calciu în profilele solurilor studiate crește în mod natural de la 0,36% în orizonturile superioare la 0,95% în cele de tranziție, iar în rocile carbonatice, conținutul său poate ajunge până la 35%. Acest lucru confirmă faptul că rocile carbonatice parentale au o influență semnificativă asupra fluxului tuturor proceselor elementare ale solului, iar analiza brută a confirmat prezența carbonaților pe întregul profil al solului, ceea ce nu a putut fi determinat în timpul studiilor de teren sau a celor macromorfologice. Oxizii metalelor alcalino-pământoase sunt acumulați în principal în humusul din orizonturile superioare ale tuturor tipurilor de sol, conținutul acestora scăzând pe profil. Oxizii de potasiu și fosfor, deși pot fi spălați, cu toate acestea sunt reținuți în sol și incluși în ciclul biologic și fixați parțial în minerale secundare. Conținutul de componente biologice importante precum P_2O_5, MnO, S, N, în orizonturile superioare ale solurilor studiate este strâns legat de acumularea de humus.

Cuvinte-cheie: *analiza chimică brută, compoziția chimică brută, oxizii, elementele chimice, formarea solului, solurile podzol-ice pe depozite glaciare, depuse peroci carbonatice dense*

Introduction

Soil is an arena of continuous chemical, physical and biological processes, an active participant in the cycle of substances in nature. Its physical, chemical, morphological properties reflect those complex processes and phenomena that took place during the long process of soil formation. Gross chemical analysis reveals issues related to soil genesis and to identify the peculiarities of elementary soil processes.

As Miakina and Arinushkina (1979) note, in the 1920's, soil scientists actively studied the gross content of each element in each soil horizon, in terms of the availability of elements for plant nutrition. Until the 1930's, scientists used gross chemical analysis extensively to investigate the elemental composition of soils, which was essential to assess the direction of the soil formation process. In the 1940's, scientists paid considerable attention to the definition of molecular relations. Modern soil scientists use significantly less of so-called "old-fashioned materials" of gross analysis. But it must be noted that both gross analysis and molecular relations are extremely important and useful. After all, in 1944 Polynov noted that gross chemical analysis was the necessary initial stage of all researches and determined the direction of the following analyses and definitions. The further development of analytical technology in world science has led to a change in the ways in which the quality composition of soils is assessed, therefore, many laboratories, making extensive use of the new technique, have paid much less attention to gross analysis. Even now, for genetic purposes, gross analysis is only partially used in various modifications. The results of studies of gross chemical analysis of soils we find in quite recent works (Krasnov et.al., 2017; Melkerud et.al, 2000; Olsson et.al., 2000; Sanborn et.al., 2011).

The question of the genesis of the turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks, is poorly addressed by the literature, which is due to insufficient information base about their properties. Some information about these soils can be found in the works of Andrushchenko (1970); Friedland (1986); Polupan et.al. (1988); Vernander et.al. (1986). Therefore, gross chemical analysis will allow to substantiate important issues about the nature of these soils; to study the dependence of their natural properties from the depth of the laid carbonate rocks; to establish classification accessory.

The purpose of the research is to study the gross chemical composition of the turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks, to investigate changes in their chemical composition, to justify the dependence of this composition on soil-forming rocks, to identify the influence of laid rocks on the overall soil formation process.

Tasks to be solved: to estimate the gross chemical composition of soils; to interpret the data and to trace their changes depending on soil-forming and laid rocks; to justify the removal or accumulation of chemical elements according to the soil profile; to provide an analysis of the soil leaching factor.

The practical significance of the results. Gross analysis data will make it possible to trace changes in the content of chemical elements by soil profile, to identify the direction of soil-forming processes (or soil genesis). The obtained results allow to trace the chemical composition of the mineral part of the soil and their functional dependence on the soil-forming and laid rock and the depth of its occurrence, which in the future will allow to apply the obtained results to clarify the criteria of classification of the studied soils.

Materials and Methods

Maly Polissya is located in the most western part of Ukraine (Fig. 1). It borders the Volyn Upland in the north, Roztocze in the northwest, Opillia in the south and southwest. The territory stretches in a latitudinal direction for 220 km, from the town of Rava-Ruska, Lviv region, to the outskirts of Ostrog, Rivne region. The average width of Maly Polissya is 20–25 km, and the widest part is 75 km. The melting waters of the lower Quaternary glacier (Oka glaciation) played an important role in the formation of the territory of Maly Polissya. Wide valleys are filled with sandy water-glacial deposits, which lie on water-resistant Cretaceous deposits, which in some places come to the surface.

The dominant type of relief is flat-undulating accumulative aluvial-glacial plains, which alternate with alluvial and swampy plains along the main rivers Rata, Solokia and Bolotna - left tributaries of the Western Bug. Dominant absolute heights - 210-240 m, maximum height - 274 m. The background soils on the territory of Maly Polissya are sod-podzolic soils on water-glacial deposits and sod-carbonate soils. Less common are sod-podzolic soils on water-glacial deposits, lined with dense carbonate rocks, which occupy more than 30 thousand hectares (4.3% of the total area of Maly Polissya) and are located as relatively large areas (up to 10-15 hectares), and insignificant areas (within 0.1–0.2 hectares) among the background soils.

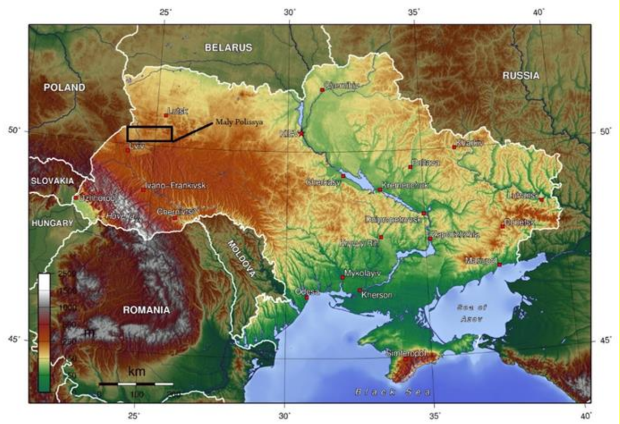

Fig. 1: Location Map of the Study Area

The object of the current research is the least studied in the region of Maly Polissia (Fig. 1), i.e. turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks. The gross chemical composition was determined for such soils: turf and slightly podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks from the depth of 1–1.5 m (soil cut 3R and 5B); turf and slightly podzolic (soil cut 4B) and turf and podzolic secondary-carbonized slightly deflated soil (soil cut 7B) on alluvial and glacial deposits, laid by dense carbonate

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rocks from the depth of 0.5–1 m. The gross composition of the soil-forming and laid rocks on which these soils were formed was also studied (Tab. 1–2).

The gross analysis includes the determination of hygroscopic moisture, losses from calcination, organic carbon and nitrogen content and element content, which are part of the mineral part of the soil, and the determination of CO_2 carbonates in carbonate soils. The results of the determination of SiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, MgO, SO_3, P_2O_5, K_2O, Na_2O, TiO_2 are expressed by the content of oxides (Arinushkina, 1970).

During the research were performed complete gross chemical analysis and determination in percentage by weight of air-dry soil oxides: SiO_2, Al_2O_3, Fe_2O_3, FeO, TiO_2, MnO, CaO, MgO, SO_3, P_2O_5, K_2O, Na_2O, H_2O, CO_2, and losses from calcinations. A complete silicate analysis was done for 15 elements. SiO_2 was determined by weight method after the decomposition of sample weight by fusion with sodium carbonates. The main soil-forming components: Al_2O_3, Fe_2O_3, CaO, MgO were determined by volumetric complexometric method at appropriate pH values of titration was carried out by trilon B. The content of oxides MnO, P_2O_5, TiO_2 – by photometric method on a photocolorimeter, alkaline oxide content – by the method of atomic absorption spectrophotometry.

The obtained results were transferred on dry, calcareous carbonate-free soil. The content of oxides is converted to the content of chemical elements, the molar ratios of these oxides are calculated. Data processing of the GCA was carried out according to the generally accepted method concluded in the manual of Arinushkina (Arinushkina, 1970).

According to Bowl et.al. (1977) the dominant issue of genetic study of the mineral part of the soil is the elucidation of changes in its chemical composition under the action of soil-forming processes, and comparison of data, expressed as a percentage of dry soil weight does not give a correct understanding of changes in the mineral part of the soil, because the amount of each oxide is affected by the content of humus and chemically bound water. Therefore, methodically correct will be the recalculation of the results, expressed as a percentage from dry soil weight to a percentage of mineral part weight, that is, it is necessary to exclude from calculations the content of humus and chemically bound water.

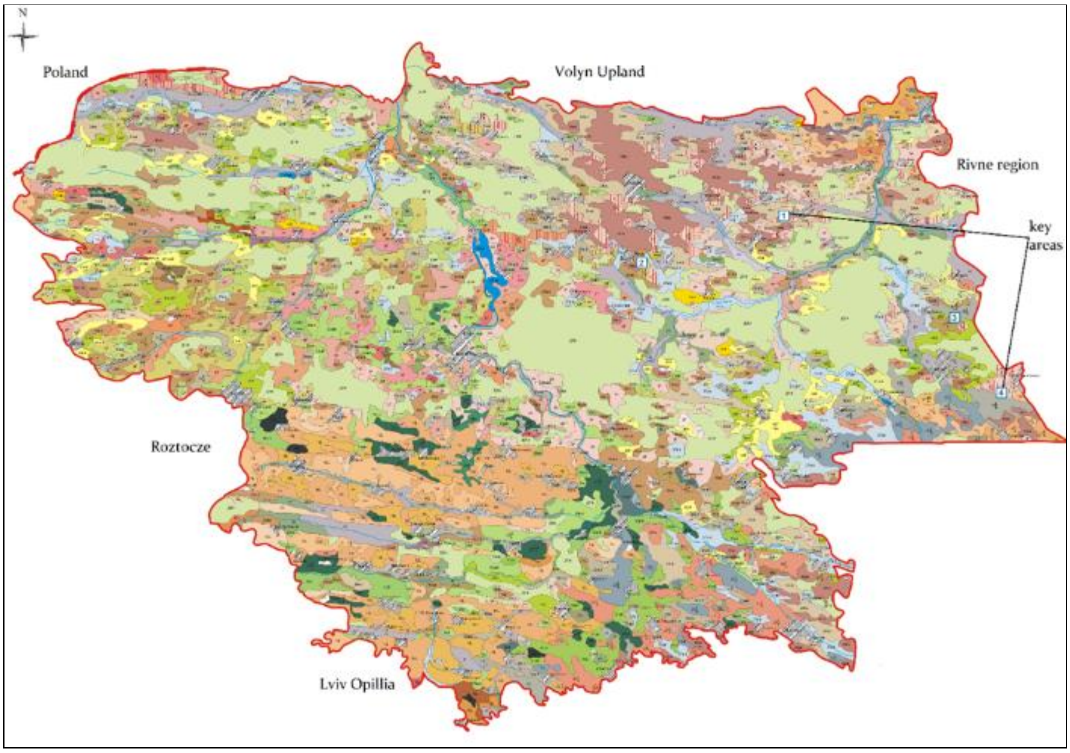

Fig. 2: Soils of Maly Polissya

Results and Discussion

The results of the gross analysis of turf and podzolic soils on glacial deposits, laid by dense carbonate rocks are presented in Tables 1-2. According to the obtained results, we will be able to establish the peculiarities of flow of elementary soil processes and identify changes that have occurred during the process of soil formation. Obligatory to detect changes as part of soil profile is necessary to carry out the analysis of maternal rock (or laid rock, if it is at a slight depth within the profile). As Vynohradov (1949) noted, from a geochemical point of view, a type of soil-forming process can be characterized first of all by the depth of destruction of the mineral substance of soil-forming rock and the final composition of this type of soil. The gross chemical composition of the rocks is crucial in identifying changes in the chemical composition of soils that have occurred during the process of soil formation. Comparison of these data, according to Samoilova (1983), is possible only if the soil is formed from homogeneous rock. From this point of view, it is difficult to characterize the studied soils, because they were formed on alluvial and glacial deposits, which at different depths lie on dense carbonate rocks (cuts 3R,4B,5B). The studied soils in the lower part of the profile are carbonate, and in the cut 7B carbonate is observed in all horizons. According to Fridland (1986), presence of free carbonates in soil, by virtue of existing laws, slows down the destruction of primary minerals, because silicates do not break down until free calcium is removed, which is in the rock.

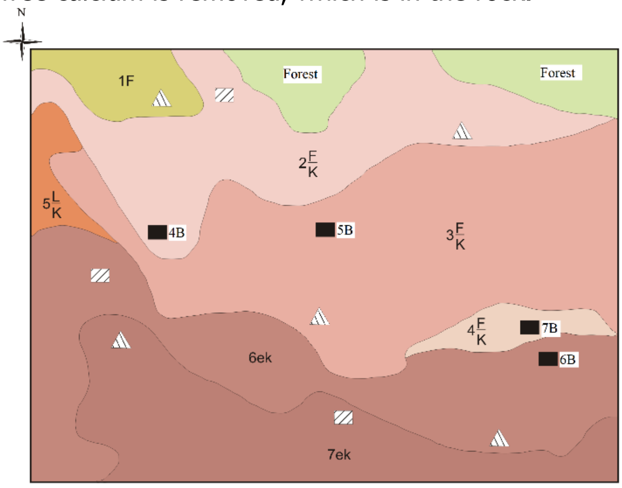

Fig. 3: Investigated soil cuts (4B, 5B, 7B)

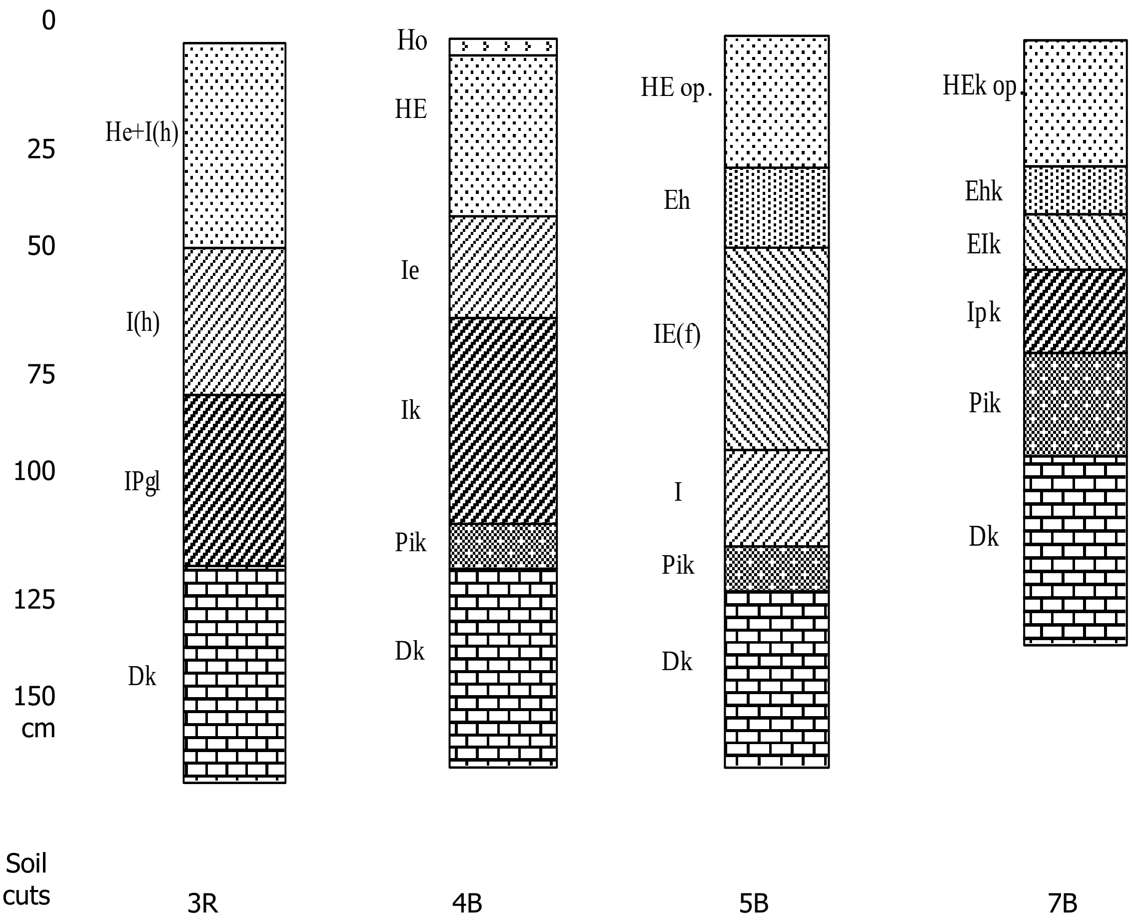

Fig. 4: Structure of soil profiles of sod-podzolic soils on water-glacial deposits lined with dense carbonate rocks

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The question of the evolution of soils formed on dense carbonate rocks was posed for the first time by K. Glinka in his work "Soil formers and soil formation". As noted by the author at the initial stage of soil formation, due to the excess of carbonates in the rock, there will be a delay in the decomposition of organic residues, resulting in the accumulation of humus. At the same time, on the overlying horizon, there is water, which is enriched with carbonic acid, and here there is a brown or yellow loam. And when the moment comes that the humus horizon will be separated from the parent rock by a layer of carbonate-free loam, then the conditions due to which humus accumulated in the soil will disappear (Semashchuk, 2014).

Soil cuts 4B, 5B and 7B are laid within Brodiv alluvial-water-glacial plain when approaching to the Holohoro-Kremenets hills. The relative heights of the territory are 244–263 m. The cuts are laid at a short distance from each other, but, having analyzed the gross analysis data, one can see a sharp difference in the gross chemical composition of the laid rocks of these soils. The laid rocks of the soil cuts 5B and 7B have the same content of silicon oxide (5.61–5.21%) and calcium oxide (50.98-51.10%). The content of one and a half-oxides is also almost the same, and is 1,20–1,56% (Al_2O_3) and 0,58–0,60% (Fe_2O_3) (Tab. 1). The laid rock of the cut 4 B differs sharply – it has a relatively high content of SiO_2 and one and a half oxides due to possible intensive leaching; as a result, there is a residual accumulation of the silicate portion (sand) and the removal of carbonates, which was confirmed by physical and chemical analyzes. In addition, a decrease in calcium and CO_2 oxides was observed (Tab. 1).

Table 1: Gross chemical composition of soils, % by weight of dry soil

№ Soil cuts	Genetic horizons, sampling depth, cm	Loss on ignition, %	Hygroscopic moisture, %	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	K_2O	Na_2O	P_2O_5	Sзar.	TiO_2	CO_2
3R	He+I(h)(0-40)	3,89	1,62	86,97	5,12	0,91	0,02	0,85	0,10	0,07	1,11	0,27	0,08	0,22	0,38	-
	I(h) (59-69)	5,85	5,68	74,12	13,50	2,44	0,01	0,89	0,10	0,05	1,69	0,33	0,06	0,13	0,63	-
	PIgl (92-102)	4,92	3,78	68,27	14,59	4,45	0,02	0,26	0,20	0,04	1,12	0,30	0,06	0,18	0,55	-
	Dk (137-147)	2,80	0,90	31,91	3,98	1,55	0,04	33,26	0,40	0,03	0,66	0,24	0,07	0,26	0,19	24,26
4B	HE (5-40)	1,80	0,59	90,33	4,16	1,14	0,07	0,42	0,10	0,04	1,14	0,52	0,04	0,23	0,27	-
	Ik (85-95)	1,83	1,57	86,45	5,97	2,37	0,05	0,43	0,10	0,02	1,20	0,46	0,04	0,41	0,22	-
	Pik (110-120)	1,14	0,76	77,26	4,85	2,83	0,05	1,94	0,20	0,02	1,15	0,37	0,04	0,40	0,17	
	Dk (120-140)	0,78	0,25	50,12	2,04	1,06	0,03	25,06	0,40	0,02	0,43	0,25	0,04	0,33	0,11	18,93
5B	HE (0-30)	1,75	0,25	92,40	2,74	0,96	0,04	0,35	0,05	0,03	0,86	0,40	0,04	0,27	0,18	-
	IE(f) (55-65)	1,92	2,46	86,25	4,85	3,58	0,03	0,28	0,10	0,03	1,52	0,33	0,05	0,32	0,15	-
	Pik (115-125)	1,28	0,30	81,43	6,23	2,94	0,03	4,48	0,30	0,02	0,40	0,21	0,07	0,35	0,11	-
	Dk (125-150)	0,84	0,35	5,61	1,20	0,58	0,02	50,98	0,61	0,02	0,19	0,12	0,11	0,44	0,07	38,85
7B	Hek op (0-30)	3,03	1,09	87,65	4,53	1,21	0,13	0,85	0,24	0,04	1,11	0,39	0,07	0,22	0,26	-
	Ipk (60-70)	2,60	2,75	82,85	7,87	2,90	0,10	0,58	0,50	0,04	1,31	0,35	0,07	0,29	0,27	-
	Pk(i) (75-85)	3,11	1,87	80,64	6,77	2,12	0,10	1,45	0,50	0,04	1,02	0,27	0,08	0,26	0,15	-
	Dk (100-110)	3,70	0,60	5,21	1,56	0,60	0,60	51,10	0,51	0,03	0,22	0,09	0,08	0,25	0,07	36,52

Table 2: Gross chemical composition of soils,% by weight of calcined carbonate-free soil

№ Soil cuts	Genetic horizons, sampling depth, cm	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	K_2O	Na_2O	P_2O_5	Sзar.	TiO_2	Silicate CaO
3R	He+I(h)(0-40)	90,49	5,33	0,95	0,02	0,89	0,11	0,07	1,15	0,29	0,08	0,23	0,39	-
	I(h) (59-69)	78,73	14,34	2,59	0,01	0,95	0,11	0,06	1,79	0,35	0,07	0,14	0,66	-
	PIgl (92-102)	76,25	13,63	3,25	0,07	2,15	0,24	0,06	1,62	0,45	0,11	0,61	0,57	-
	Dk (137-147)	75,89	9,46	3,70	0,10	5,60	0,96	0,07	1,56	0,58	0,17	0,62	0,46	2,35
4B	HE (5-40)	91,99	4,24	1,16	0,07	0,43	0,10	0,04	1,16	0,53	0,04	0,24	0,28	-
	Ik (85-95)	88,06	6,09	2,41	0,05	0,43	0,10	0,02	1,22	0,47	0,04	0,41	0,23	-
	Pik (110-120)	87,02	5,92	2,95	0,05	1,25	0,50	0,03	0,80	0,46	0,06	0,50	0,22	-
	Dk (120-140)	89,21	3,62	1,89	0,05	1,69	0,71	0,04	0,77	0,45	0,07	0,59	0,20	0,95
5B	HE (0-30)	94,05	2,79	0,98	0,04	0,36	0,05	0,03	0,88	0,41	0,04	0,28	0,18	-
	IE(f) (55-65)	87,48	5,42	4,03	0,03	0,30	0,10	0,03	1,42	0,33	0,04	0,33	0,15	-
	Pik (115-125)	82,85	7,97	3,85	0,03	0,82	0,35	0,26	1,89	0,30	0,05	0,48	0,27	-
	Dk (125-150)	51,84	11,13	5,38	0,19	13,76	5,66	0,19	1,76	1,11	1,02	4,08	0,65	1,49
7B	Hek op (0-30)	90,39	4,67	1,25	0,14	0,88	0,25	0,04	1,15	0,41	0,07	0,23	0,27	0,85
	Ipk (60-70)	85,06	8,08	2,98	0,01	0,59	0,52	0,04	1,34	0,36	0,07	0,30	0,27	0,58
	Pk(i) (75-85)	82,59	7,96	3,25	0,10	3,15	0,77	0,03	1,16	0,30	0,08	0,28	0,30	1,25
	Dk (100-110)	39,32	11,77	4,55	4,55	34,49	3,87	0,23	1,67	0,68	0,61	1,90	0,53	4,57

Table 3: Content of chemical elements,% by weight of calcined carbonate soil

№ Soil cuts	Genetic horizons, sampling depth, cm	Si	Al	Fe	Ca	Mg	Mn	K	Na	P	S	Ti
3R	He+I(h)(0-40)	42,35	2,82	0,35	0,64	0,06	0,06	0,96	0,21	0,04	0,09	0,23
	I(h) (59-69)	36,84	7,58	0,86	0,68	0,06	0,04	1,49	0,26	0,03	0,05	0,40
	PIgl(92-102)	36,12	6,48	0,69	1,41	0,11	0,04	1,33	0,30	0,05	0,03	0,31
	Dk (137-147)	35,52	5,00	0,46	4,00	0,58	0,06	1,29	0,43	0,07	0,25	0,27
4B	HE (5-40)	43,05	2,24	1,41	0,31	0,06	0,03	0,96	0,40	0,02	0,09	0,17
	I (85-95)	41,21	3,22	2,00	0,31	0,06	0,02	1,01	0,35	0,02	0,17	0,14
	Pik(110-120)	41,62	2,47	1,87	1,02	0,12	0,02	0,99	0,34	0,02	0,21	0,13
	Dk (120-140)	41,75	1,92	1,35	1,21	0,43	0,03	0,64	0,33	0,03	0,24	0,12
5B	HE (0-30)	44,02	1,47	1,29	0,26	0,03	0,02	0,73	0,30	0,02	0,11	0,11
	IE(f) (55-65)	42,58	2,54	2,01	0,32	0,07	0,02	1,22	0,27	0,02	0,19	0,11
	Pik(115-125)	41,69	4,02	1,78	1,47	0,31	0,10	1,57	0,45	0,22	0,27	0,21
	Dk (125-150)	24,26	5,89	1,32	9,84	3,41	0,14	1,46	0,83	0,44	1,63	0,39
7B	Hek op (0-30)	42,30	2,47	2,81	0,63	0,15	0,03	0,95	0,30	0,03	0,09	0,16
	Ipk (60-70)	39,81	4,27	2,81	0,42	0,31	0,03	1,11	0,27	0,03	0,12	0,16
	Pk(i)(75-85)	38,48	3,54	2,81	1,56	0,32	0,04	1,28	0,35	0,08	0,44	0,24
	Dk (80-90)	18,40	6,22	2,81	24,66	2,33	0,18	1,39	0,51	0,26	0,76	0,32

3R – turf and slightly podzolic sand and light loam soil on water and glacial deposits, laid by dense carbonate rocks from the depth of 1–1.5 m (under the virgin soil)
4B – turf and slightly podzolic sandy soil on water and glacial deposits, laid by dense carbonate rocks from the depth of 0,5–1 m (under the forest)
5B – turf and slightly podzolic sandy soil on water and glacial deposits, laid by dense carbonate rocks from the depth of 1–1.5 m (under the arable land)
7B – turf and slightly podzolic secondary-carbonized slightly deflated soil on water and glacial deposits, laid by dense carbonate rocks from the depth of 0.5–1 m (under the arable land)

Having observed the results of the gross soil analysis (Tab. 1-2), more destruction of the silicate portion in the cut 4B can be observed, which characterizes turf and slightly podzolic soils on water and glacial deposits, laid from the depth of 0,5–1m by dense carbonate rocks. According to Fridland (1986) the destruction of the mineral part of the soil is more active in acidic conditions where the solutions are not rich in bases. The value of the pH of this soil is 4.7–5.1, which causes more active destruction of the mineral part. This cut is laid under the forest, where forest vegetation determines the concentration of hydrogen ions in the soil solution, that cause an acid reaction of the environment, and calcium is a component of the potential part of the soil and does not normally accumulate in the humid conditions of forest zones, which results in faster destruction of silicates and aluminosilicates.

The turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks are characterized by an increase of calcium oxides in the lower part of the profile. The upper humus-eluvial horizons of the cuts 4B, 5B and 7B are characterized by high content of SiO_2 (90,39–94,05%) and one and a half oxides, among which aluminum oxide prevails, with its maximum amount found in the illuvial horizons (Tab. 1-2). In general, as Andrushchenko (1970) noted, the gross composition of the iluvial horizons is very variable, due to the presence of pseudofibers that have formed at the boundaries between rock layers. In addition, a decrease of SiO_2 content and an increase of alkaline earth oxides have been recorded in the iluvial horizons. The increase of the content of K_2O and Na_2O in the illuvial horizons is due to the decay of primary minerals – feldspar on plagioclase and kalischpat, the basis of which are elements K+ and Na+, which was also noted at the micromorphological level of research. Such division of chemical elements by profile of the turf and podzolic soils on water and glacial deposits, laid by dense carbonate rocks, is characteristic for podzolic soil formation, when, as Karpachevskyi points out, in the upper horizons there is destruction of minerals, except silicon, and the products of destruction (usually Al_2O_3 and Fe_2O_3) are brought into the lower horizons. The accumulation of one and a half oxides in the lower horizons is mainly due to the increase in the content of the sludge fraction (Karpachevskyi, 1960). At the same time, the large amount of silicon which is released during the primary soil-forming process from the aluminosilicate minerals is brought by surface, ground and underground water (Parfenova and Yarylova, 1956).

Having studied the average chemical composition of the main soil types of the European part of the USSR, Kudrin (1963) came to the conclusion that the average 'maternal rock' in its aluminosilicate part is very close to the 'middle soil', and this indicates that losses of individual chemical elements from the soil profile are not observed or are expressed very weakly; it concerns mainly of calcium oxide, judging that its content in "middle soil" is lower than that of "middle maternal rock," then this is due to the processes of soil formation. The conclusions drawn by S.A. Kudrin can also be applied to the soils under consideration.

The content of calcium oxides in the turf and podzolic soils, laid by dense carbonate rocks naturally increases downward to the soil-forming and laid rock. The highest content of this oxide is characterized by the laid rocks of the cuts 7B (51,1%) and 5 B (50,98%). Accordingly, the highest content of silicate calcium has the cut rock 7B (Tab. 2). The content of silicate CaO and CO_2 directly correlates with the carbonate content ($CaCO_3$).

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Oxides of alkaline earth metals are mainly accumulated in the upper humus horizons of all soils, their content decreases down the profile and in some cases increases in soil-forming and laid rocks (Tab. 1-2). According to Parfenova (1956), potassium and phosphorus oxides, although pliable to washing, however, are delayed in the soil and "trapped" in biological circulation, but still partially fixed in the secondary minerals. Sodium and sulfur compounds are typical biological additives, transiting through the tissues of organisms, carried outside the profile. However, changes of these components in the soil profile are not major in soil formation. The content of biologically important components such as P_2O_5, MnO, S, N in the upper horizons of the studied soils is closely related to the accumulation of humus, and is modified under the influence of life activity of microorganisms. So, the nature of alkaline earth metals is mainly biogenic, because soil organic matter is the main source of nitrogen and a reserve of such elements as phosphorus and sulfur. One of the main reasons for the accumulation of a significant amount of humus in soils is the slowing down of the decomposition of organic matter due to excess carbon dioxide and alkaline soil solution (Semaschuk, 2014).

Turf and slightly podzolic soils, laid from the depth of 1–1,5 m by dense carbonate rocks (3R), differs from the soils described above. Note that it was laid within Buho-Styrskoi alluvial-water-glacial plain, the relative heights of which are 238–243 m. In the gross chemical composition of the laid carbonate rock, the content of the SiO_2 is higher, and is 31.91%, which is related to the deeper occurrence of the laid carbonate rock (Table 1). Soil-forming and laid carbonate rocks of Buho-Styrskoi alluvial-water-glacial plain have a significant increase in this oxide with simultaneous relative loss of calcium and magnesium oxides. These results are also consistent with the researches of Kyrylchuk and Pozniak (2004). One and a half oxides in the profile of this soil are divided in the eluvial-illuvial type with a clear expression of the washing horizon in which their number is increased in 2–3 times, compared with the upper horizon. A similar type of division is characterized by the content of calcium, magnesium, potassium, sodium, sulfur and titanium (Table 1-2).

Thus, the gross content of chemical elements in the turf and podzolic soils on water and glacial deposits, laid by dense carbonate rocks, is characterized by the depletion of humus horizons with aluminum and ferum and the enrichment of silicon.

Another important approach of researching the content of chemical elements in soils and soil-forming rocks is the recalculation of the content of oxides to the content of chemical elements. The results of the corresponding recalculation are shown in Table 3. The gross content of chemical elements is characterized by the depletion of humus horizons Al^{3+} and Fe^{2+} and the enrichment of Si^{+}. The results of the gross analysis of the cut 4B, which was laid under the forest, are interesting. Accordingly, these soils with forest bedding gets about twice as many ash elements, among which significant percentage belongs to K, Na, Ca i Mg. This may be the main cause of the turf process in these soils.

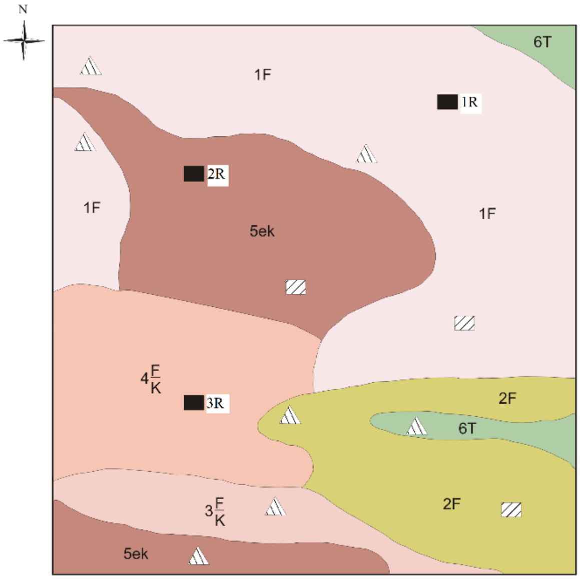

Fig. 4: Investigated soil cut (3R)

It should not be ignored the change of the content of elements of the turf and podzolic soils on water and glacial deposits, laid by dense carbonate rocks, under the influence of agricultural activity. Thus, with the increase of soil cultivation, the aluminum and ferum content decreases, which is especially sharply noticeable when comparing their numbers on arable land (cuts 5B, 7B), under the forest (cut 4B) and on the fallow (old abandoned arable land – cut 3R). In the lower part of the profile (iluvial horizons) aluminum is more, which is due to the lower degree of cultivation of this horizon. The decrease in aluminum and ferum below the iluvial horizon is associated with a decrease in acidity and an increase in the amount of absorbed bases in the carbonate rock.

Conclusion

The data of the gross chemical analysis allowed to establish regularities of the gross composition of the profile of soils, soil-forming and laid rocks and the changes that took place in the process of soil formation. Research has established that the turf and podzolic soils on alluvial and glacial deposits, laid by dense carbonate rocks and their soil-forming rocks are practically two-component: they consist of silica (SiO_2) and one and a half oxides (Al_2O_3 and Fe_2O_3), such division of chemical elements indicates the process of ashes (accumulation of SiO_2 in upper horizons and removal of destruction products down the profile). In the lower genetic horizons, the content of calcium oxides increases. According to the results of the research, the content of oxides in soils can be arranged in such a sequence (in the descending direction): $SiO_2 \rightarrow Al_2O_3 \rightarrow Fe_2O_3 \rightarrow CaO \rightarrow K_2O \rightarrow MgO \rightarrow TiO_2 \rightarrow MnO \rightarrow P_2O_5$. The most modified part of the soil profile is the upper layers; maximum accumulation of one and a half oxides is noted in the illuvial horizon and coincides with the maximum accumulation of silt and clay particles. The gross chemical analysis confirms lithological heterogeneity of soil-forming rocks and their influence on soil-forming processes. Underlayment of sod-podzolic soils with carbonate rocks affects the increase of humus content in humus-eluvial horizons (1.5–3%) and growth to 80–90% of the degree of base saturation. This in turn affects all agrochemical parameters of these soils. In the territory of Maly Polissya, the studied soils in terms of natural fertility are in second place after sod-carbonate soils (rendzin), so they are actively used in agriculture. There is a change in the gross chemical composition of soils in intensive agricultural activities, at which content of aluminum and ferum in profile is reduced, processes of internal soil leaching are faster.

The practical significance of the study. Gross chemical analysis confirmed the lithological heterogeneity of soil-forming and laid rocks and their influence on the chemical composition of genetic horizons. The results of the gross analysis allowed to trace the chemical composition of the mineral part of the soil. It has been established that the study of the gross composition of soils (in particular, the process of decomposition of aluminosilicates and silicates) should be in one line with the study of such important soil formation processes as turf, podzolic, gley etc.

Given the large areas of distribution areas of sod-podzolic soils, underlain by dense carbonate rocks, within the Ukrainian Polissya (approximately 210 thousand hectares), the results of our research can be used to further study their genesis, evolution and properties. Also our research is important in terms of analysis of agricultural land. In addition, the results of comprehensive research will improve agricultural production, help calculate the value of these soils.

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On the linear trends of a water discharge data under temporal variation. Case study: the upper sector of the Buzău river (Romania)

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Abstract

The aim of this paper is to provide a statistic overview of the hydrological impact of the Siriu Dam on the Buzau River (Romania), taking into account the temporal variations. Our case study uses the daily mean discharges of the Buzau River (1st of January 1955 to 31st of December 2010), registered at Nehoiu hydrometric station. The building of the Siriu Dam in 1984 required the division of the study interval into two sub-periods, each being analyzed annually and seasonally, on the series themselves or on the pre-whitened ones when prior required. The existence of a linear trend on different periods and sub-periods has been studied by using the Mann-Kendall and Seasonal Mann-Kendall tests. In the case of the existence of a linear trend, the slopes have been calculated with Sen's Slope Estimator. The stationarity has been studied by using the Dickey-Fuller and Kwiatkowski–Phillips–Schmidt–Shin tests. According to our preliminary results, the stationarity in trend after the dam's construction, respectively increasing linear trends for almost all the data series and subseries was observed. The trend and stationarity outcomes proved that the Siriu Reservoir has a good impact on the homogeneity of the Buzau River's discharge and the increasing trends are related to human activity impact coupled with climate change/variability.

Keywords: *Buzau river, discharge, linear trend, Siriu Dam, seasonality, stationarity*

Rezumat. În legătură cu tendințele liniare ale debitelor râurilor în timp. Studiu de caz: sectorul superior al râului Buzău (România)

Acest articol dorește să ofere o imagine dinamică de ansamblu, din punct de vedere statistico-hidrologic, asupra impactului barajului Siriu asupra râului Buzău (România). Studiul de caz folosește debitele zilnice ale râului Buzău, colectate la stația hidrometrică Nehoiu în perioada 1 ianuarie 1955 - 31 decembrie 2010. Construcția barajului Siriu în 1984 a determinat împărțirea intervalului în două sub-perioade care să fie analizate anual și sezonal, pe seriile de date inițiale sau pe cele procesate, când este cazul. Existența tendinței liniare pe diferite perioade și sub-perioade a fost studiată cu ajutorul testelor Mann-Kendall și Mann-Kendall Sezonal. În cazul existenței trendului linear, panta a fost calculată cu Evaluatorul de pantă Sen. Staționaritatea a fost studiată cu ajutorul testelor Dickey-Fuller și Kwiatkowski–Phillips–Schmidt–Shin. Conform rezultatelor obținute, a fost observată staționaritatea în tendință după construcția barajului, respectiv liniar crescătoare, pe aproape toate seriile și sub-seriile de date. Rezultatele referitoare la tendință și staționaritate demonstrează impactul pozitiv al construcției rezervorului lacului Siriu asupra omogenității debitului râului Buzău și tendințele crescătoare sunt corelate cu activitatea umană coroborată cu schimbările climatice.

Cuvinte-cheie: *râul Buzău, debit, tendință liniară, barajul Siriu, sezonalitate, staționaritate*

Introduction

Stationarity and trend studies offer a general overview of the river's discharge values, an image that helps in the implementation of adequate measures to diminish the effects of natural disasters.

Long term analysis of rivers' discharges reveals the effects of climate change, precipitation regime, human activity, exploitation of the water resources on the environment and helps in the adjustment of the consequences and implementation on management plans for better use. These studies have been carried out in Europe (Wang, Van Gelder, & Vrijling, 2005), Canada (Zhang et al., 2001), United States (McCabe & Wolock, 2002). In Romania, there have been studied trends at the country-scale (Birsan et al., 2014), or variability at local scale (Stefann et al., 2004).

Various studies based on Indicators of Hydrologic Alteration (IHA) of Richter, Baumgartner, Powell & Braun (1996), often used to assess dam construction on streamflow by means of comparing pre- and post-dam hydrographic characteristics. These studies have suggested that the natural flow of rivers has been substantially altered through dam construction, which resulted, for example, in reduced or increased flows, altered seasonality of flows, changed frequency, duration, and timing of flow events (Kendall, 1975).

Minea and Bărbulescu (2014) investigated the impact of the construction of Siriu dam on the Buzău river (i.e. 1955-1984 vs 1985-2010) and found the following aspects: i) the flow during the month of January increased by 30.2%; ii) significant changes occurred during the May-July period, when the flow decreased by 13–25%; iii) flow intensity was affected, e.g. extreme values registered the most significant decrement in the post-impact period: the (90-day max)'s minimum – from 28.6 to 16.4 m3/s, and the (90-day max)'s maximum – from 92.6 to 69.8 m3/s, and, in contradiction, the maximum of 90 - day minimum increased with 45.8%.

Žibienė, Žibas & Blažaitytė (2015) analyzed the impact on the Šušvė river (Lithuania) in relation to the Angiriai dam (1940-1979 vs 1981-2010) and found that the flow of every month, except for those of April, August and September, have increased; the change in the increased flows variated from 15.70% to 153.48%, while that of the decreased flows variated from 28.8 % to 35.67%; the maximum 1-day, 3-day, 7-day, and 30-day flows decreased by 25–32% and the minimum 30-day flow decreased by 8.86 %.

Recently, do Vasco, Netto & da Silva (2019) analyzed changes in the flow regime before and after the construction of the Xingó reservoir on the São Francisco river (1979–1994 vs 1995–2013) from Brazil and detected reduction values of 31%, 21% and 35% for the average, the minimum and the maximum flows of the study periods, indicating that the flow of the São Francisco river declined by more than thirty percent in the last 18 years.

The Buzău river has also been a topic for other studies, which analyzed the monthly discharges (Mocanu-Vargancsik & Barbulescu, 2018), the maximum flow (Minea & Chendeș, 2013), the impact of the Siriu Dam and the characteristics before and after its construction (Minea & Barbulescu, 2014; Barbulescu, 2017). Various mathematical models have been used in modeling and forecasting a river discharge: from classical ones (Mocanu-Vargancsik & Barbulescu, 2018), to artificial intelligence (Postolache et al., 2010).

In this context, we observe that many studies evaluate the hydrological behavior, the impact of dam construction on hydrological regimes etc., but it has not been clarified yet which is the stationarity of a water discharge data under temporal variations. The aim of this paper is to provide a statistic overview on water discharge of the Buzău River (Romania), downstream the Siriu Dam, under temporal variations. At the same time, the focus was on trend and stationarity from the annually and seasonally scale.

Study area

Positioned in the external region of the Curvature Carpathians, the upper part of Buzău river catchment covers an area of 1,567 sq km. It lies at an average altitude of 1,043 m, between Lăcăuţi Peak (1,777 m a.s.l.) and Nehoiu hydrometric station - hs (385 m) (National Institute of Hydrology and Water Management Bucharest, 2013). The main tributaries of the Buzău river are the Dalgiu, the Lădăuți, the Crasna, the Siriul Mare, and the Bâsca (the most important) (Fig. 1.).

In 1985, the Siriu Dam started operating on the Buzău river, upstream Nehoiu h.s., so the station records the discharges after the streamflow has been modified by the passing through the dam. This station is located on the Buzău river, 45°25′29″ lat., 26°18′27" long., the multi-annual mean flow being 21.9 m³/s, and the specific mean being 17 l/s.km² (Fig. 1).

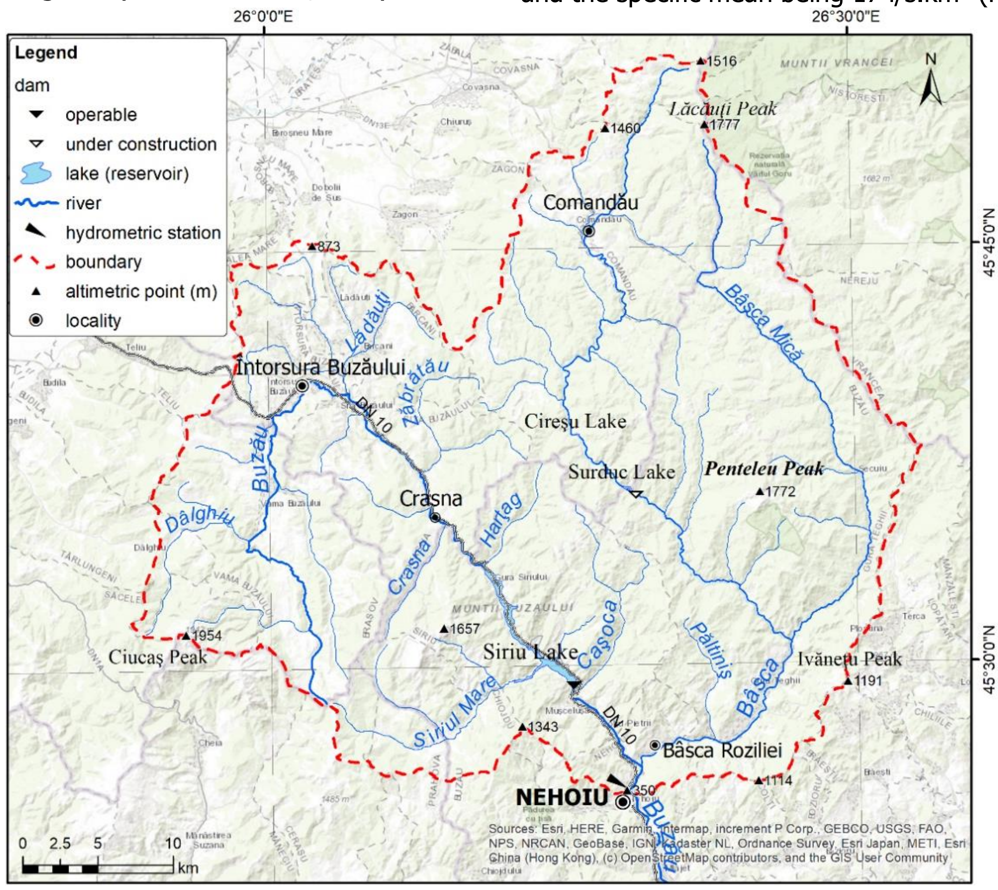

Fig. 1: The upper part of the Buzău river catchment

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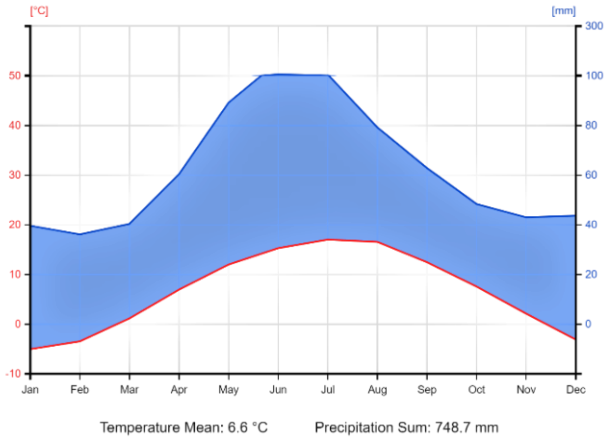
The climate is in the temperate-continental class "dbf". The Föhn phenomena moderate the characteristic parameters of climatic elements (e.g. reduced precipitation amounts and moderate air temperature values).

The average multiannual temperature in the study area, at high elevation, ranges among 1.2°C at Lăcăuţi (1961-2006), 2.4°C at Penteleu (1988-2007), and 6.6°C at Întorsura Buzăului and 8.7°C at Nehoiu (1955-2010). According to Costache, average multiannual precipitation values range between 595 and 961 mm/year. At both meteorological stations, summer is the wettest season, with 45% of the yearly amount of precipitation, followed by spring and autumn with comparable amounts (23% and 18% respectively), whilst winter is the driest, with 14% of the total annual amount of precipitation.

The pluviometric regime has a summer (June and July) torrential character, being favorable to flow occurrences, e.g., 105.7 mm in June at Întorsura Buzăului and 86.1 mm at Nehoiu (Fig. 2.). This study employs graphics related to precipitation and temperature (1955-2010), which were provided by https://climatecharts.net/ and the CRU at the University of East Anglia.



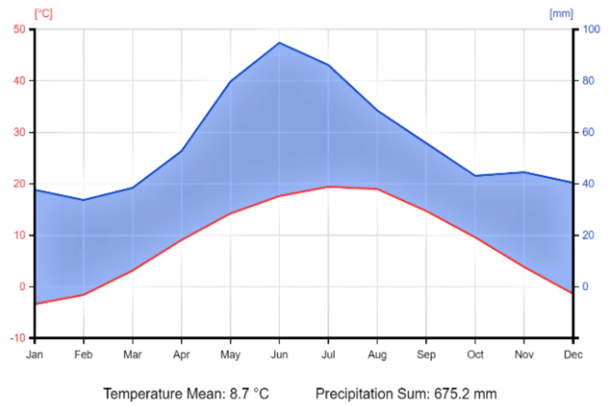


Fig. 2: Monthly average temperature and precipitation (1955-2010) at Întorsura Buzăului (up) and Nehoiu (down)

Data and methodology

Hydrological Data

The hydrologic data for the study spans on 56 years (from the 1st of January 1955 up to the 31st of December 2010) and consists of the daily mean water discharges registered at Nehoiu h.s., data provided by the National Institute of Hydrology and Water Management Bucharest, Romania. For a complete image, the time series is daily, monthly, seasonally, and annually investigated for trend and stationarity, at a global level and on the time subperiods imposed by the starting year of operation at the Siriu Dam. This date is late in 1984, so the subperiods are 1955-1984 and 1985-2010.

Trend estimation

One of the worldwide non-parametric methods for trend detection is Mann-Kendall (MK), which tests the null hypothesis of a non-existence trend against the alternative hypothesis that assumes existence. Counting the data entries in chronological order, the test statistic S is computed by Mann's formula (Mann, 1945):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \quad (1)$$

where $sign(x_j - x_i) = \begin{cases} 1 \; if \; x_j - x_i > 0 \\ 0 \; if \; x_j - x_i = 0 \\ -1 \; if \; x_j - x_i < 0 \end{cases}$.

For n ≥10, the statistic S forms an approximate normal distribution with the mean zero E(S)=0 and the variance given by:

$$\sigma^2 = \frac{1}{18}[n(n-1)(2n+5) - \sum t_i(t_i-1)(2t_i+5)] \quad (2)$$

where t_i denotes the number of ties to the extent i and the terms in the sum exist only the data series contains tied values. The standard test statistic z_S calculated as:

$$z_S = \begin{cases} \frac{S-1}{\sigma} \; if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S+1}{\sigma} \; if \; S < 0 \end{cases} \quad (3)$$

helps to draw the conclusion of the existence of a monotonic trend if $|z_S| > z_{\alpha/2}$.

The Seasonal Mann-Kendall test (SMK) ascertains the existence of a monotonic trend in seasonal data. SMK works as the MK test for each season (Hirsch, Slack, & Smith, 1982). For the same season, the individual mean and variance are added up and then applied (3) to find the test statistic. The outcomes of the Mann-Kendall test are affected by autocorrelation. More exactly, in the case of a positive autocorrelation, the resulting trend of the time series becomes significant random more often than the level of significance (Kulkami & Von Storch, 1995).

To eliminate this shortcoming, before applying the MK test, the "pre-whitening" has to be performed. The procedure implies the computation of lag-1 serial correlation. If it is smaller than 0.1, the MK test is applied to the series itself, otherwise, MK is applied to the new series. Each term of the new series is obtained by subtracting from the old series the term of the previous one multiplied by the lag-1, procedure starting with the second term (Storch & Navarra, 1999).

Sen's Slope Estimator

It is used to find the slope of a linear trend, if any, and works jointly with the MK trend test (Sen, 1968). The procedures assume that the estimation of the real slope is the median of all values of the paired data:

$$m_i = \frac{x_j - x_k}{j-k}, i = 1,2,\dots,n, j > k \quad (4)$$

The method is robust, insensitive to outliers, more competitive than the linear regression for skewed and heteroskedastic data (Wilcox, 2010).

Stationarity

The study of stationarity helps to find out whether the mean value or the variance of a series undergoes changes in time. Actually, traditional methods in time series analysis and implementation of mathematical models require some type of stationarity. Moreover, non-stationarity can bring up some mechanisms, otherwise difficult to detect. In our case study, the stationarity has been tested annually and seasonally by using the augmented Dickey-Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test.

The ADF test is an extension of the Dickey-Fuller test from 1979 (Dickey & Fuller, 1979), conducted through Ordinary Least Square (OLS) method that includes an AR (1):

$$x_t = \rho x_{t-1} + \varepsilon_t, t = \overline{1,N} \quad (5)$$

where $(x_t)_{t-\overline{1,N}}$ is the time series, $x_t = 0, |\rho| \leq 1$, and $(\varepsilon_t)_{t-\overline{1,N}\ t}$is the sequence of independent identically (iid) distributed random variables with mean zero and finite variance σ^2 called white noise (WN). The null hypothesis consists in $\rho = 1$, meaning the process has a unit root and is non-stationary, known as a random walk. The alternative hypothesis states that $|\rho| < 1$, equivalent the process is stationary. The test t-statistic is

$$t = \frac{\hat{\rho} - 1}{SE(\hat{\rho})} \quad (6)$$

where $\hat{\rho} = (\sum_{t=1}^{N} x_{t-1}^2)^{-1} \sum_{t=1}^{N} x_t x_{t-1}$ is OLS estimation for the coefficient ρ and $SE(\hat{\rho})$ is its standard error. Under the null hypothesis, Dickey and Fuller (Dickey & Fuller, 1979) obtained the limiting distribution of the statistic with the percentiles presented in (Fuller, 1976). If *t* is "too negative", the null hypothesis is rejected. It has been demonstrated that this procedure remains valid asymptotically for a general ARIMA (*p,1,q*) process with unknown *p* and *q* orders (Hamilton, 1994).

It is to be noticed that under the same null and alternative hypotheses, the test works for the random walk with drift and random walk with drift and time trend with different regression testing and different distribution of the test statistics (Dickey & Fuller, 1979; Guilkey & Schmidt, 1991).

KPSS test. We assume that our time series can be decomposed into a sum (Kulkami & Von Storch, 1995) of the deterministic trend, a random walk, and a stationary error:

$$x_t = \beta t + r_t + \varepsilon_t,\ t = \overline{1,N} \quad (7)$$

where: r_t is the random walk, i.e., $r_t = r_{t-1} + u_t$, u_t is i.i.d. (0, ${\sigma_u}^2$), βt is the deterministic trend and ε_t is a stationary error. For testing the stationarity in trend, the null hypothesis is ${\sigma_u}^2 = 0$, the meaning of the series is stationary around a deterministic trend. The alternative hypothesis is positive ${\sigma_u}^2$. In the case of testing the stationarity in level, the null hypothesis becomes $\beta = 0$. For trend stationarity, the residuals are $e_t = \varepsilon_t$, while for the level trend the residuals come only from an intercept, so $e_t = x_t - \bar{x}$. Let be $S_t = \sum_{j=1}^{t} e_j$ the partial sum of the errors and σ^2 the "long-run variance" of e_t, defined as $\sigma^2 = \lim_{N\to\infty} N^{-1} E[S_N^2]$, mean is the significance of E. A consistent estimator of σ^2 is given by:

$$\hat{\sigma}^2(p) = \frac{1}{N}\sum_{t=1}^{N} e_t^2 + \frac{2}{N}\sum_{j=1}^{p} w_j(p) \sum_{t=j+1}^{N} e_t e_{t-j} \quad (8)$$

where p is the truncated lag, $w_j(p)$ is an optional weighting function that corresponds to the choice of a spectral window, e.g. Bartlett window $w_j(p) = 1 - j/(p+1)$. The statistic test is

$$KPSS = N^{-2} \sum_{t=1}^{N} S_t^2 / \hat{\sigma}^2(p) \quad (9)$$

The KPSS statistics follow an asymptotic distribution in which upper tail values are given in (Kwiatkowskiv et al., 1992).

Results

The autocorrelation lag-1 has been performed for the monthly, seasonal and annual series, and for the subseries obtained by the Siriu Dam operation year. As per the XLStats findings, its construction increased the autocorrelation for all the series. Only for the Annual, the autocorrelation has become moderate (Table 1).

The applicability of the MK has been verified for winter, spring and fall, while the other series needed pre-whitening. The monthly, summer and 1955-1984

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annual subseries, as well as all 1985-2010 subseries, except Summer, also required pre-whitening.

Table 1 ACF values for streamflow series

Series	Lag-1	Lag-1 1955-1984	Lag-1 1985-2010
Monthly	0.495	0.462	0.537
Winter	0.076	-0.203	0.433
Spring	0.018	-0.117	0.124
Summer	0.186	0.182	-0.106
Fall	-0.049	-0.162	0.231
Annual	0.292	0.407	0.148

Summer displays a significantly decreasing trend at a 10% level of significance (Sen's slope of -0.186). Its graphical representation is shown in Fig. 3.

The weak negative linear trend confirms the good influence of the Siriu Dam on smoothing the streamflow and gives evidence that few flooding summer episodes don't have a serious impact on the mean discharges.

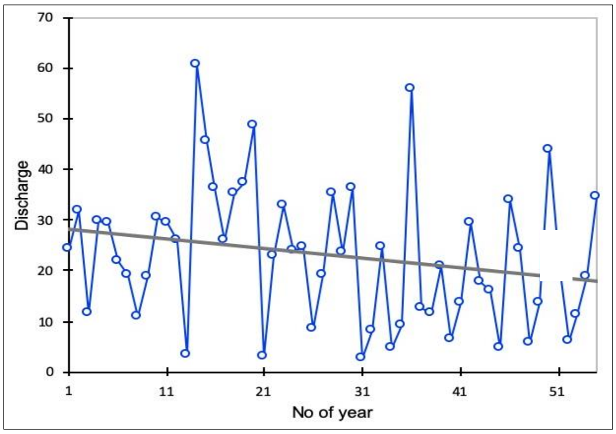

Fig. 3: Summer 1985-2010 pre-whited series with the trend

The subseries has significant trends only for 1985-2010 monthly, winter, fall and annual levels (Table 2).

Table 2 Significant MK test results and corresponding Sen's slopes for pre-whitened 1985-2010 series

Series	Conclusion
Monthly	Increasing trend. Slope=0.015
Winter	Increasing trend. Slope=0.330
Fall	Increasing trend. Slope=0.294
Annual	Increasing trend. Slope=0.419

The mean streamflow discharge for the monthly series has a slope almost equal to zero, so it is almost constant, while the winter, fall, and annual series display increasing trends (Fig. 4).

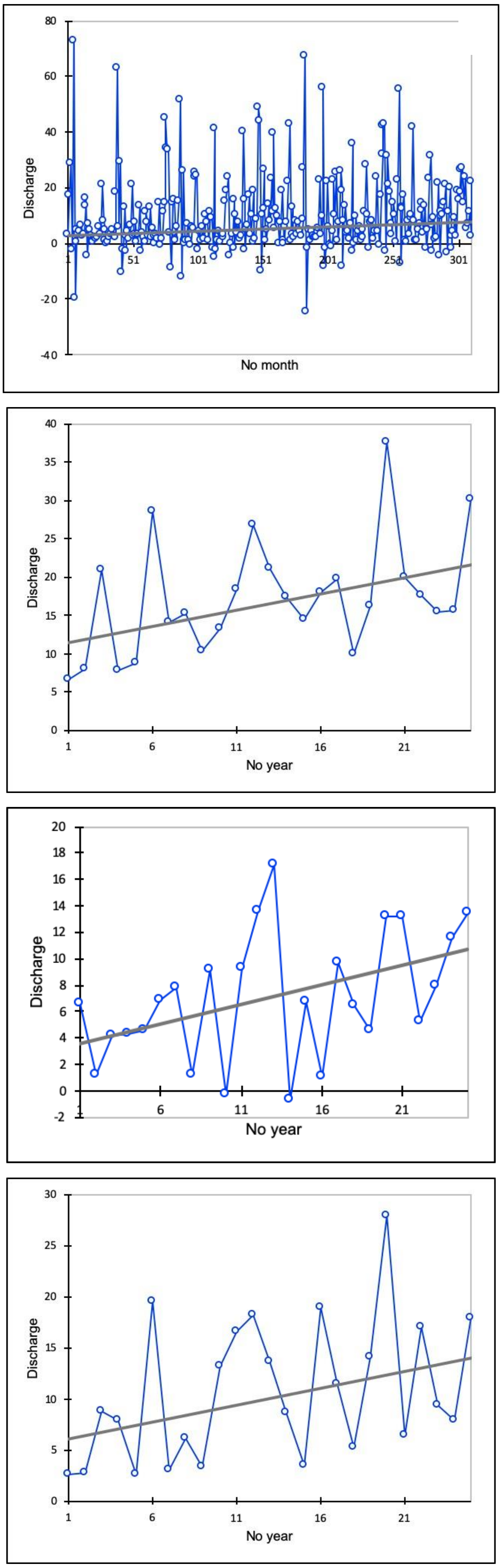

Fig. 4: Pre-whited series with significant trend 1985-2010 subseries a) Monthly b) Annual c) Winter d) Fall

The increase has occurred slowly; thus, it couldn't be detected at a smaller scale, but it has become evident at a larger one. The annual growth is significant (slope=0.419), so globally speaking, the mean streamflow increases. For both ADF and KPSS tests, the choice for the lag length is very important, as it affects the power of the test. This shortcoming has been adjusted by Schwert (Schwert, 1988) and Harris (Harris, 1992). Their proposed formula is $p = \left[x\left(\frac{N}{100}\right)^{1/4}\right]$, with $x = 4;\ 12$, where $[x]$ represents the integer part. The stationarity ADF test results can be seen in Table 3 and those of KPSS test in Table 4. The tests have been performed at a 5% significance level. The lag length has been chosen according to the smallest tau-value/p-value. According to the results of our study, the entire streamflow processes on daily, monthly and annual timescale are basically non-stationary, lacking in trend (Table 3 and Table 4). The stationarity has occurred after 1985 (Table 5).

Table 3 ADF stationarity test results for streamflow series

Series	Lag	P-value	Test conclusion
Daily	15	<0.0001	No unit root. The series is stationary.
Monthly	6	<0.0001	
Winter	3	0.093	There is a unit root. The series is non-stationary.
Spring	3	0.093	
Summer	3	0.127	
Fall	3	0.262	
Annual	1	0.007	No unit root. The series is stationary.

Table 4 KPSS trend and level stationarity test results for streamflow series

Series	Lag	Trend P-value	Level P-value	Test conclusion
Daily	15	<0.0001	<0.0001	The series is non stationary in trend and non-stationary in level
Monthly	6	0.002	0.120	
Winter	3	0.060	0.413	The series is stationary in trend and level.
Spring	3	0.241	0.236	
Summer	3	0.200	0.016	The series is stationary in trend and non-stationary in level.
Fall	3	0.119	0.428	The series is stationary in trend and level.
Annual	1	0.023	0.291	The series is non-stationary in trend, but stationary in level.

Table 5 KPSS trend and level stationarity test results for streamflow 1985-2010 series

Series	Lag	Trend P-value	Level P-value	Test conclusion
Daily	12	<0.0001	<0.0001	The series non-stationary in trend and non-stationary in level.
Monthly	5	0.318	0.000	
Winter	2	0.568	0.001	The series is stationary in trend, but non-stationary in level.
Spring	2	0.776	0.058	The series is stationary in trend and level.
Summer	2	0.973	0.950	
Fall	2	0.544	0.006	The series is stationary in trend, but non stationary in level.
Annual	1	0.935	0.031	

Conclusions

The streamflow process on the Buzău river at Nehoiu h.s. has been investigated for trend and stationarity propose. The Mann-Kendall and Seasonal Mann-Kendall tests have been applied on the series themselves or on the pre-whitened ones. The slopes for the linear trends have been calculated by using Sen's Slope Estimator.

Our results proved that after 1985, the streamflow has increasing trends at some seasonal, annual and monthly scales. The stationarity has been investigated by using ADF and KPSS tests and proved, with no exceptions, that after 1985 the streamflow series has become stationary in trend.

The daily series can pass neither the stationarity level nor the trend stationarity test at a 1% significance level. The results imply that the streamflow processes on the Buzău river have been globally impacted by the Siriu Dam.

Probably, the non-stationarity in trend and level after 1985 is more likely to be caused by human interventions and periods of flood and draught. The exploitation of the Siriu Dam, of its reservoir for water necessities, such as to produce electricity, also induces variations that may result in significant discharges at a short time scale.

The statistically non-significant increasing slopes of the seasonal series convey that the flood prone nature of this location doesn't have a significant impact on the Buzău river discharge. In this regard, Retegan, Barbuc & Petre (2016), indicate in their research that the impact of the Siriu Reservoir upon the water discharge of the Buzău river is very low, the alteration of the natural conditions being insignificant (approximately 1%). At the same time, the annual series displays a statistically significant upward slope that suggests an important influence on the streamflow regime in this location. This statistically significant aspect may be due to climate change/variability. The studies showed that from 1901 to 2000, the average temperature has globally increased by $0.61 \pm 0.18°C$, while for the northern hemisphere it increased by $0.71 \pm 0.31°C$ (Cooper, Houghton, McCarthy, & Metz, 2002). To climate change can be added other factors such as topography, land use/land cover, anthropic intervention (e.g., deforestation). Moreover, it is known that, in the rainfall-runoff behavior, the key role is played by land cover, while in the flood event the soil and topography play this role.

We consider that during seasons, there are specific phenomena that disturb the streamflow process: heavy snows in winter, snow-melting in spring, short, heavy rains that produce floods or periods of drought in spring, summer, and fall. Therefore, we appreciate that our work provides a useful baseline for additional work (e.g., a detailed analysis of the relationship runoff-genetic factor, precipitation), and the authors did not pretend to find exhaustive clarification.

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Estimation of changes in land surface temperature using multi-temporal Landsat data of Ghaziabad District, India

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Abstract

The rapid growth in urban population in India is seen to create an essential for the development of more urban infrastructures. Land surface temperature (LST) is a significant factor in many areas like climate change, urban land use/land cover (LULC), heat balance studies and a key input for climate models. The main objective of this paper is to examine multi-temporal land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) changes of Gaziabad district in Uttar Pradesh, India using LANDSAT satellite data in GIS platform. To compute the changes and relationship between Land Surface Temperature (LST) and Land Use Land Cover (LULC), Landsat LST data for the months of September of year 2000, 2011 and 2018 were used in this study. The LST has been estimated with respect to Normalized Difference Vegetation Index (NDVI) values determined from the Red and Near Infrared bands. The Land Surface Emissivity (LSE) is retrieved directly from the Thermal Infrared bands. The present study focuses on ArcGIS Raster functions and Raster calculation using the LANDSAT in September, thermal Bands (10, 11 & 6). The output of this paper shows that the surface temperature was high in the barren and built up area whereas it is comparatively low in the thick vegetation and agriculture land. It is also recommended that in order to reduce the land surface temperature of urban areas, sustainable urban planning strategies that include increasing the vegetated areas and embracing other green initiatives such as urban forestry should be adopted.

Keywords: *Remote sensing, GIS, Land Surface Temperature (LST), Land Surface Emissivity (LSE), Normalized Difference Vegetation Index (NDVI).*

Rezumat. O estimare a schimbărilor de temperatură a suprafeței terenului utilizând date Landsat multi-temporale din districtul Ghaziabad, India

Creșterea rapidă a populației urbane din India creează un element esențial pentru dezvoltarea mai multor infrastructuri urbane. Temperatura suprafeței terenului (LST) este un factor semnificativ în multe domenii precum schimbările climatice, utilizarea terenurilor urbane/acoperirea terenului (LULC), studiile privind echilibrul termic și un aport cheie pentru modelele climatice. Obiectivul principal al acestei lucrări este examinarea multi-temporală a temperaturii suprafeței terenului (LST) și a modificărilor Indexului de vegetație cu diferențe normalizate (NDVI) din districtul Gaziabad din Uttar Pradesh, India, folosind datele satelitului LANDSAT în platforma GIS. Pentru a calcula schimbările și relația dintre temperatura suprafeței terenului (LST) și utilizarea/acoperirea terenului (LULC), datele Landsat LST pe pentru lunile septembrie ale anului 2000, 2011 și 2018 au fost utilizate în acest studiu. LST a fost estimat în ceea ce privește valorile Indexului de vegetație cu diferențe normalizate (NDVI), determinate din benzile infraroșii și roșii. Emisivitatea suprafeței terestre (LSE) este preluată direct din benzile infraroșu termic. Studiul de față se concentrează pe funcțiile ArcGIS Raster și calculul Raster folosind LANDSAT din septembrie, benzi termice (10, 11 și 6). Rezultatul acestei lucrări arată că temperatura suprafeței a fost ridicată în zona deschisă și construită, în timp ce este relativ scăzută în zonele cu vegetație bogată și terenuri agricole. De asemenea, se recomandă ca, pentru a reduce temperatura suprafeței terenurilor din zonele urbane, să fie adoptate strategii de planificare urbană durabilă care includ densificarea zonelor de vegetație și adoptarea altor inițiative verzi, cum ar fi silvicultura urbană.

Cuvinte-cheie: *teledetecție, SIG, Temperatura suprafeței terenului (LST), Emisivitatea suprafeței terestre (LSE), Indicele de vegetație cu diferențe normalizate (NDVI).*

Introduction

Urbanization is an extreme factor of Land Use and Land Cover Change (LULC) that occurs when the natural vegetation of an area is replaced with buildings and roads, which tend to have significantly higher air temperatures than their rural surroundings. This phenomenon is described by the term Urban Heat Island (UHI) (Oke, 1982; Gartland, 2008).

Rapid changes in the land use and land cover of a region have become a major environmental concern in recent times. This has led to unsustainable development with the reduction of green spaces in the urban area and changes in local climate and formation of urban heat islands (UHIs). The UHI result defines the observation that temperatures in any urban are often higher than in its rural area (Tomlinson et al., 2010; Schwarz et al., 2012).

The identification and characterization of UHI is typically based on Land surface temperature (LST) that varies spatially, due to the nonhomogeneity of land surface cover and other atmospheric factors (Zhibin et al., 2015). LST is a key parameter in land surface processes, not only acting as an indicator of climate change, but also due to its control of the upward terrestrial radiation, and consequently, the control of the surface sensible and latent heat flux exchange with the atmosphere (Aires, 2001; Sun and Pinker 2003). It is a key area of urban climate research (Voog and Oke, 2003; Pu et al., 2006; Niclos et al., 2009). The relationship between the LST and urban landscape patterns is the focus of many studies of the UHI effect (Dousset and Gourmelon, 2003; Weng et.al., 2004). Obtaining surface temperatures and using them in different analyses is significant to analyse the problem related with the environment (Orhan et al. 2014). Therefore, the impacts of the changes of continuous urban features and vegetation, on the variability of the urban thermal environment in different seasons needs to be examined in order to mitigate the UHI impact and adapt effectively to climate change (Zhang et al., 2017).

The UHI effect can be attributed to many physical differences between urban and rural areas, including absorption of sunlight, increased heat storage of manmade surfaces, obstruction of re-radiation by buildings, absence of plant transpiration, differences in air circulation, and other phenomena (Oke, 1982). There are two main reasons for this elevated heating in built-up areas i.e. urban materials are often water resistant, so evapotranspiration does not take place. Furthermore, impervious surfaces absorb and retain more of the sun's heat rather than natural vegetation does (Gartland, 2008) due to the darker color. Therefore, most of the world's cities experience higher temperatures in their urban core than in the surrounding sub-urban and rural areas (Gartland, 2004; Schwarz et al., 2012).

Impermeable surface areas (ISAs) i.e. built-up area and vegetation are two majors urban LULC types. Assessing the spatial distribution of impermeable surface areas and vegetation is critical for analyzing urban landscape patterns and their impact on the thermal environment (Zhang et al., 2017). The thermal comfort of city inhabitants is directly (Harlan et al., Lafortezza et al., 2009) and indirectly (Stafoggia et al., 2008) affected by UHIs. UHIs not only influence water use and biodiversity change but also contribute to human discomfort by increasing the cause of mortality and disease (Basara et al., 2010).

Remote sensing satellite data provides valuable inputs for understanding the spatio-temporal LULC in relation to the basic physical properties in terms of the surface radiance and emissivity data (Mishra and Rai, 2016; Mishra et al., 2016; Vishwakarma et al., 2016; Singh and Rai, 2017). It is an extremely useful for understanding the spatio-temporal land cover change in relation to the basic physical properties in terms of the surface radiance and emissivity data. Since the 1970s, satellite-derived (such as Landsat Thematic Mapper-TM) surface temperature data have been utilized for regional climate analyses on different scale (Amiri et al., 2009; Chander and Groeneveld, 2009; Chander et al., 2009). Nowadays thermal remote sensing has been used over urban areas to assess the urban heat island and climatic conditions. Until now, there are many studies concerning urban heat island (UHI) on regional and global climate (Rajasekar and Weng, 2009; Li et al., 2009; Li et al., 2012; Weng, 2009; Weng et al., 2004; Quattrochi and Luvall, 1999). Many studies had been made to observe the consequence of the vegetation on the LST, which showed that there was a negative correlation between LST and urban vegetation abundance measured by Normal Difference Vegetation Index (NDVI) and the percent cover of urban vegetation (Weng et al., 2004; Chen et al., 2006; Mallik et al., 2008; Senanayake et al., 2013). To analyse the thermal condition of earth features by remote sensing data, it is essential to find the relationship between the surface temperature, surrounding topography and LULC (Weng, 2009).

In India, studies concentrating on the relationship between urban vegetation and LST using Landsat TM, ETM+ and OLI imagery are rather limited. Hence through this study, it was examined the relationship between urban vegetation and LST of Ghaziabad district, India. Specific objectives of this study were: i) to calculate LST and analyses of the temporal changes in land surface temperature from 1991 to 2018; ii) to assess urban vegetation abundance, Normalized Difference Vegetation Index (NDVI) and also to investigate the relationship between LST and NDVI.

Study area

The geography of Ghaziabad gives information about the geographical details of the city of Uttar Pradesh. It lies around 1.5 km away from the Hindon river. The main rivers that flow through the Ghaziabad district are Hindon, Ganges and Yamuna. All through the year these three rivers remain full of water. Besides these main rivers, there are several other small rivers, the most remarkable among them is the river Kali. It is basically a rain-fed river. Added to this, the district uses water from the Ganga Canal for the purpose of irrigation.

The north part of Ghaziabad is bounded by Meerut district, whereas on the southern part there are Gautambudh Nagar and Bulandshahar. On the other hand, on the south-western part of Ghaziabad lies Delhi, whereas the eastern part is limited by the Jyotibaphule Nagar. Since its boundary is quite close to Delhi, Ghaziabad serves as an important entrance path to Uttar Pradesh. Therefore, Ghaziabad is popularly known as the Gateway of Uttar Pradesh, India.

While talking about the geography of Ghaziabad, it should be mentioned that this Indian city is located in between Ganges and the Yamuna plain. Its length is approximately 72 Km and the width is 37 km. According to the 1991 report it is said that the total district area was approximately 2590.0 sq. km. The climate of Ghaziabad is similar to Delhi with summer

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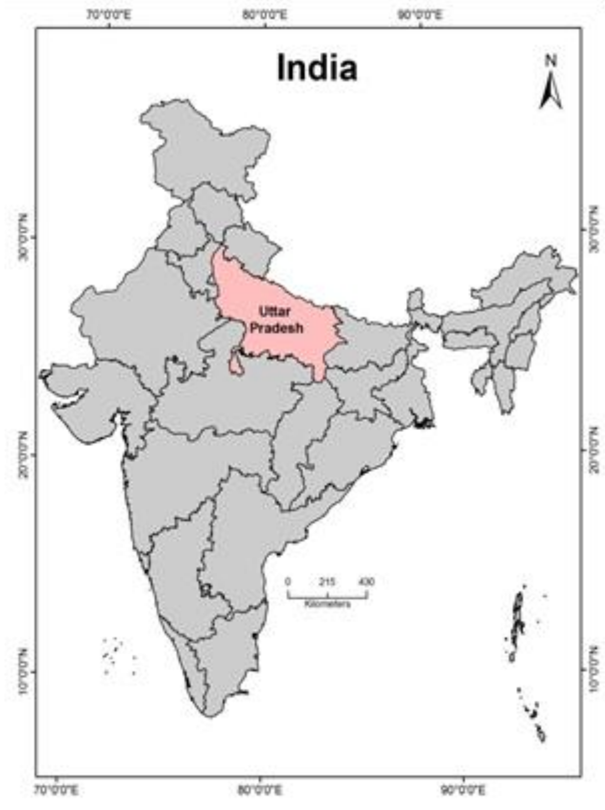
temperatures ranging between 43°C to 30°C and in winter the temperature fluctuating between 25°C to 5°C. Ghaziabad Climate provides information regarding the climatic condition of the Indian city, Ghaziabad of Uttar Pradesh. Ghaziabad experiences almost the similar type of rainfall and temperature like Delhi.

It is assumed that the dust storms of Rajasthan and snowfall in the Kumaon, Himalayas and Garhwal hills play a great role in the regular alteration of Ghaziabad's weather. Generally, in Ghaziabad, the monsoon time arrives at the end of June or at the beginning of July. The city dwellers get the opportunity to enjoy this rainy season until October.

Like other northern districts of India, Ghaziabad also experiences 3 distinct seasons of winter, summer and monsoon. However, sometimes, due to extreme snowfall in the Kumaon Hills and Himalayas, adverse weather conditions occur in the city of Ghaziabad. Visitors should try to visit Ghaziabad in between the months of October and March since the temperature is very pleasant during this time. Location of the study area is shown in Fig. 1.



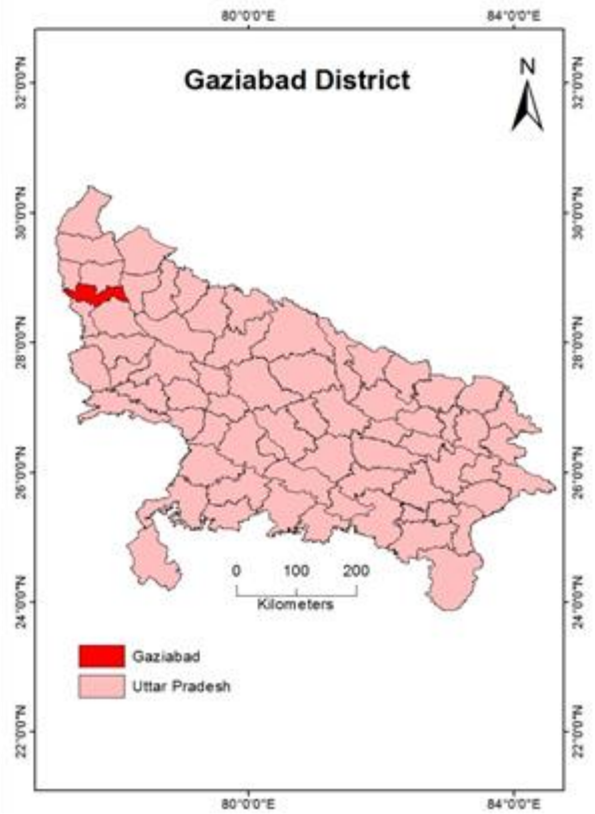


Fig 1: Location of the study area

Objective of the study

The objectives of the present study are as follows:

(a) to study the changes in LST of study area from 2000 to 2018 using Landsat satellite data;

(b) to analyse NDVI, atmosphere brightness temperature and its relationship with LST, using Landsat data.

Data used and methodology

During this study, multi-temporal Landsat data of 1992 (TM), 2000 (ETM+), 2011 (ETM+) and 2018 (OLI) are used for the analysis of temporal variation in LST in the study area. Landsat-8 carries two sensors, i.e., the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI collects data at a 30m spatial resolution with eight bands located in the visible and near-infrared and the shortwave infrared regions of the electromagnetic spectrum, and an additional panchromatic band of 15m spatial resolution. TIRS senses the TIR radiance at a spatial resolution of 100m using two bands located in the atmospheric window between 10 and 12μm (Juan et al., 2014; Charlie et al., 2011). Landsat-8 is the latest among the Landsat series of NRSA. The data of Landsat 8 is downloaded from the Earth Explorer website free of cost. In this study, Landsat TM of 1992, Landsat ETM+ of 2000, 2011 and Landsat-8 OLI Image of 2018 of pertaining to the study area were used to calculate NDVI and the estimation of LST. Details of Landsat data used in this study and their characteristics are given in Table 1 and Table 2.

In this study, band 10 is used to estimate brightness temperature and bands 4 and 5 are used to calculate NDVI. Two thermal bands (TIRS) capture data with a minimum of 100m resolution but are registered and delivered by the 30m OLI data product. Single-window algorithm method has been employed to find out LST in the study area. Vegetation proportion calculation, emissivity calculation, LST calculation etc. were executed in ArcGIS-10.3 software platform. The multi-temporal Landsat satellite images were processed using ERDAS Imagine and classify the Land use/Land cover thematic map with ground truth data collected from GPS using digital image processing supervised classification method. The methodology applied in this research is illustrated in Fig. 2. Data used in this study is shown in Fig. 3 (a to d).

First, the raw data of remote sensing are used to carry out some processes. Second, the spectral indices are applied to carry out equations of LST; the land use type is extracted from Landsat. All these were used to estimate land surface temperature.

Following Meta data values are used for calculation:

- Radiance of thermal bands from Landsat 8,7,5
- K Constant bands.

Land surface temperature analysis

The most commonly LST retrieval algorithms are split window algorithm (Becker and Li, 1995; Sobrino et al., 1996), temperature/emissivity separation method, mono-window algorithm and single channel method (Jiménez-Muñoz et al., 2009). Although Landsat 8 images are provided by two thermal bands, in this study to determine LST, a single-channel algorithm was used to calculate the LST. The Landsat sensors obtain temperature data and store this information as a digital number (DN) with a range between 0 and 255. Before calculating the LST, Landsat 8 images require pre-processing to improve their quality that were done in software ENVI.

The detailed step by step process for LST calculation is given as below. Following processes have been performed for the calculation:

i. Top of Atmosphere (TOA) Radiance:

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance.

The following equations were adopted sequentially.

$L\lambda = ML * Qcal + AL$; (1)

Where, $L\lambda$= TOA spectral radiance (Watts/(m2*sr*μm)); (2)

ML=Radiance multiplicative band (No.)

AL= Radiance add band (No.)

Qcal= Quantized and calibrated standard product pixel values (DN).

ii. Top of Atmosphere (TOA) Brightness Temperature

Brightness temperature is the temperature of a blackbody which is used to produce the radiance perceived by the sensor, according to NASA, 2012. It is the temperature that has been received by the satellite at the time that the image was taken. Therefore, this is not the real temperature on the ground; it is the temperature at satellite (Alipour et al., 2003). TIRS band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file, the Equation 2 used to convert from spectral radiance to brightness temperature.

Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

$BT = K2 / \ln (k1 / L\lambda + 1) - 272.15$; (3)

Where, BT=Top of atmosphere brightness temperature (°C)

$L\lambda$= TOA spectral radiance (Watts/m2*sr* μm))

K1=K1 constant bans (no.)

K2=K2 constant band (no.)

iii. Normalized Difference Vegetation Index (NDVI)

NDVI is a standardized vegetation index which is calculated using Near Infra-red (Bnad 5) and Red (Band 4) bands. In this present study NDVI is used to examine the relationship between LST and greenness. The NDVI were calculated as the ratio between measured reflectance in the red and near infrared (NIR) spectral bands of the images using the following formula:

$NDVI = (NIR – RED) / (NIR + RED)$; (4)

Where, RED= DN values from the Red Band

NIR=DN values from NIR-Infrared band

The output value of NDVI ranged between -0.04 and 0.54. To get NDVI, the NDVI image was reclassified into soil and vegetation; the classified data were used to find out FVC. After generating LSE for both the bands of TIR, the mean and difference LSE was found as: $\varepsilon = (\varepsilon 10- \varepsilon 11)/2$; (5)

$\Delta\varepsilon = \varepsilon 10- \varepsilon 11$ (7) Where ε – Mean LSE; (6)

Δε – LSE difference; (7)

ε10 and ε11 - LSE of band 10 and 11.

Finally, the LST in kelvin was determined using SW algorithm.

iv. Land Surface Emissivity (LSE)

Land surface emissivity (LSE) is a significant parameter that describes the radiative absorption power of a surface in the long wave radiation spectrum (Tardy et al., 2016). The calculation of land surface emissivity (LSE) is required to estimate LST since LSE is a proportionality factor that scales the black body radiance (Plank's law) to measure emitted radiance and it is the ability of transmitting thermal energy across the surface into the atmosphere (Ugur and Gordana, 2016). LSE depends on the target surface top layer composition, such as presence of soil, soil type, vegetation and density, or roughness of the surface (Li et al., 2013; Sobrino et al., 2008). At the pixel scale, natural surfaces are heterogeneous in terms of variation in LSE. Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values.

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PV = [(NDVI – NDVI min) / (NDVI max + NDVI min)]2; (8), where:

PV= Proportion of Vegetation

NDVI=DN values from NDVI image

NDVImin.=Minimum DN values from NDVI image

NDVImax.=Maximum DN values from NDVI image

E = 0.004 * PV + 0.986; (9) where: E=Land surface emissivity, PV=Proportion of vegetation.

v. Land Surface Temperature (LST)

LST is the radiative temperature, which is calculated using Top of atmosphere brightness temperature, Wave-length of emitted radiance, Land Surface Emissivity:

LST=(BT/1)+W*(BT/14380)*ln(E); (10)

Where, BT=Top of atmosphere brightness temperature (°C)

W=Wavelength of emitted radiance

E=Land surface emissivity

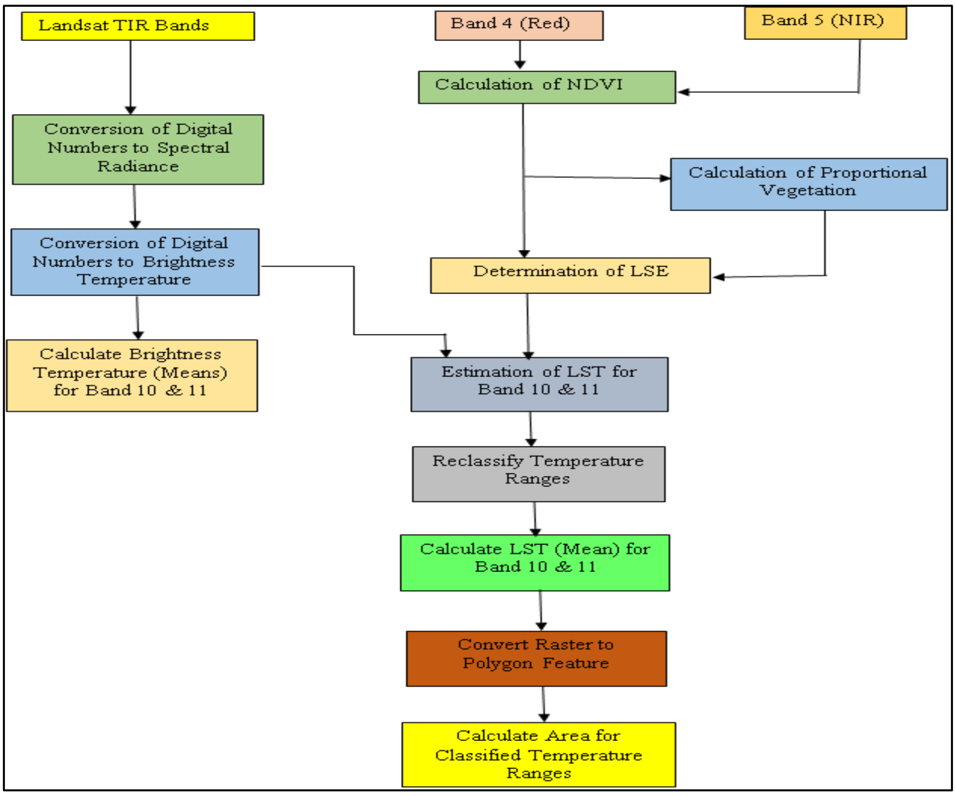

Fig. 2: Flow Chart of Methodology

Table 1 Details of Landsat Data collected for this study

Date of Acquisition	Sensor	No. of Reflective Bands	No. of Thermal Bands	Resolution (m)
September 2000	Landsat TM	06	1	30m & 120m
September 2011	Landsat ETM+	08	1	30/60
September 2018	Landsat OLI	11	1	30/60

Table 2 Characteristics of LANDSAT-8 OLI&TIRS

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

vi. Land Use Land Cover Estimation Using Supervised Classification

This study uses the maximum likelihood classification method (Liu et al., 2016; Otukei and Blaschke, 2010), in which if the observed value of a selected image sample of an unknown class is most similar to that of a sample (training) of a known class, and then it is classified as that class. According to the specific characteristics of Shenzhen land use/coverage, the land cover type is divided into the following categories: agriculture land, fallow land, barren land, vegetation, built-up area and water bodies.

Most of the studies on land coverage are based on a linear spectral mixture model, which has been successfully applied to estimate land coverage from multispectral images at the subpixel scale. The decomposition of mixed pixels based on the mixture model with three or four end members has also achieved good results in extracting land coverage. In this study, linear mixture model to calculate the components of impervious surface, vegetation, soil and shadow of each pixel of the Landsat images and compare the extracted land cover fraction with land coverage data measured on the high-resolution image are used.

The accuracy assessments provide more information on where the errors of classification happened. To know how much a classification is accurate, a set of random points must be created to evaluate the data, at the location of each random point. The result would be finding the type of land use of that spot using Google earth (truth points) and comparing it to land use of the classified raster (Jensen, 2016). Three standard criteria were used to assess the accuracy of the classifications (overall accuracy, producer's accuracy and user's accuracy).

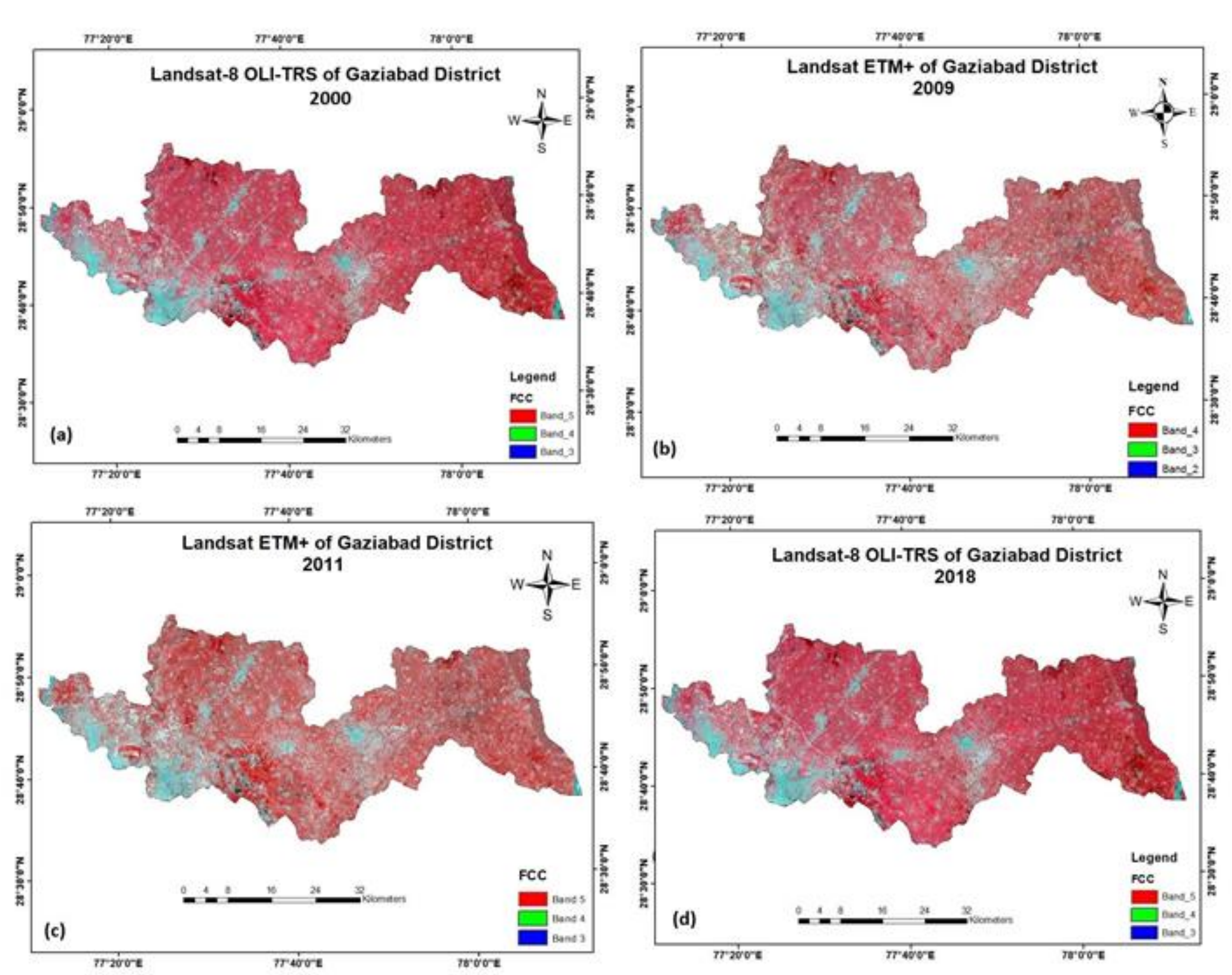

Fig. 3: False Color Composite image (FCC) of Landsat Data of 2000 (a), 2009 (b), 2011 (c) and 2018 (d) respectively.

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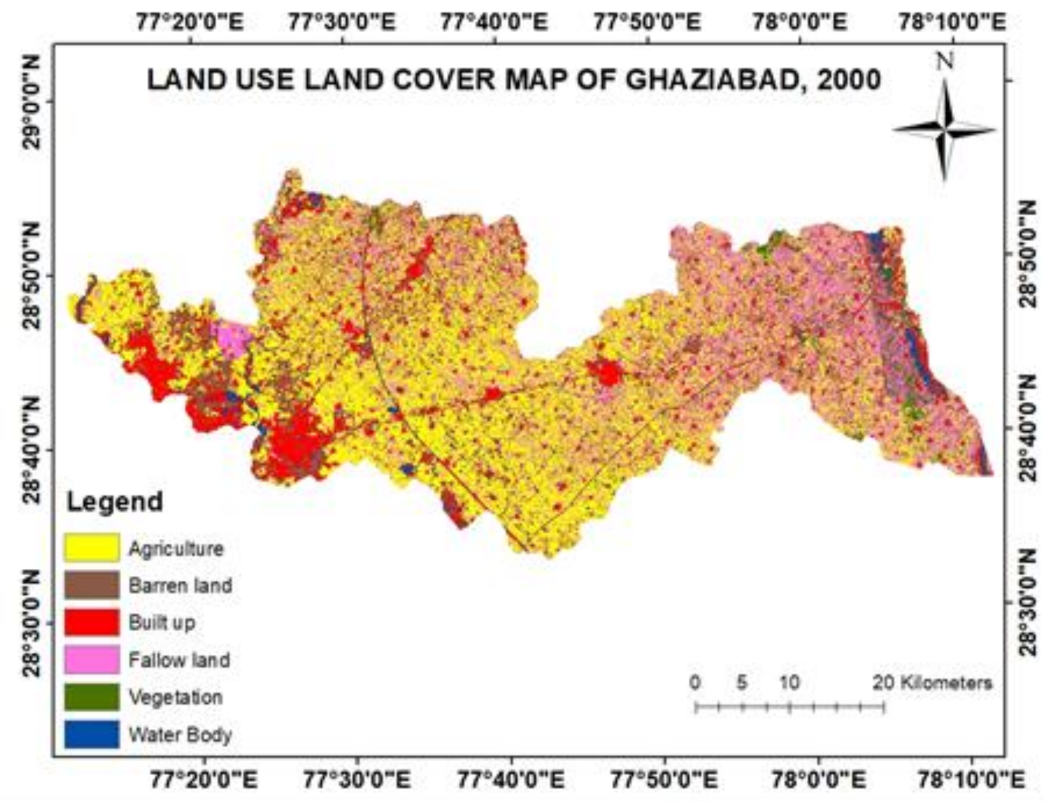

Fig. 4: Land Use Land Cover Map of Ghaziabad District in 2000

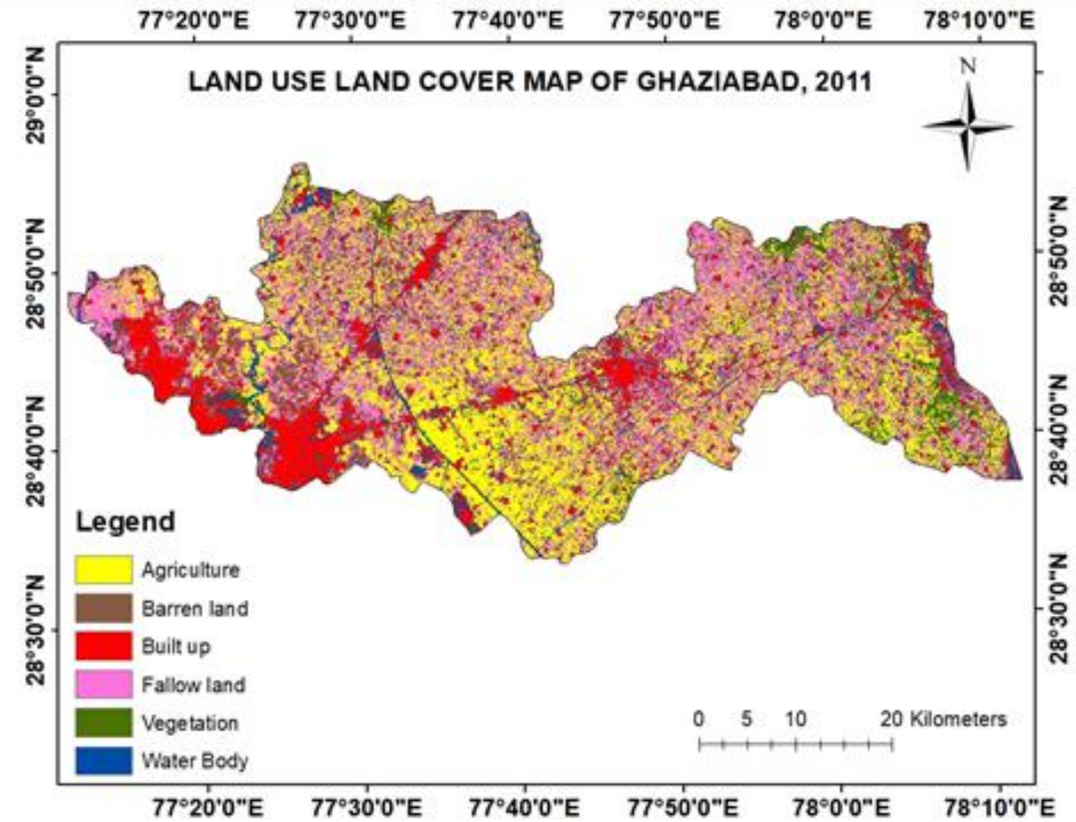

Fig. 5: Land Use Land Cover Map of Ghaziabad District in 2011

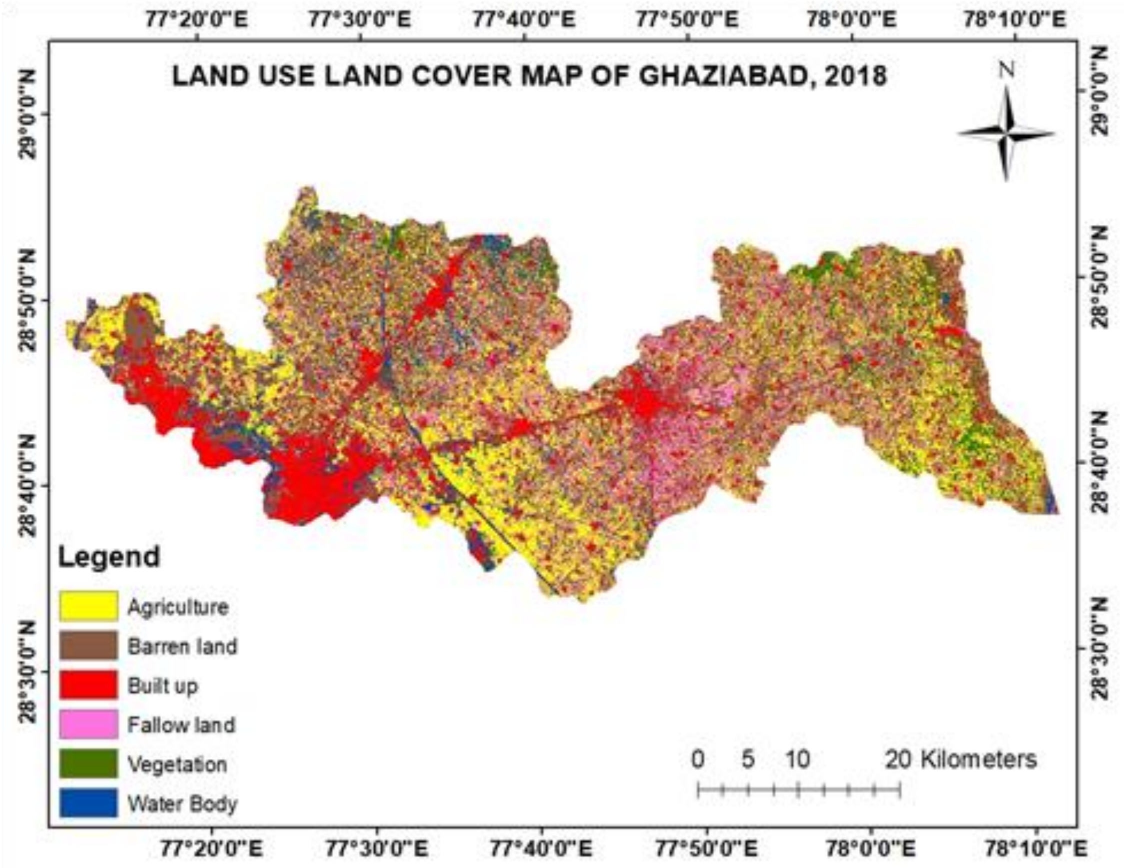

Fig. 6: Land Use Land Cover Map of Ghaziabad in 2018

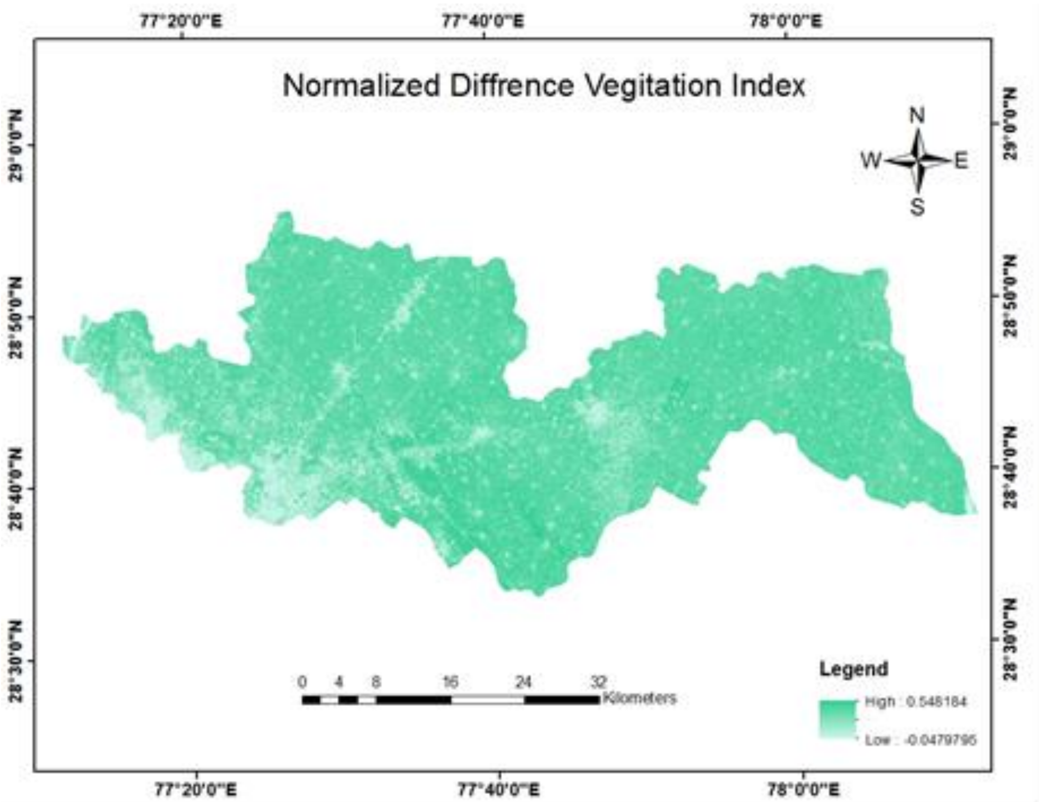

Fig. 7: Normalized Difference Vegetation Index (NDVI) in 2018

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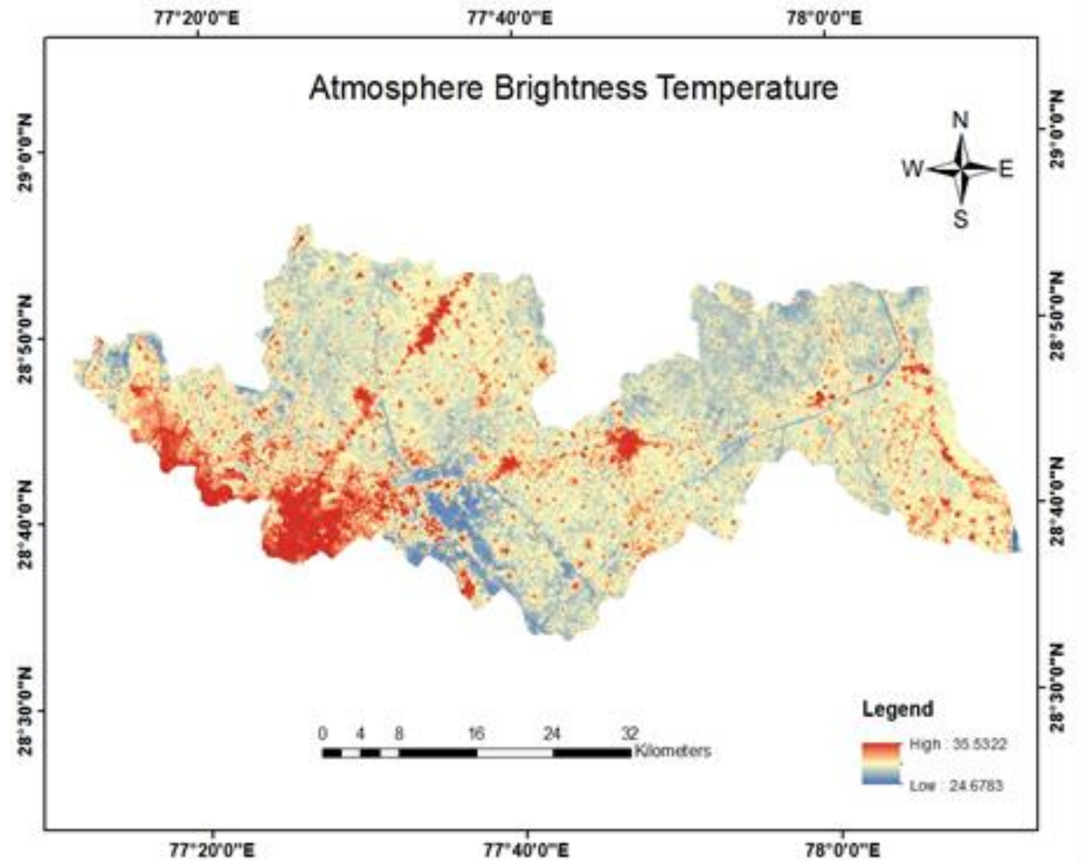

Fig. 8: Representation of Top of Atmosphere Brightness Temperature (in Degree C.) of Ghaziabad in 2018

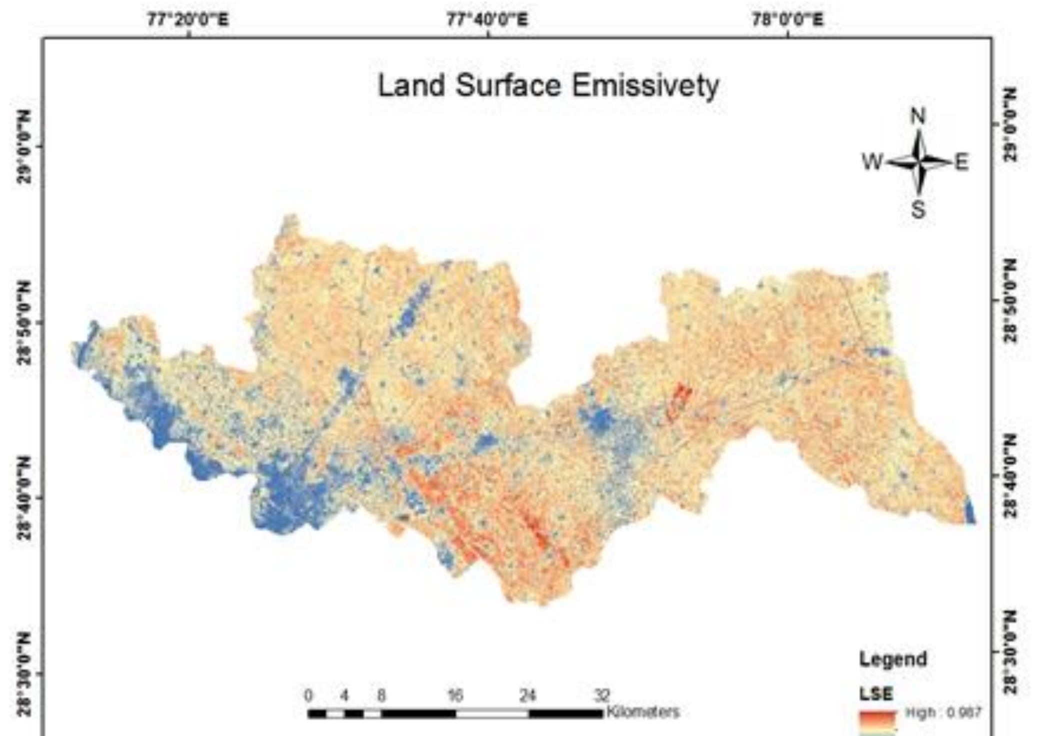

Fig. 9: Land Surface Emissivity of Ghaziabad in 2018

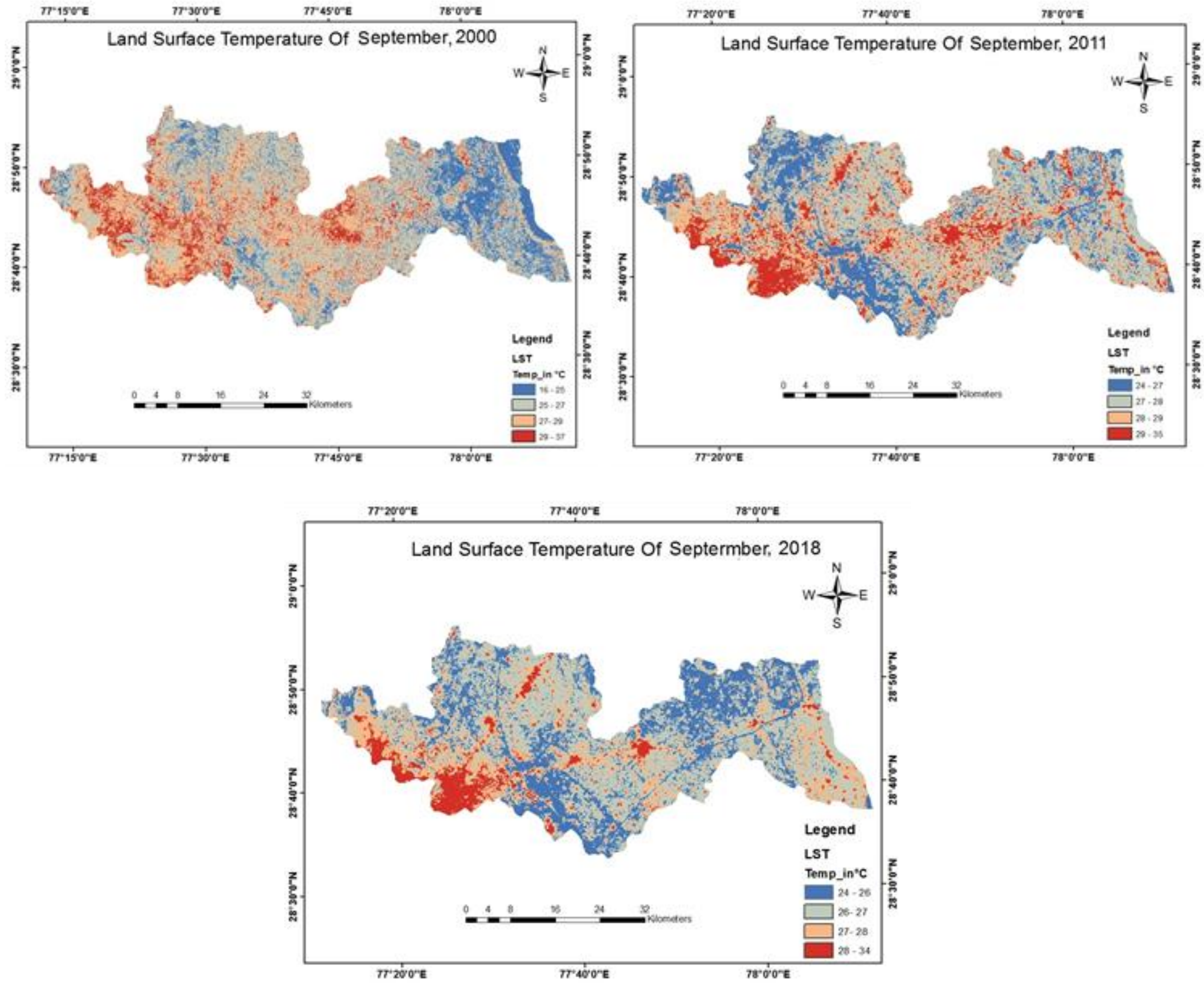

Fig. 10: Land Surface Temperature of Ghaziabad District in September 2000 (a), 2011 (b) and 2018 (c)

Table 3 Area Distribution of Each LULC classes in Ghaziabad District

LULC classes	Area (sq. km) 2000	Area (sq. km) 2011	Area (sq. km.) 2018
Agriculture	695.51	514.37	491.99
Barren land	363.40	309.27	424.00
Built up area	225.93	295.78	319.53
Fallow land	399.07	593.29	492.24
Vegetation	150.56	147.45	137.16
Water bodies	142.86	117.17	112.41
Total	1977.33	1977.33	1977.33

Results and discussion

Land Use Land Cover Change Detection

The classification of the images of the study area at different periods was necessary in the detection of changes which has occurred in the various land use within the study area over the study period. Land use changes arising from built-up area, agriculture, fallow land, barren land, vegetation and water bodies are some of the contributing factors to land cover changes in Ghaziabad district. The urban expansion witnessed in Ghaziabad is characterized by uncontrolled growth of urban development coupled with lack of appropriate land use planning and the measures for sustainable development. The changes in the LULC are described in terms of number of pixels for each classification category. Fig. 4, 5 & 6 represent LULC maps of Ghaziabad district in 2000, 2011 &

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2018 prepared through supervised classification method. Statistics show that as in 2000, agriculture and fallow land constitutes the largest LULC categories in Ghaziabad followed by barren land and built-up area. They collectively occupy an area of 1098.58 sq km, representing 55.52% of the total land cover of the study area. The water bodies are the least land cover type. They occupied an area of 142.86 sq km which represents 7.22% of the total land cover of the study area. Observations from the 2011 show a significant increase in the built-up environment/settlement from 225.93 sq km in 2000 to 319.53 sq km in 2018, which implies an increase from 11.42% to 16.15%. Whereas, the surface covered by vegetation land decreases from 7.61% to 6.93% while barren land increased from 18.37% to 21.44%. Table 3 shows that the classification of different types of land uses land cover and its area distribution.

Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST)

NDVI is a measure of the vegetation density of an area and tends to reduce the increase in the alteration of natural surfaces and replacement them with impervious surfaces. It is observed that lower NDVI corresponds to the developed settlements while high NDVI values correspond to the less developed natural surfaces as presented in Fig. 7 and Fig. 11. Year 2000 has the highest NDVI value while 2018 has the lowest, which indicates that the NDVI decreases with the urban expansion. NDVI map of 2018 revealed that the NDVI value ranged between -0.04 to 0.54. The south western part of Ghaziabad district had the highest NDVI value whereas water bodies have negative value (Fig. 7). The NDVI value of the surfaces covered by vegetation was greater than 0.17 and for built-up and barren land it was 0 to 0.17.

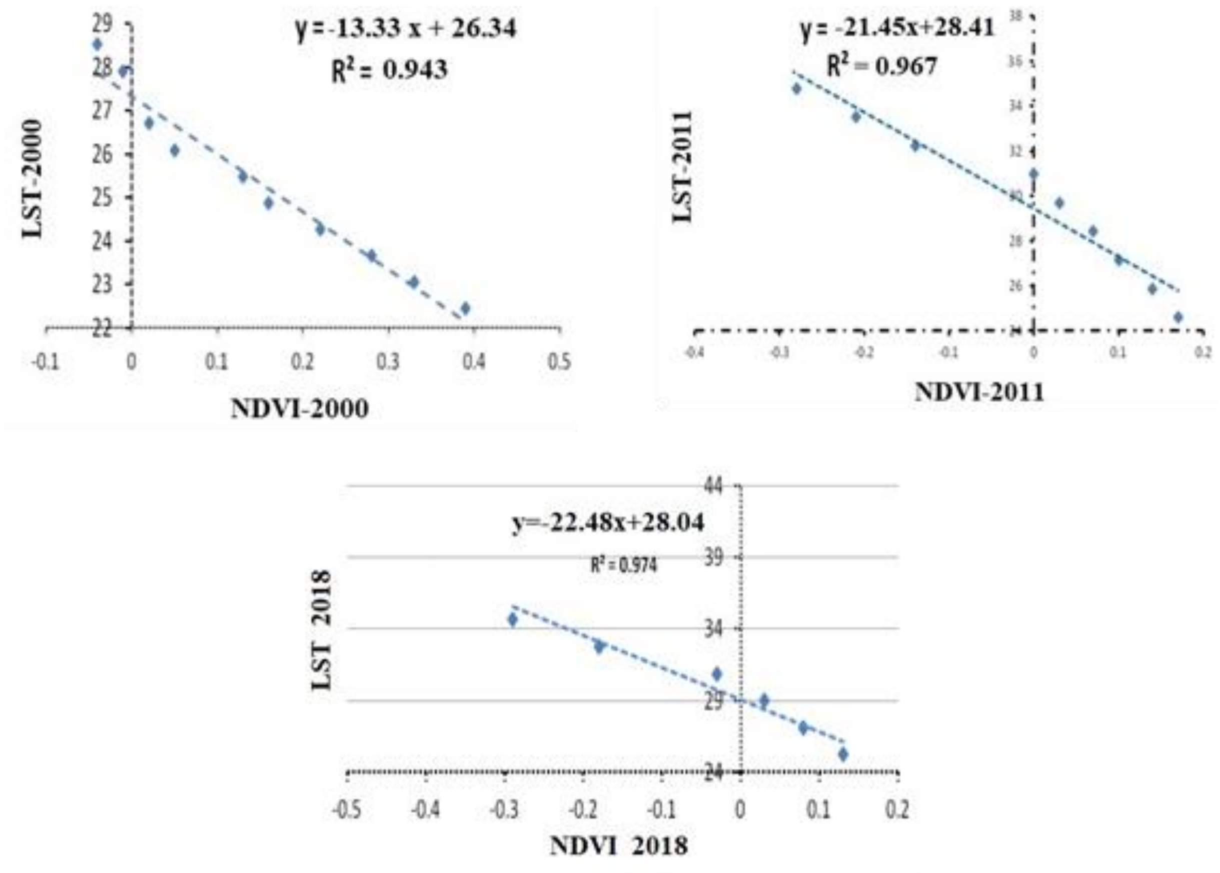

Fig. 11: Relationship between NDVI and LST for 2000, 20011 and 2018 respectively

The relationships between NDVI and LST for 2000, 2011 and 2018 respectively are shown in Fig. 11 (a to c) which show a very strong negative correlation between LST and NDVI. This figure designates that features in pixels with high NDVI values have low values and those in regions with low NDVI values have high LST. The regions with low NDVI values have less vegetation density as a result of urban growth and regions with high NDVI values have very high vegetation density. It is seen that the NDVI value decreases from 2000 to 2018 due to continuous growth in built-up area which reduced the green areas from the study area.

Land Surface Temperature (LST)

The main aim of this study was to analyse the effect of land use on LST in the urban environment. Hence, in order to evaluate the effect of different land use on LST, Landsat satellite imagery and single-channel method in ERDAS imagine and ArcGIS was used. LST was obtained in different areas of Ghaziabad in September 2000, September 2011 and September 2018 and it varied from 27.013°C and 35°C. The results of the LST estimated using the radiative transfer method presented in 2000, 2011 & 2018 are given in the table 4, 5, 6 and 7 which show that the land surface temperature in the study area increases with the increasing rate of urbanization in the city. The representation of Top of Atmosphere Brightness Temperature (in °C) and Land Surface Emissivity of Ghaziabad in 2018 is shown in Fig. 8 and 9. LST maps of Ghaziabad in 2000, 2011 and 2018 are shown in the Fig. 10 (a to c).

The table 6 and 8 show that LST over Ghaziabad has increased from a minimum of 16°C in 2000 to 24°C in 2018 which represents an increase of 8°C within 18 years resulting into an average annual increase of 0.44°C. The rapid increase in the values of LST over the years of study can be attributed to the rapid increase in the urbanization the city has witnessed. The maximum temperature reduced from 37°C to 34°C during 2000 to 2018. During 2000, 39.60% of the area was coming under 16-25°C which is the area covering under agriculture vegetation, fallow land etc.

The population of the Ghaziabad has increased from 3,290,586 in 2001 to 4,681,645 in 2011. This has led to terrible depletion of considerable number of natural surfaces and replacing them with impervious surfaces such as settlement, roads and other materials. Due to this, the capability of retaining heat increased and thereby causing serious environmental stress which in-turn, affects our urban micro-climate; but, public awareness is also increasing so that people and development authority started afforestation activity in Ghaziabad. Due to this, the maximum temperature-as seen in LST of 2018-is quite reduced.

The lowest and highest radiant temperatures for 2000 were 18.2°C (in the high-density vegetation area and agricultural land) and 30.7°C (in the built-up area) respectively. Meanwhile, for 2011, the radiant temperatures range between 24.9°C and 36.5°C; the highest temperatures were also recorded within the built-up areas while the lowest were within vegetative areas (Table 7).

Table 6 Area statistics of LST of Ghaziabad in September 2000

S. No	Temperature (°C)	Area (Sq. km)	Percentage (%)
1	16-25	782.98	39.60
2	25-27	738.33	37.34
3	27-29	352.71	17.84
4	29-37	103.30	5.22

Table 7 Area statistics of LST of Ghaziabad in September 2011

S. No	Temperature (°C)	Area (Sq. km)	Percentage (%)
1	24-27	994.73	50.31
2	27-28	542.66	27.44
3	28-29	256.34	12.96
4	29-35	183.59	9.28

Table 8 Area statistics of LST of Ghaziabad in September 2018

S. No	Temperature (°C)	Area (Sq. km)	Percentage (%)
1	24-26	993.31	50.24
2	26-27	615.67	31.14
3	27-28	216.56	10.95
4	28-34	151.78	7.68

Conclusion

This study mainly focuses on the application of using Remote Sensing data and Geographic information systems in the drive towards sustainable environmental development with interest in uneven urban development, green area loss and significant thermal changes. This study has shown the LULC dynamics of Ghaziabad at different time periods with the corresponding deviation in the thermal environment as influenced by the LULC change. In this study, LST resulting from the Landsat ETM+ and OLI spectral data proved to be a good substitute for UHI. Image-induced LST can assess urban surface temperature not only in quantity but also in spatial patterns in any highly developing city. The results shown in this study reflects that the built-up areas in Ghaziabad district has expanded significantly on the

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expense of the vegetative-covered areas. The total geographical area of Ghaziabad identified in the image is equivalent to 1977.33 sq.km. In 2000, the built-up areas were 225.93 sq.km but it has increased to 319.53 sq.km. in 2018. Surface temperature variations control the surface heat and water exchange with the atmosphere resulting climatic change in the region. However, other climatic indicators play a significant role in temperature variation, the major role such as land conversion due to rapid growth of urbanization and from deforestation etc. resulting in temperature variations.

Although this study is not the end, initial outputs of this works have shown that there are noteworthy increases in the built-up areas in the Ghaziabad district which resulted in higher LST in built-up areas as compared to the vegetation areas and agricultural land. During this study, a strong negative correlation between LST and NDVI, which emphasizes that vegetation helps to reduce the LST of an area. The relationship between urban surface temperature and land cover types allowed us to find out the best solution for urban planning strategies that meet urban heat island reduction in the study area. Green space plays very important roles to improve the heat island impact by means of transpiration and heat absorption to minimize the emissivity of the hard surface reflectivity by covering the built-up area by its shadow. It is recommended to surround the highly dense built-up area and industrial areas of Ghaziabad by green belt buffers to more than 400 m for improving temperature condition and to decrease pollution effects to the acceptable limits.

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Detection and characterization of an archaeological wreck site in Sunda Strait, Indonesia

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Abstract

A number of shipwreck archaeological sites worldwide have underlined the importance of shipwreck localization and detection. Accidents that led to sinking are one of the possible causes of those shipwrecks. The shipwreck of MV Bahuga Jaya, which is located in the Sunda Strait, Indonesia could be such an example. A multibeam swath survey is a suitable technique to map the wreck location since it can produce high-resolution Digital Elevation Model (DEM) and backscatter imagery. Both the analysis of the bathymetry DEM and backscatter use visual examination. However, morphometric analysis of the DEM and texture analysis of the backscatter, subsequently combined with the machine learning classification, could give a preferable result in shipwreck detection and monitoring. In this paper, slope analysis of DEM bathymetry and texture analysis of multibeam backscatter imagery are presented. Those first-order textural features are used to carry out a Support Vector Machine (SVM) classification to separate between the wreck and non-wreck objects. A combination of SVM classification and slope analysis is investigated to detect the wreck location. Following that, K-means clustering is also performed to obtain the seabed characterization. Results indicate that the combination of machine learning and morphometric analysis can give a promising outcome in shipwreck detection. In addition, the result of K-means clustering reveals that soft seabed is more dominant than the hard seabed in the study area with 56.4% and 43.6% respectively. This study could play a role as a complementary tool to monitor and manage the shipwreck archaeological site location.

Keywords: *archaeological site, wreck, multibeam backscatter, slope and texture analysis, SVM classification, K-means clustering, Indonesia*

Rezumat. Detectarea și caracterizarea unui sit arheologic cu epave în Strâmtoarea Sonde, Indonezia

O serie de situri arheologice subacvatice din întreaga lume au evidențiat importanța localizării și detectării epavelor. Accidentele sunt o posibilă cauză a scufundării acestor nave. Naufragiul vasului MV Bahuga Jaya, situat în Strâmtoarea Sonde, Indonezia, ar putea fi un astfel de exemplu. Sondajul multi-fascicular reprezintă o tehnică adecvată pentru cartografierea locației epavei, deoarece poate produce un model digital (DEM) de înaltă rezoluție, cât și imagistică de radioreflectie. Pentru ambele se utilizează examinarea vizuală. Cu toate acestea, analiza morfometrică a DEM și analiza texturii obținute prin retrodifuzie, combinate ulterior cu clasificarea automată, ar putea oferi un rezultat mai bun în detectarea și monitorizarea epavelor. Lucrarea de față prezintă analiza pantelor pe baza batimetriei DEM și analizei texturii pe baza imaginilor de radioreflectie. Aceste caracteristici texturale de prim ordin sunt folosite pentru a efectua o clasificare SVM (Support Vector Machine), cu scopul de a distinge între epavă și elementele ce nu aparțin acesteia. Pentru a detecta locației epavei, se folosește o combinație între clasificarea SVM și analiza pantelor. Ulterior, un algoritm de grupare (K-means clustering) este utilizat pentru a caracteriza fundul mării. Rezultatele indică faptul că o combinație între învățarea automată și analiza morfometrică poate oferi rezultate promițătoare în detectarea epavelor. În plus, rezultatul aplicării algoritmului de grupare menționat relevă faptul că în arealul în studiu domină fundul marin cu duritate scăzută, care deține 56,4%, față de 43,6%, cât revine celui dur. Acest studiu ar putea juca rol de instrument complementar în monitorizarea și gestionarea locației sitului arheologic subacvatic.

Cuvinte-cheie: *sit arheologic, epavă, analiza pantelor și a texturii, clasificare SVM, Indonezia*

Introduction

On the early morning of the 26th of September 2012, there was a marine accident, following the collision of two vessels in Sunda Strait, Indonesia along the traffic route, involving Indonesian Ro-ro Passenger Ferry MV Bahuga Jaya and Singapore tanker MT Norgas Cathinka. MV Bahuga Jaya was 92.30 m long and 16.20 m wide, with a draft of 5.23 m (National Transportation Safety Committee (KNKT), 2013). Paroka et al. (2014) explained that the accident, resulting in more than 7 casualties and 10 serious injuries of passengers, was caused by poor maneuvering of both vessels due to the wind and wave condition. The MV Bahuga Jaya finally sank 40 minutes after the collision. The body of this vessel remains in the location and becomes a shipwreck archaeological site in Sunda Strait.

According to UNESCO, there are over three million wrecks as archaeological heritage on the seafloors around the world. However, those shipwreck sites are vulnerable by the threat of damage due to human activities such as mobile fishing, trawling, and dredging and the quantifying of this damage has not been finished recently (Brennan et al., 2012). Additionally, Masetti & Calder (2012) also asserted that shipwrecks could contribute to marine pollution by releasing toxic materials from their corrosive body and could harm the environment. As a result, several projects have been carried out to map and diagnose the underwater archaeological site (Reggiannini & Salvetti, 2016). Thus, Bahuga Jaya wreck as one of that archaeological wreck sites also needs to be mapped and investigated.

Marine surveying and mapping of the wreck site aim to examine the texture and stratigraphy of the wreck location and the seafloor surroundings. The distinction between areas of wreck archaeological interest and its surroundings can be useful for determining archaeological prospection (Thabeng et al., 2019). Moreover, the result then could be used to monitor and to manage the site, particularly related to morphological alteration and anthropological impacts (Geraga et al., 2017). Depicting and analyzing the environmental condition of a wreck-site is an essential action in examining the quality of remaining wreck debris.

To date, underwater acoustic and imaging technologies have been used widely in underwater sea wreck studies. The multibeam echosounder and side-scan sonar become two major technologies to investigate the wreck sites for decades and can be found in several studies (Brennan et al., 2012; Roberts et al., 2017; Delgado et al., 2018; Ødegård et al., 2018). A shallow seismic survey such as sub-bottom profiling also could perform the estimation of the thickness of the seafloor sediment layers in the wreck location (Geraga et al., 2017). In addition, photographic and video imaging also have been predominant techniques either for direct investigation or as complementary ground truth data for the multibeam and side-scan sonar system. Due to its popularity, the multibeam swath system was chosen for landscape mapping in a wreck site investigation in this study. It is due to its capabilities to not only produce a dense and high-resolution bathymetric digital terrain model (DTM), but also the intensity of returned pulse (backscatter) that can be used for wreck investigation.

The bathymetric digital terrain model (DTM) analysis is well-known as "geomorphometry" or "morphometric analysis" (Brown et al., 2011). This model as a representation of the seabed topography could be derived to several terrain attributes (e.g. slope, aspect, curvature) and could contribute for several purposes such as seafloor classification and object detection (Lecours et al., 2016). Several comprehensive literatures regarding marine geomorphometry can be found in Lecours et al. (2016) and Lucieer et al. (2018). Micle et al. (2010) argued that marine geomorphometry becomes a promising technique to analyse the shipwreck archaeological sites.

On the other hand, the backscatter intensity usually builds up an acoustic grayscale image of the seafloor. Parnum & Gavrilov (2011) asserted that the backscatter data could represent the composition and morphological characteristics of the seabed. In general, the low backscatter values in the image represent soft and smooth surfaces, whereas high backscatter values depict hard and/or rough objects (Febriawan et al., 2019). Brown et al. (2011) explain that the backscatter imagery resulted from multibeam system has generally a lower quality to the side-scan backscatter imagery. However, the analysis of both backscatter imageries is relatively the same. Image-based segmentation is the most popular method for multibeam backscatter image analysis. They also stated that several backscatter characteristics such as textural features and surface features (shape) could be used in image segmentation. The textural features are then used as parameter inputs for classification and detection.

The growth of machine learning techniques has led to various research of its technology in seabed classification and object detection. Support Vector Machine (SVM) is one of the supervised machine learning methods in classification and object detection of multibeam and side-scan sonar. Febriawan et al. (2019) have demonstrated that this method has predominance in the classification of side-scan sonar mosaics using small numbers of training samples. Application of SVM classification in archaeological fields can be found in Gu et al. (2018) and Thabeng et al. (2019). In addition, unsupervised classification such as cluster analysis also could be an additional supporting tool in helping to characterize the general morphology of the wreck site. Parnum & Gavrilov (2011) explained that cluster analysis of similar regions of backscatter data could reveal its relationship to seabed morphology (phenomenological approach). In studies without adequate ground-truth sample data, cluster analysis can be a beneficial method for understanding the environmental surroundings of the wreck location especially for site securing prediction.

However, there are few studies of morphometric and textural features analysis and SVM application for underwater archaeological wreck site investigation. K-means clustering method in predicting site morphology also could be an interesting approach to characterize the seabed with an absence of field samples. Thus, this study attempts to undertake several morphometry parameters of the DTM and textural analysis of the backscatter to locate the Bahuga Jaya wreck location and to depict the peripheral seabed covers. While the Support Vector Machine classification was used to detect wreck archaeological debris, the K-means clustering technique was examined to characterize the seabed morphology. The combination of wreck localization and seafloor morphology could be an alternative solution for monitoring wreck location and managing the archaeological site location.

Methodology

Study area and data acquisition

The multibeam swath survey was carried out by the Technology Center for Marine Survey, Agency for the Assessment and Application of Technology (BPPT), Indonesia on 28th of November 2017, using

RV. Baruna Jaya I in the location of Bahuga Jaya wreck site (Figure 1).

The study area covers approximately 696,766.93 m^2, the depth varying between 59 and 110 m.

Fig. 1: Study location

A Teledyne HydroSweep DS full-depth multibeam system, which was mounted in RV Baruna Jaya I, was used for data acquisition. This multibeam system was operated in the frequency of 14 kHz and has a beam resolution of 2° x 2°.

In addition, this system also has 140° swath coverage and 320 beams in both sides (port and starboard). The multibeam system was equipped with a Hemisphere R330 DGPS system (± 20 cm of horizontal accuracy) (Jensen et al., 2017) and a TSS Saturn 10 Fiber Optic Gyrocompass (heading accuracy: 0.1°, pitch/roll accuracy: 0.01°, and heave accuracy: 5 cm) (TeledyneMarine, 2020b) for positioning and inertial motion system. A surface Sound Velocity Keel Sensor AML Micro and a Sound Velocity Profile AML Minos X (accuracy: ± 0.025 m/s, precision: ± 0.006 m/s) (AML Oceanographic, 2020) were also used to perform sound velocity correction both in the water surface and through the water column.

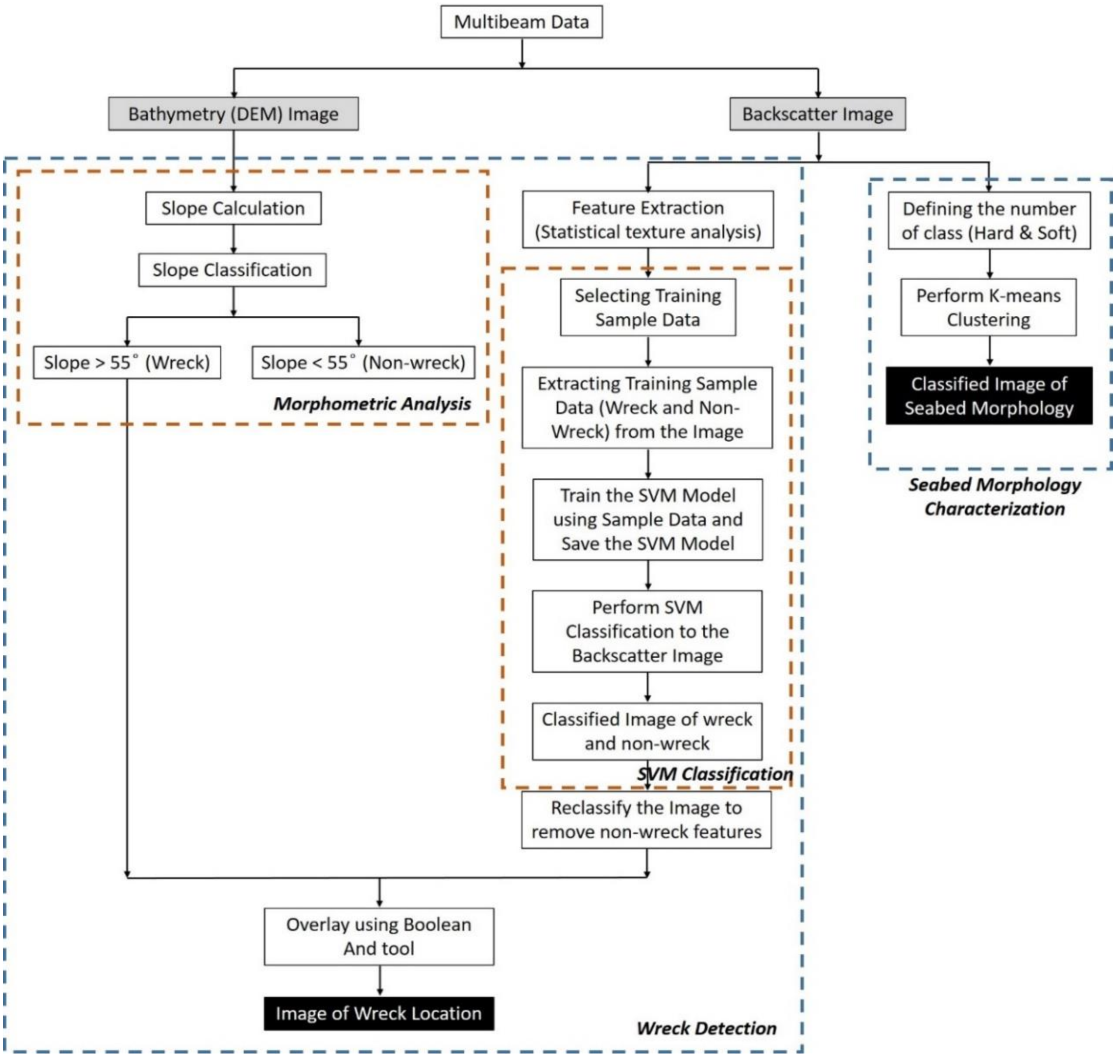

Fig. 2: Flowchart of the study

Both bathymetric raw data and backscatter data were recorded during the acquisition using a PDS 2000 software (TeledyneMarine, 2020a). By default, this software records the raw data in *.pds format but has options to record in other formats (e.g. *.s7k, *.all, etc.), too. Overall, the flowchart of the study can be seen in Figure 2.

Data processing

The raw MBES data was processed using PDS 2000 software with a standard processing workflow as conducted by Junior & Jeck (2009). A sound velocity profile acquired with AML Minos was used in the data processing. The manual editing technique by the human operator was performed to remove data outliers that can lead to inaccurate digital elevation model (DEM). After that, a DEM with a grid cell size of 1 m was produced from the bathymetry data.

The backscatter data—resulted from relationship calculation of backscatter intensity value and angular response—was also processed using PDS 2000 software. The processing of backscatter data yielded the amplitude value of each point in the survey area. This method is called *mosaicking of backscatter data* and could give information of sediment characteristics of the seabed. Thus, as the focus of this study, the backscatter mosaic of Bahuga Jaya wreck provided some distinct amplitude values to distinguish from its surroundings.

The processing of backscatter data was carried out by integrating beam swath coverage and backscatter swath volume. Subsequently, magnitude calibration was performed using coverage of beam survey area, backscatter swath volume, and calculation of absorption coefficient. Finally, the mosaicking process was carried out to create a backscatter base-surface, which then can be exported in XYZ format or geoTIFF imagery in 1 m of cell size.

Wreck detection

Feature extraction

Feature extraction is aimed to determine the properties of the image that represents the objects and can be used as parameters for classification (Solomon & Breckon, 2011). The two common features used in underwater mapping and classification are Terrain Features and Texture Features. While Terrain Features are based on a number of terrain parameters which is derived from a digital terrain model (DTM) and including in morphometric domain (Di Stefano & Mayer, 2018), textural features (patterns segmentation) are based on the group pixels of the image and then be derived to several textural features (images) which could reveal seafloor characteristics (Reggiannini & Salvetti, 2016).

In archaeological studies, slope analysis could be an effective instrument for archaeologists to detect the wreck location and analyze its location with the surroundings (Micle et al., 2010). Thus, this study tried to examine the slope as a feature derived from the DTM using the Benthic Terrain Modeller (BTM). BTM is an add-on plug-in in ArcGIS well-recognized for geomorphometry features extraction. Then, the slope was reclassified in ArcGIS into two different classes: wreck (slope > 55°) and non-wreck (slope < 55°). Based on the interpretation of the Slope image, the wreck location produced a high sloping feature of its surroundings. Subsequently, the wreck of slope > 55° was used for the final detection of wreck location.

In regards to the backscatter imagery, several first-order textures (Variance, Skewness, Kurtosis, Standard Deviation) have been tested to segment and detect the wreck location. Febriawan et al. (2019) stated that the first-order textures are based on a statistical calculation of the pixel's grey values. Those features calculations are based on the following formulas:

$$Skewness = \frac{|\sum(BV_{ij} - \mu)|^3}{(n-1)(V)^{3/2}} \quad (1)$$

$$Kurtosis = \frac{\sum(BV_{ij} - \mu)^4}{(n-1)(V)^2} \quad (2)$$

$$Variance\ (V) = \frac{\sum(BV_{ij} - \mu)^2}{(n-1)} \quad (3)$$

$$\mu = \frac{(\sum BVij)}{n} \quad (4)$$

where:
n = number of pixels in the window
$BVij$ = brightness value of pixel *(i,j)*
μ = mean grey values in the moving window

Implemented in Matlab, a moving window method, which usually has an odd number of window size, was used to produce the textural images mentioned above. A 19 x 19 pixels of the moving window dimension was chosen to derive the textural images as it was suggested by Hamilton (2017).

The new pixel value of the textural images was calculated from the central pixel of the window. After that, visual interpretation was carried out to examine the most suitable textural features in wreck detection. Brown et al. (2011) also asserted that an expert (visual) interpretation is commonly used. This method is involving "expert's eye" and "expert's knowledge" to delineate the imagery based on similar texture and usually be used as training samples in case the ground-truth data is not possible as was conducted in this study.

Support Vector Machine for textural classification

Support Vector Machine (SVM) represents one of the machine learning techniques in supervised classification. It works by fitting an optimal hyperplane in the feature space to split the data into different classes (Liu et al., 2015). Foody & Mathur (2006) explained that the hyperplane is determined by using data points (support vectors) that are located close to the hyperplane. The optimal hyperplane with the maximum margin would be selected if there were several numbers of hyperplanes exist. Although there are some options in tuning the parameters (e.g. using non-linear kernels), this study used a linear kernel in defining the hyperplane.

Febriawan et al. (2019) have demonstrated that the linear kernel is more suitable for side-scan sonar classification using texture features than the Gaussian kernel. The SVM model is created to store the information of hyperplane after the hyperplane has been determined by training the sample data.

Initially, the training data set of a number of images that represent each class (wreck and non-wreck) were obtained by clipping the backscatter image based on each class. After that, those images were set up in order and labelled accordingly. Then, the data set was trained to fit the multiclass model for SVM (*fitcecoc).* Only then does the classification of an image recall the model to check on which class of the data (pixel) is located.

In the present study, two different classes (wreck and non-wreck) were established in the classification based on sample data that trained previously. This method then resulted in a textural SVM classified image of the wreck and non-wreck. In order to get the result of a binary image of the wreck and non-wreck objects, the result of SVM classification then was combined with the slope analysis result using Boolean logic “And” operator in ArcGIS. This operator has proven to be an effective tool in raster operation to overlay spatial layers and removing all unnecessary objects in the image (Cheng & Thompson, 2016). The final result was the map of the wreck location.

Seabed morphology characterization

K-means unsupervised classification

K-means unsupervised classification is a clustering method that divides the data into clusters (classes) and produces an index of the cluster that has been assigned to each data (Matlab, 2019). In multibeam backscatter data analysis, k-means clustering has demonstrated its capability for seabed classification particularly with the lack of ground-truth data.

Some research in using k-means clustering for seabed classification can be found in Fonseca & Calder (2007), Fakiris et al. (2012), and Samsudin & Hasan (2013). Initially after the number of classes has been defined, the centroid of each cluster will be created randomly.

After that, the distance of each data (point) to each centroid is calculated. By default, K-means uses Euclidean distance to calculate the distance of each point. The distance calculation could be based on either the closest distance of each point to the closest centroid or assign points to a different centroid individually.

Then, the centroid locations are up-dated based on the average of the data to each cluster. The iteration is repeated until all of the centroids are stable and converge (below the user’s tolerance) or it reaches the maximum number of iterations.

As a result, points in a cluster will be as close to each other as possible and will be far from points in other clusters. In the application of K-means for image clustering, the algorithm of K-means requires converting the image into a vector before assigning this vector along with the number of clusters into the algorithm. After the class index of each point has been created, it needs to reshape back into an image to get the classified image.

Results

Bathymetry and backscatter image

Bathymetry processing resulted in a Digital Elevation Model (DEM) of the seabed in an 8-bit georeferenced image (*.tif) as shown in Figure 3(a).

It can be seen that the depth of the study area varies between 59.14 meters and 110.41 meters. Visually, the wreck location can be detected from the colour contrast that represents the depth of 59 meters to 70 meters.

There is an underwater seabed channel at 350 meters, northwest of the wreck location. This channel is approximately 240 meters wide, the depth ranging from 90 meters to 110.41 meters. It can be noticed that the north-west side of the study area shows a shallower depth and goes deeper through the southeast of the area.

Figure 3(b) depicts the backscatter image of the study area that has backscatter values ranging from -18.94 dB to -37.62 dB. The wreck itself has backscatter values between an approximately -35 dB and -37.62 dB. One interesting thing that can be noticed is that although both DEM bathymetry and backscatter images cover the same area, it shows a different pattern of features.

While in bathymetry DEM, the seabed topography relief can be easily distinguished (e.g. shallow area, channel, or wreck), the backscatter image only depicts clear features of the wreck and the southeast side of the channel. The wreck, as it is a man-made structure, reflects different backscatter signals than the surroundings and resulting noticeable backscatter values.

However, the notably backscatter values at the southeast side of the channel do not represent the

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morphology type and are probably due to the incidence angle of the location during the acquisition since the vessel sailed in the northwest–southeast direction. This resulted in the southeast side of the channel reflected the backscatter signal stronger than the opposite side and created different backscatter values.

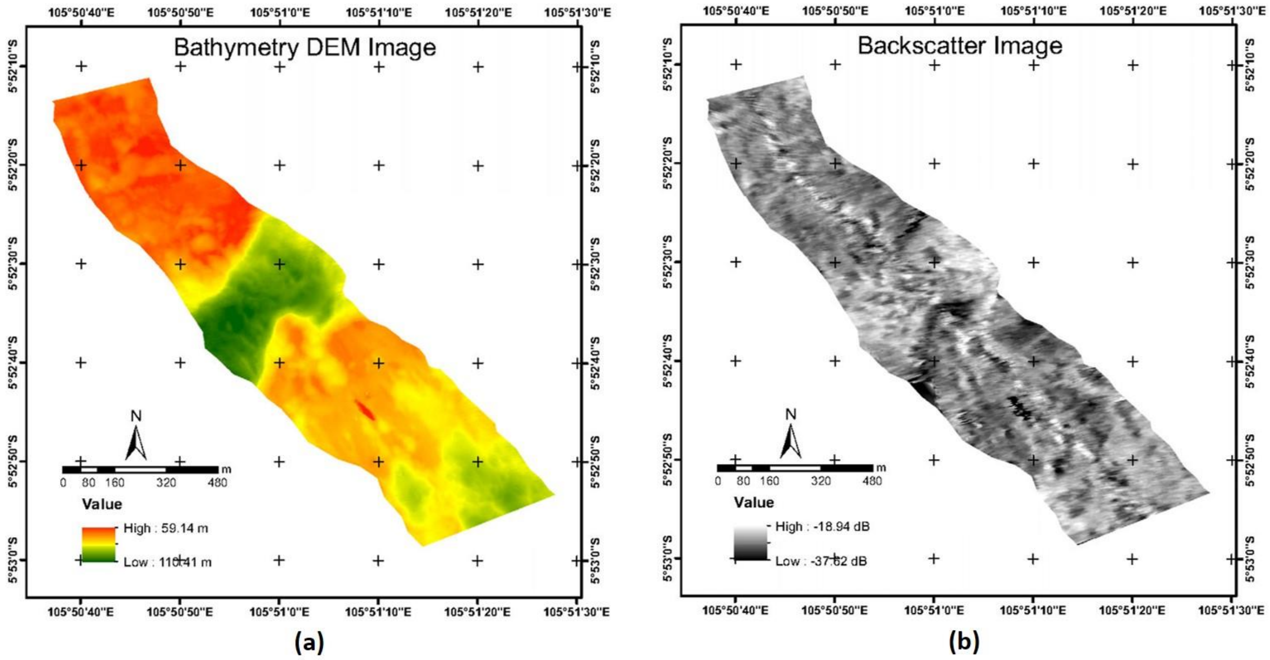

Fig. 3: Results of: Digital Elevation Model (DEM) bathymetry (a), Backscatter imagery (b)

Feature extraction

Initially, the slope feature was created as a terrain derivation feature and the result can be seen in Figure 4(a). The result shows clearly that only wreck feature and the edge of the channel that has a high degree of slope since the elevation difference is high than its surroundings.

However, for the wreck detection purpose, slope > 55° was classified to remove the flat terrain (Figure 4(b)). The result of classification indicates that there are some terrains at the edge of the channel that has slope over than 55°.

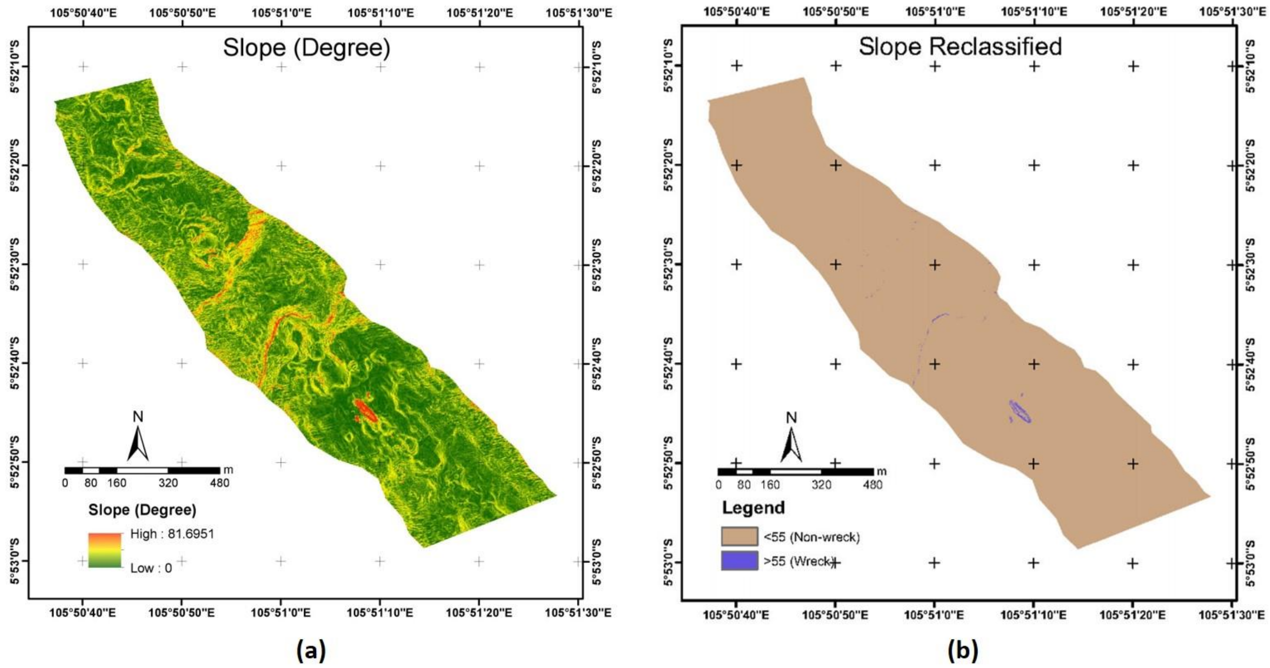

Fig. 4: Slope in degree (a), slope reclassified into wreck and non-wreck classes (b)

In addition to the slope feature, the textural feature extraction also shows a good result. Of the four first-order textures tested, variance and skewness seemed to be the most suitable features for the classification (Figure 5). In visual, the wreck location can be well noticed in both textures and differentiate with the surroundings.

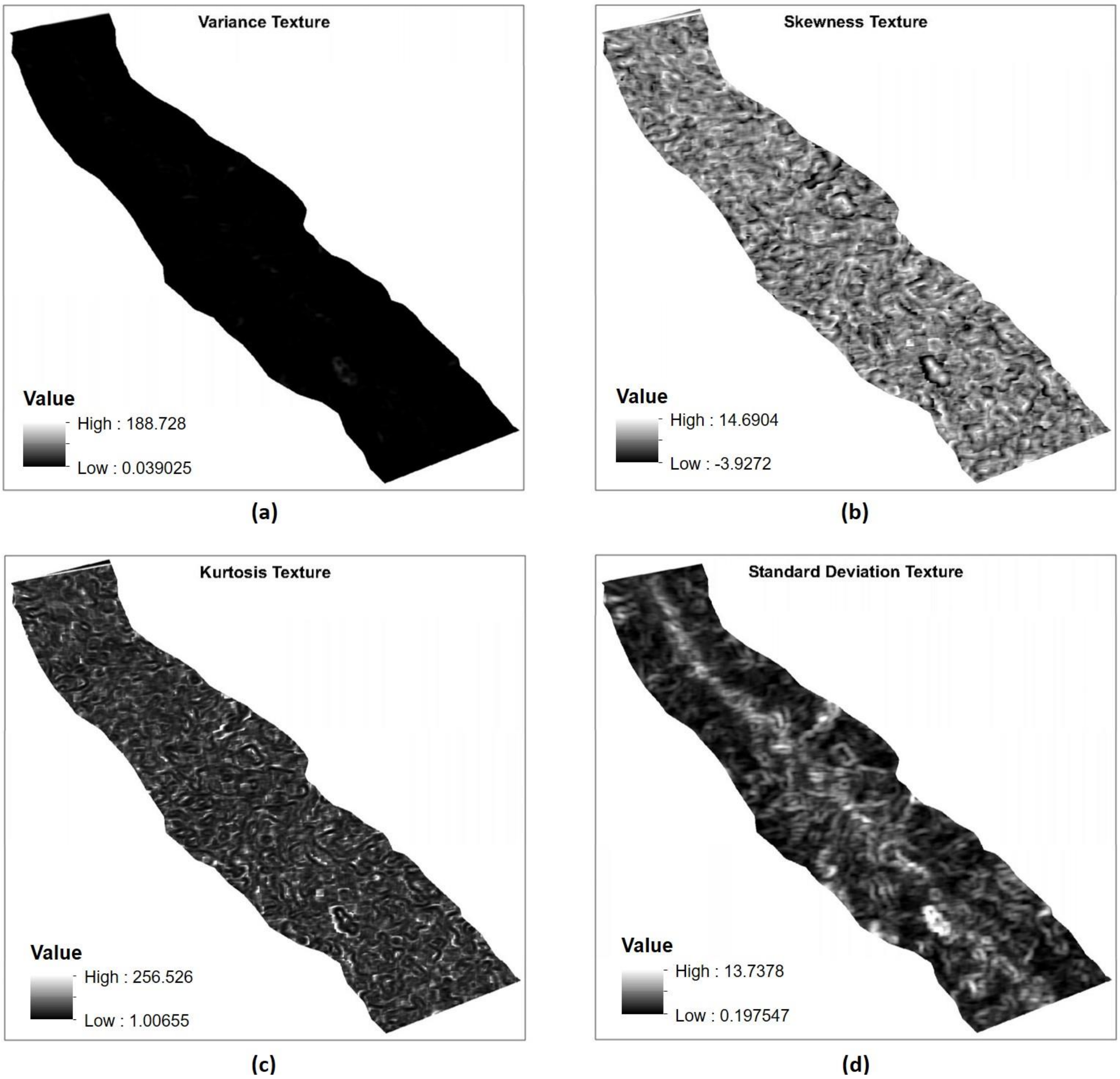

Fig. 5: Results of textural features: Variance (a), Skewness (b), Kurtosis (c), Standard Deviation (d)

Classification and wreck detection

There were six training samples of wreck location and 12 training samples of the non-wreck locations taken from the backscatter image and covered the entire image. Those samples were then trained in SVM to get the model that will be used for the classification. Afterward, the SVM model was used in the classification of a backscatter image. The result of the classification can be seen in Figure 6.

It can be inferred that the result of classification still contains several non-wreck features (terrain) that were classified as a wreck. It is assumed that the texture features used in the classification did not work quite well to detect the wreck. Thus, it needs another feature for the final detection. For that reason, the slope feature became a suitable combination feature for wreck detection. The classified image and slope feature were then overlapped using "*Boolean And*" tool in ArcGIS (result in Figure 7).

The result of wreck detection indicates that the wreck position can be accurately recognized. Although there are still a few issues of miss-detection of channel edge, however, the number was significantly reduced compared to the previous input features (slope, as well as Support Vector Machine/SVM results).

The result of segmentation (Figure 8(b) revealed that the soft seabed is more dominant than the hard seabed (56.4% and 43.6% respectively).

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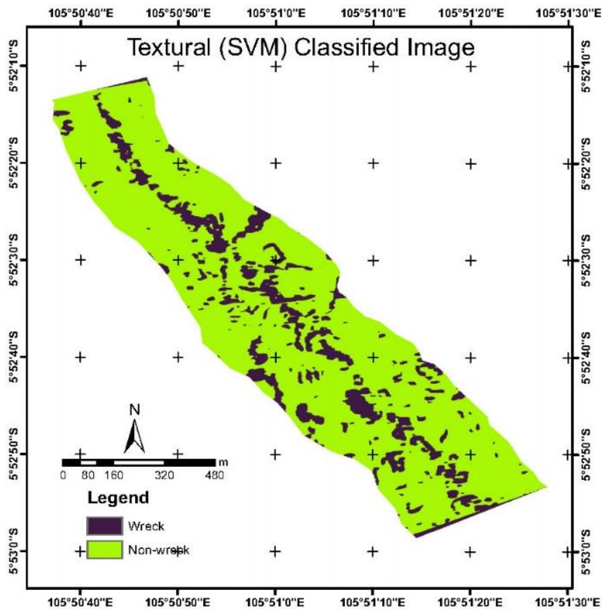

Fig. 6: Result of SVM classification

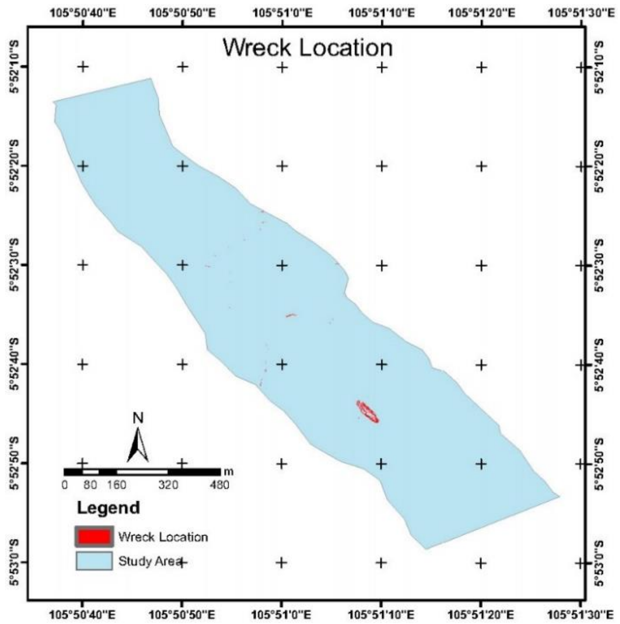

Fig.7: Result of wreck location detection

Morphology characterization

In order to get a general overview of the seabed morphology of the study area, the backscatter image was segmented using K-means clustering into two classes (hard and soft seabed). The result can be seen in Figure 8(a).

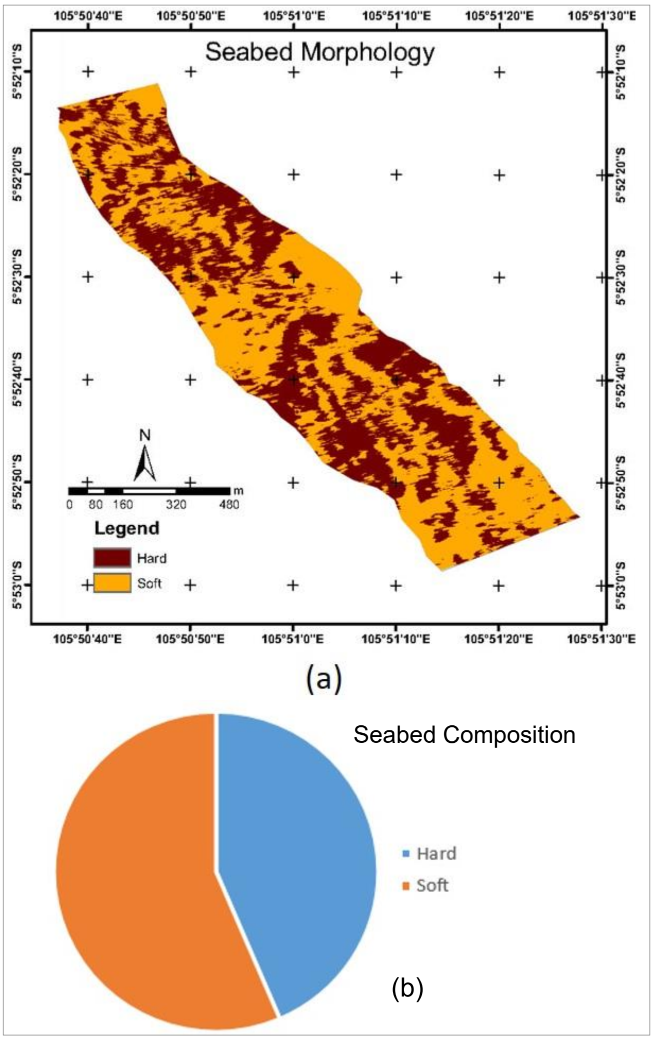

Fig. 8: K-means result of seabed morphology (a), percentage of seabed composition (b)

The study area is the northern slope of the Sunda Strait channel and lies closer to Sumatra Island. Astawa & Wayan (2014) reported that this seabed area covered by igneous rock (interpreted as andesite and diorite), volcanic rock, and sedimentary rock. In addition, Novico et al. (2015) conducted numerical modelling of the current condition at Sunda Strait and was found that the current velocity was up to 4.6 m/s, which possibly could cause sub-aerial erosion.

These conditions are also represented by seabed morphology in this research. Based on the segmentation result, the distribution of seabed geomorphology could be classified as igneous rock and volcanic rock for hard seabed and sedimentary rock and tuff for the soft seabed. Furthermore, the composition of soft seabed slightly dominant that controlled by current velocity.

Discussion

This study investigates two applications in the use of multibeam products (bathymetry and backscatter) for underwater wreck detection (study case: MV Bahuga Jaya) and seabed morphology depiction. Features extraction was carried out of bathymetry (slope feature) and backscatter (textural features). Support Vector Machine then was examined to classify the textural features and with combination with the slope, it used to detect the wreck location. In addition, a K-means clustering was also used to characterize the seabed morphology by segmenting the backscatter image into two classes (hard and soft).

The result of bathymetry depicts a clear seabed topography with some interesting features (wreck location and seabed channel) that are clearly portrayed. Although in visual, the wreck is easily detected, however, the visual interpretation would be rather helpless in detecting many seabed features (e.g. man-made debris, outcropped rocks etc.). Thus, a more automatic method, such as the one that has been tried in this study is required. The resulted backscatter image has a noise at the nadir of the image (bright line in the centre of the image). This is because the near-vertical angles of incidence (nadir) have a strong variation of backscatter value and need to be removed for further analysis. Detailed explanation of methods in removing angular dependence can be found in several papers (Kloser et al., 2010; Parnum & Gavrilov, 2011).

In this study, the slope feature generally is adequate for detecting the wreck location. However, since there is a steep edge of the channel, it can mix with the detected wreck itself and therefore requires additional features. Vector Ruggedness Measure (VRM) is another morphometric feature that could be examined. The VRM represents seafloor ruggedness (3D orientation variation of grid cells within neighbour pixels) and could depict the variety of slope and aspect (SAPPINGTON et al., 2007). For instance, Pirtle et al. (2015) demonstrated the use of Vector Ruggedness Measure (VRM) to classify the trawlable and untrawlable seabed regions.

The two resulted textures (Variance and Skewness) were chosen for the classification due to their capability to distinguish between the wreck and non-wreck features (terrain). It seems that the Kurtosis feature cannot depict a clear feature of the wreck and it tends to mix with the surroundings. In addition, the brighter tone at the nadir in the Standard Deviation feature is probably due to the effect of non-removed angular dependence in the backscatter image. This effect could lead to non-optimal results in the classification, though the wreck tends to have a noticeable visual appearance with surroundings. However, this study has not tried to examine the use of second-order texture analysis. The second-order texture such as Grey Level Co-occurrence Matrix (GLCM) could be a promising subject. This method has been successfully demonstrated in backscatter classification as proven by Hamilton (2017), Buscombe (2017), and Hamill et al. (2018). Febriawan et al. (2019) also argues that the combination of both first-order and second-order GLCM textures can give a promising result. As alternative to the feature selection above, a Principle Component Analysis of all features is interesting to investigate. However, it was not a part of this study and could be a direction for future research.

Angular dependence also leads to the nadir effect in the SVM classified image. Although the textural features used in the classification could predict the wreck location quite well, a number of miss-classified wreck features exist in the nadir and reduce its accuracy. Removing angular dependence could lead to a smoother result and improve the accuracy assessment. The final detection map shows that the combination of SVM classified image and slope feature has demonstrated that it can lead to a good performance in wreck detection. This research has also verified that SVM could be a promising method in shipwreck detection and classification with limited numbers of training samples with a clear margin of separation between classes (e.g. wreck and non-wreck). However, this method cannot perform conveniently with the noisy data (e.g. side-scan sonar and backscatter imagery) and could lead to some miss-classifications as proven in this study. Thus, other machine learning techniques need to be investigated. Some machine learning methods in archaeological studies such as fuzzy K-means for site maintenance (Malinverni & Fangi, 2009), neural network for archaeological sites formation study (Sharafi et al., 2016), and random forest classification for prospecting archaeological sites (Thabeng et al., 2019). Further study could use those other machine-learning methods in underwater shipwreck investigation.

In general, K-means segmentation used in this study also showed an adequate result to depict the distribution of seabed covers. However, field data samples are mandatory to achieve more reliable results and to reveal other information. For instance, Richards et al. (2016) carried out the in-situ preservation and long-term monitoring for the archaeological shipwreck site. They found that biogeochemistry is an important factor for that process since it could control the degradation of the shipwreck. Thus, further research regarding this topic is required. Richards et al. (2016) also argued that seabed morphology analysis could correlate to shipwreck preservation methods. Seabed features that can be found in the study area consist of a channel, slightly slope, hard and soft seabed characteristics. In general, seabed morphology is controlled by geological activities (e.g. earthquake, fault zone, erosion, and Krakatau eruption). They are implied to sediment grain size and transportation process (e.g. gravity mass flow and suspended sediment). In this study, the wreck site itself lays on the soft seabed and low-medium slope, but is surrounded by both seabed type and low-high slope. Thus, the wreck site may be affected by covered sediment and/or partly moved. This site is also closed to a deep valley and has regional seabed landslide potential (Yudhicara & Budiono, 2008). For that reasons, regular monitoring of the shipwreck site using the same method in this study is required to get comprehensive and continued results.

Conclusion

This study attempted to investigate the use of bathymetry DEM and backscatter image resulted from multibeam swath survey. The combination of Support Vector Machine classification and Slope analysis of the data was carried out to detect the Bahuga Jaya wreck location. Derived from the backscatter image, first-order textural features were used as parameters for the SVM. Based on the texture analysis, the most suitable ones were variance and skewness textures. The backscatter image then was classified into two classes (wreck and non-wreck). Slope analysis was conducted using bathymetry DEM and successfully removed almost all of the non-wreck objects (terrain seafloor) using a slope threshold of 55°. The combination of SVM classification and Slope analysis has been demonstrated as a promising tool for detecting the wreck location.

Additionally, K-means clustering of the backscatter image was conducted to characterize the region into two classes: hard and soft seabed. According to the segmentation result and other research, 56.4% of the area consists of the soft seabed (there were presumably sedimentary rock and tuff), which was influenced by current velocity and sub-aerial erosion. Conversely, 43.6% of the area was hard seabed, probably igneous rock and volcanic rock. Since the wreck was surrounded by the soft seabed and low-high slope, sediment could potentially cover the wreck or could move the wreck's body. Although the K-means clustering showed a potential result, a more accurate outcome could be achieved by applying ground reference samples.

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Assessment of spatial changes of land use/land cover dynamics, using multi-temporal Landsat data in Dadri Block, Gautam Buddh Nagar, India

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Abstract

The present work aims at presenting certain important observations on food and water security of the peri-urban environment, by considering field data and satellite image classification to understand the spatial change pattern of natural resources and its impact on agriculture and water resources. Gautam Buddh Nagar is considered one of the important urban areas of the National Capital Region (NCR), being associated with multi-functional activity; it continues to grow in terms of infrastructure and other urban activities and the numerous infrastructural projects and other anthropogenic actions in the area cause a rising pressure on water, agriculture, and human health. The Landsat satellite images from 2000, 2005, 2010, and 2016 were classified and used to obtain the Land use / Land cover maps of the area, in order to estimate and to understand the rate of change during the last 16 years. There are mapped the important land use classes, such as the agricultural land, the vegetation surfaces, the built-up areas, the open land, and the water bodies. The results indicate the fact that during the 16 years taken into study, vegetation (2.26%), water bodies (1.65%), and agriculture (3.5%) undergone a major decline, while the built-up land displayed values increased around four times (from 3.39% to 12.26%). The results of the present work clearly showed that the large-scale changes in natural land cover affected the agriculture, as well as the surface and groundwater resources of the area.

Keywords: *Land use, Satellite image classification, Dadri, India*

Rezumat. Evaluarea modificărilor spațiale asociate dinamicii utilizării/acoperirii terenurilor, folosind date Landsat multi-temporale, în unitatea administrativă Dadri, Gautam Buddh Nagar, India

Lucrarea prezintă observații importante referitoare la securitatea alimentară și a apei din mediul periurban, luând în considerare datele din teren și clasificarea imaginilor satelitare pentru a înțelege tiparele modificărilor spațiale ale resurselor naturale și impactul lor asupra agriculturii și resurselor de apă. Gautam Buddh Nagar este una dintre zonele urbane importante ale Regiunii Capitalei Naționale, fiind asociată activității multifuncționale; numărul mare de proiecte de infrastructură în continuă dezvoltare, precum și alte activități antropice în zonă determină o presiune crescândă asupra apei, agriculturii și sănătății umane. Imaginile satelitare Landsat din 2000, 2005, 2010 și 2016 au fost clasificate și utilizate pentru a obține reprezentarea utilizării/acoperirii terenului din zonă, pentru a estima și a înțelege rata modificărilor din ultimii 16 ani. Sunt cartografiate clasele importante de utilizare a terenului, precum terenurile agricole, vegetația, terenurile construite, terenurile deschise și corpurile de apă. Rezultatele indică faptul că în cei 16 ani vegetația (2,26%), corpurile de apă (1,65%) și terenurile agricole (3,5%) au înregistrat un declin major, în timp ce suprafețele construite au câștigat aproximativ de patru ori mai mult teren (de la 3,39% la 12,26%). Rezultatele lucrării arată clar că extinsele modificări ale acoperirii naturale a terenurilor afectează agricultura, precum și resursele hidrografice locale de suprafață și subterane.

Cuvinte-cheie: *Utilizarea terenurilor, clasificarea imaginilor satelitare, Dadri, India*

Introduction

Urbanization is a continuous process and unplanned urbanization leads to many natural, environmental, and social issues. Land use / Land cover changes in the peri-urban areas create many problems such as a change in water quantity and quality, agricultural land loss, and urban environmental issues. The society today is already in the mainstream of another revolution, the information revolution, due to those massive changes to life and living, providing new approaches to resource mapping and monitoring. Land-use change is a combined activity of natural and anthropogenic activity, mainly affecting the natural resources and the environment (Singh et al. 2012). The assessment of land use patterns of any terrain is an important aspect for natural resources evaluation and their management. Climate changes are the significant driver for the modification of the land resources, and they are the main component of spatially and temporally changes in land use patterns. Apart from climate changes, anthropogenic activities such as deforestation, overexploitation of natural resources, rapid urbanization, the impact of pesticides, and other human influences have significant changes in land-use categories. Satellite-based earth observation and monitoring is a very scientific and useful tool for the proper management of the natural resources (Vishwakarma et al., 2016; Verma et al., 2019).

In developing countries like India, efforts are being made for sustainable land resource planning and management, with reliable and updated geoinformation, which is the pre-requisite for land use planning. Such information could only be obtained through modern techniques and equipment for research and mapping. Since land use and land cover changes are powerful features over space and time, it is challenging to obtain real-time information through conventional resources, and these methods are time-consuming, laborious, high cost, and workforce oriented. In modern times, satellite-based remote sensing technology has been developed, which are of immense value for preparing LULC map and their monitoring at regular periodic intervals of time (Kumar et al., 2004; Rao et al., 2006; Chaudhary et al., 2008; Singh et al., 2012). Remote sensing offers unique perspectives to study the land use/land cover and their changes, because it provides spatially explicit and synoptic views of the landscape that are available over time. It is, therefore, able to provide detailed information from individual resources to regional and local change. Earth observation technology plays an important role in providing information on landscape mapping and monitoring to help the management of natural resources. Remote sensing provides the basic data to undertake an inventory of land, as well as the temporal information required to monitor sustainable land management.

Remote sensing data, along with an increased resolution from satellite platforms, makes these technologies appear poised to induce a better impact on land resource management. Initiatives involved in monitoring LULC mapping and change detection at varying spatial ranges in semi-arid regions are undergoing severe stresses due to the combined effects of the growing population and climate change. Recent advances in remote sensing and geographic information system (GIS) techniques allow researchers for mapping, analysis of land cover/use, and model the growth rate of urban areas. Images of remotely sensed satellite give excellent data that contain efficient information about land cover/ use. It can be easily extracted, simulated, analyzed by GIS techniques with better accuracy in less time, and low cost (Alberti et al., 2004; Rai et al., 2011; Mishra et al., 2014 & 2016; Kikon et al., 2016; Mishra & Rai, 2016; Chaudhuri et al., 2017 & 2018; Singh & Rai, 2017). Dadri block of Gautam Budh Nagar is one of the important agricultural and fast-growing suburban areas, where numerous urban and industrial projects take place and the development continues. In the present work, recent satellite data covering 16 years were classified, and changes were analyzed in order to understand the spatial changes in the land-use practices, particularly in agriculture and built-up land and their possible short term and long-term impact on food and water security.

Study Area

Dadri is a Nagar Block of Gautam Buddha Nagar, Uttar Pradesh, India and it represents an important sub-urban area of National Capital Region (NCR), Delhi. The Dadri block extends between the 28°25′–28°40′N latitude and 77°30′–77°40′E longitude. It covers an area about 203 km2 (Fig. 1).

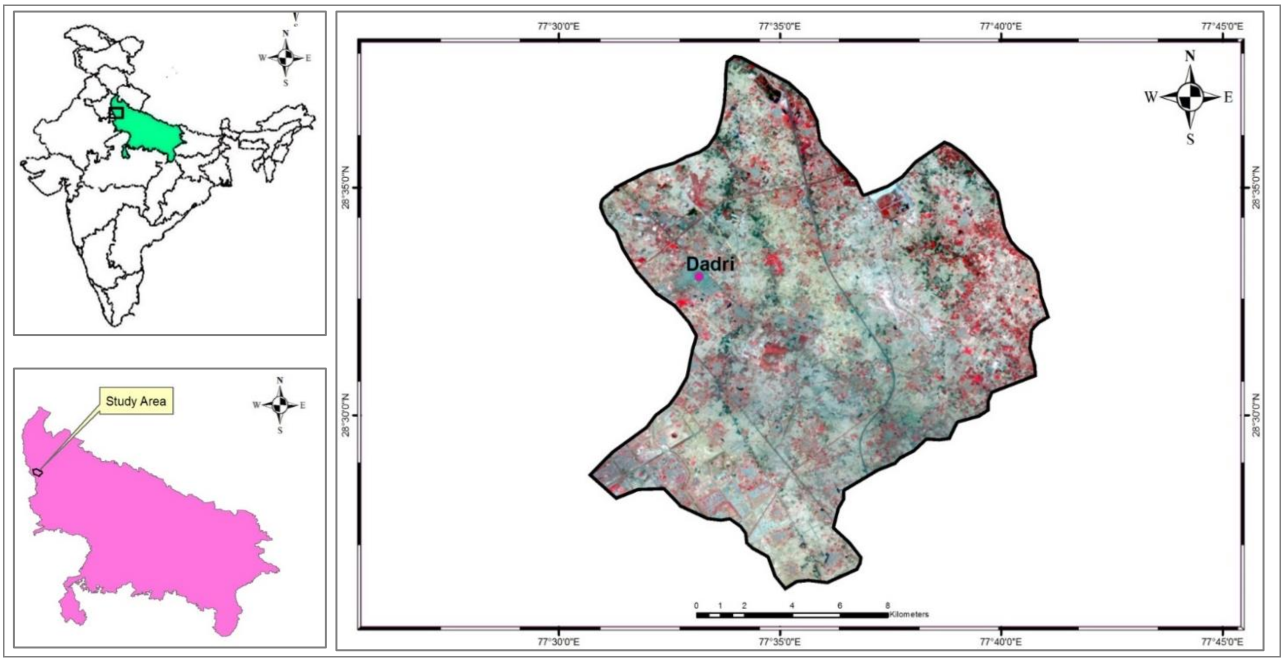

Fig. 1: Location of Dadri Block, Gautam Budh Nagar, India, as viewed on Landsat data (OLI TIRS) of 2016

It is located 25 km towards north from the District headquarter of Noida and 445 km towards East from State capital of Lucknow. Topographically, the area comes under the Indo-Gangetic plain and two important rivers flowing in the area, namely the Hindon and the Yamuna rivers, represent the major sources of water for irrigation purposes. The elevation of the area is 210 m above mean sea level (MSL). As per the Indian Meteorological Department, Pune (India), the temperature of the area variates from 23°C to 44°C in the summer, while the lowest temperature in the winter season reached up to 4°C. The region comes under the semi-arid climatic zone and the average rainfall in the area is around 790 mm. The area is characterized by the fertile soil of Ganga alluvial plain, with major crops such as rice, wheat, sugarcane, barley, mustard etc. The block has a very high growth rate in terms of population, due to the large number of industrial activities in the area and it continues to increase. At the 2011 Census, the block had a total population of 91,189 persons, out of which 48,856 are males and 42,333 are females. The literacy rate of the Dadri is 74.37%, which is higher than the state average (i.e. 67.68%).

Data and Methodology

During this study, multi-temporal Landsat data sets for the years 2000, 2005, 2010, and 2016 were used for the development of land use / land cover maps and for the assessment of spatial changes in the area (Table 1).

The standard image processing techniques were used to develop the signature file for each land-use class and the classification of the images was conducted by using the ERDAS Imagine and Geomatica software. The analysis of land use/ cover hybrid classification process has been used along with the field verification.

Field visit has been carried for ground truth verification of the classified data, using the GARMIN Oregon 550 GPS receiver. The ground truth data were used as the reference data point collected by using Geographical Positioning System (GPS) for image analysis, these data used for image classification and overall accuracy assessment of the classified data.

The study aims to assess the urban growth and its impact on the natural resources of Dadri town. Land use/land cover is prepared by hybrid classification (visual interpretation and unsupervised classification), and spatial statistics have been calculated using ERDAS Imagine software. After the classification and mapping of all the data sets, the spatial change assessment has been performed. An accuracy assessment has been performed for all the classified maps using the kappa coefficient to assess the mapping accuracy. Five major land use/cover classes are identified in the study area (i.e. vegetation, agricultural land, built-up land, water bodies, and open land/construction sites).

Table 1 Data used in the study

Satellite data	Path & Row	Spatial resolution (m)	Date acquired	Cloud coverage	Source
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	08-10-2000	0%	https://earthexplorer.usgs.gov
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	22-10-2005		
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	20-10-2010		
Landsat 8 (OLI TIRS)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic), 100 m (Thermal)	09-10-2016		

Results and Discussion

Temporal Land use / Land cover change monitoring

Assessment, identification, and mapping of land cover/land use and its temporal changes over time represent important steps towards land management. Land cover/land use has been used extensively to derive several variables, such as built up, vegetation, biomass, water bodies, and other landscape features. Land use/ land cover pattern and its changes produce the underlying natural and social processes, thus providing essential information for understanding many different phenomena within the area. Periodic land use mapping and its temporal change assessment represent a necessary requirement for the sustainable land, water, and environmental management of any area (Singh et al. 2012; Somvanshi et al. 2020).

Land use/land cover mapping using temporal Landsat satellite data for the study area has been carried out to understand the major land-use practices in the area and its spatial-temporal change pattern from 2000 to 2016. The land use pattern under study is that of Dadri block, which covers urban and suburban parts of the Gautam Budh Nagar district, being an important city in the National Capital Region (NCR), Delhi.

The demographic size of the study area increased very fast; as revealed by the 2001 to 2011 Census data, the area has witnessed around 186.64% growth in population. Due to the speedy growth in population in the study area, many changes took place in terms of built-up land, industrial growth, and many other land conversion practices, which have a negative impact on natural resources. A standard hybrid image classification technique has been applied for the generation of LULC maps of the different years of the Dadri block for the year 2000, 2005, 2010 and 2016. Based on classified images, it has been observed that the major classes are agricultural land, vegetation areas, built-up areas, open land, including under-construction sites and water bodies. The final classified images were crossed, checked and verified in the field before the final calculation of the spatial distribution of the land use classes. The observed results from the classified data indicate that the large-scale changes in land-use practices were taken place in the area in the last 16 years.

It is observed that the vegetation cover undergone a change from 8.08 % in 2000, its decreased value reaching up to 6.80 due to the construction activity in the area. Important surfaces occupied by water bodies, in the form of small streams and wetlands, get degraded (from 3.71 % in 2000 to 2.06%) due to large scale changes in the landscape and overutilization of water bodies for agriculture and other development projects in the study area. The next important land use practice in the area and around was agriculture (78.71% in 2000) and it decreased up to 75.19 %, including many other non-agricultural areas.

Dadri is considered a rural area, having a large number of villages and being mainly associated with agricultural activities in the region, due to the fertile soil and to the availability of water resources for irrigation purposes. During the last two decades, it is observed that many changes took place in the Dadri block, such as those concerning the built-up region, with many industries occupying the area, as well as numerous big projects that are approved for development in the near future. The built-up area has extended at a very fast rate as compared to other land uses; the total built-up surface was 3.39 % in 2000 and increased up to 12.26 % in 2016. It is also observed that the open land, including wasteland and extended wetlands in the area, also undergone a decrease from 6.12% to 3.69%.

The overall changes marked the natural landscape and they severely affected groundwater quality/quantity, the urban temperature, also giving raise to pollution problems in the area. The total spatial changes and land use maps are presented (Table 2 & Fig. 2).

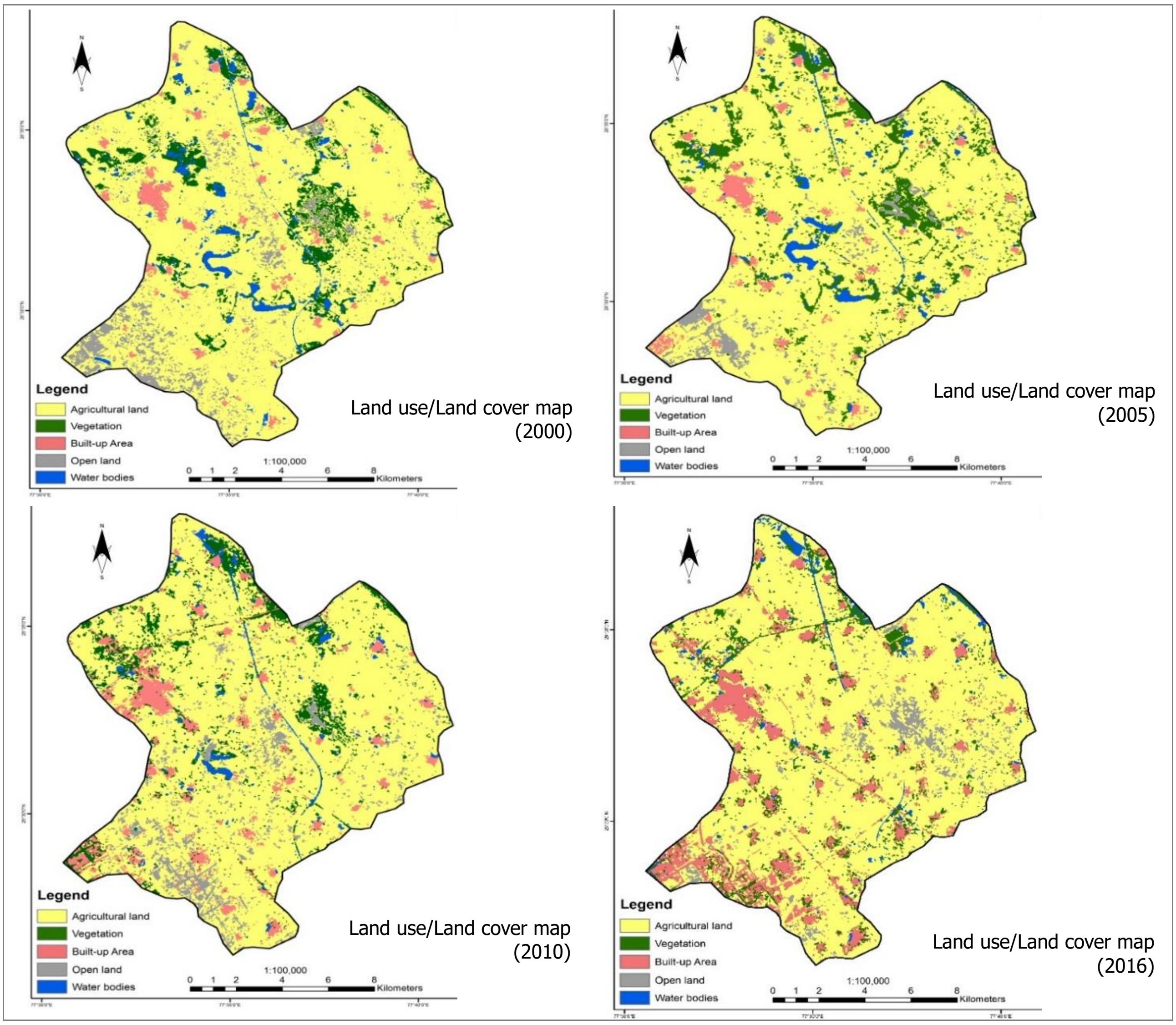

Fig. 2: Land use/Land cover changes within Dadri Block in 2000, 2005, 2010, and 2016

Table 2 Spatial changes in different Land use/Land cover classes in the area between 2000 and 2016

LULC Classes	2000 area		2005 area		2010 area		2016 area	
	sq.km	%	sq.km	%	sq.km	%	sq.km	%
Vegetation	16.41	8.08	22.03	10.81	16.82	8.25	13.85	6.80
Water bodies	7.53	3.71	6.08	2.98	3.90	1.92	4.20	2.06
Agricultural land	159.99	78.71	159.71	78.38	156.20	76.62	153.29	75.19
Built-up area	6.88	3.39	8.02	3.94	14.41	7.07	24.99	12.26
Open land	12.45	6.12	7.91	3.88	12.54	6.15	7.52	3.69
	203.27	100.00	203.76	100.00	203.86	100.00	203.86	100.00

The Accuracy Assessment

The accuracy assessment of classified land use/land cover maps is one of the important steps in the classification process for validation and verification, before the finalization of the maps. The purpose of accuracy assessment is to quantitatively check the land use classes with the reference sampled land-use classes. Assessment of accuracy includes the comparison of the different class of classified data to the reference data of the same location (Lachowski, 1996).

The overall accuracy of the classified maps of 2000, 2005, 2010, and 2016 was obtained as 99 %, 98%, 91.25 % and 93.33 % (Tables 3 & 4). The kappa coefficient of the years 2000, 2005, 2010, and 2016 classified LULC were recorded as 0.97, 0.96, 0.89, and 0.83, respectively (Table 4). All values of Kappa coefficient are above the 0.80, which indicates that the hybrid classification method has extracted very well the time-series for the analysis of land use/cover of the study area (Alexakis et al., 2012).

Table 3 Producer and user accuracy of classified images

Class Name	2000 accuracy (%)		2005 accuracy (%)		2010 accuracy (%)		2016 accuracy (%)	
	Producers	Users	Producers	Users	Producers	Users	Producers	Users
Water bodies	100	100	75	100	100	100	---	---
Vegetation	85.71	100	87.50	100	75.00	100	100	100
Agricultural land	100	98.68	100	97.47	98.25	90.32	100	91.67
Built-up area	100	100	100	100	72.73	88.89	66.67	100
Open land	100	100	100	100	66.67	100	66.67	100

Table 4 Overall accuracy assessment results of classified images

Year	Classification accuracy (%)	Kappa statistics
2000	99	0.9759
2005	98	0.9672
2010	91.25	0.8946
2016	93.33	0.8315

Conclusions

The long-term land use/land cover mapping through remote sensing data provides essential information about the area, on the temporal aspect.

There are mapped the important land use classes, such as the agricultural land, the vegetation surfaces, the built-up areas, the open land, and the water bodies. The results indicate the fact that during the 16 years taken into study, vegetation (2.26%), water bodies (1.65%), and agriculture (3.5%) undergone a major decline, while the built-up land displayed values increased around four times (from 3.39% to 12.26%). The results of the present work clearly showed that the large-scale changes in natural land cover affected the agriculture, as well as the surface and ground-water resources of the area.

Based on the above summary, it can be concluded that the rapid increase and expansion of the urban area, especially of the built-up land, can be a major factor for loss of agriculture, surface and groundwater resources, increase surface runoff, reducing natural groundwater recharge and many other environmental issues such increasing the LST. Based on the observations from the present work, it is clearly indicated that the use of satellite data for land use mapping and change assessment is an important aspect of sustainable land, water, and environmental management. It is also suggested that appropriate measures are required in the area for the conservation of local natural resources, because more constructions will be made soon in order to accommodate the increasing population. The observations of the present work prove that satellite-based image classification and mapping of land use lead to important data for urban planning and management. The quantification of LULC changes of Dadri town and its impact is very useful for environmental management and resource planning.

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Delineation of rural-urban fringe of Indian town: a case study of Uluberia Municipality, Haora

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Abstract

In India, most urban centres are expanding very rapidly both spatially and demographically. This expansion refuels the process of urbanization and spreads urban characteristics to peripheral regions. As a result, the rapid growth and expansion of urban areas to its surrounding rural hinterlands fosters unplanned and haphazard development and makes the area even more complex. Over time, the distinction between rural and urban gradually disappears, so that a new type of structure would emerge in city outskirts which is characterized by mixed forms of land-use, socio-economic activities and termed as rural-urban fringe. The paper delineates rural-urban fringe of Uluberia municipality based on selected indicators of demographic structure and economic services. Urbanity Index and Composite Urbanity Index have been used for the delineation of rural-urban fringe. Four fringe zones of Uluberia municipality have been identified and termed by applying the Mean±Standard Deviation technique.

Keywords: *rural-urban fringe, delineation, urbanity index, composite urbanity index.*

Rezumat. Delimitarea franjei rururbane: municipalitatea Uluberia, districtul Haora, India ca studiu de caz

În India, majoritatea centrelor urbane cresc foarte rapid atât spațial, cât și demografic. Această extindere alimentează procesul de urbanizare și diseminează caracteristicile urbane către regiunile periferice. Ca urmare, creșterea și extinderea rapidă a zonelor urbane către cele rurale înconjurătoare favorizează dezvoltarea neplanificată și întâmplătoare și transformă arealul într-unul cu atât mai complex. De-a lungul timpului, distincția dintre rural și urban se atenuează treptat, astfel că un nou tip de structură apare la marginea orașelor, caracterizată prin forme mixte de utilizare a terenului, activități socio-economice și denumită franja rururbană. Lucrarea delimitează franja rururbană a municipalității Uluberia pe baza unor indicatori selectați de structură demografică și servicii economice. Indicele de urbanitate și Indicele de urbanitate compus au fost utilizați pentru delimitarea franjei rururbane. Au fost identificate și denumite patru componente ale franjei municipalității Uluberia utilizând Media±Deviația Standard.

Cuvinte-cheie: *franjă rururbană, delimitare, indicele de urbanitate, indicele de urbanitate compus.*

Introduction

Nowadays, Rural-Urban Fringe (henceforth RUF) is one of the most demanding and debatable contexts in the field of urban geography (Pryor, 1968; Scott et al., 2013). A developing country like India possesses one of the largest urban systems in the world. The total urban population in the country is more than 377 million persons, constituting 31.2 percent of the total population, with a growth rate of 2.76 percent/year in the last decade (Census of India, 2011; Kolhe and Dhote, 2016). The present trend of rapid urbanization process immensely influences the socio-economic as well as spatial development of an urban centre and its peripheral regions.

The fringe area represents the transition zone where rural is sequentially transformed into rurban, next to urban areas. The word RUF is combined with two different terminologies i.e. 'rural fringe' and 'urban fringe'. In 1937, T. L. Smith first used the term 'urban fringe' to describe "the built-up area outside the corporation limits of the city" but the concept of RUF was developed and popularised by R. J. Pryor in 1968. RUF is a frontier rather than a boundary which lies between urban and rural land-use where spread effect or centrifugal force plays an important role for landscape development (Marchand and Charland, 1992; Pryor, 1968). It is a transitional and dynamic zone located beyond the corporate limits of a legal city, sometimes exterior to suburban area. Several authors have discussed the characteristics of RUF includes mixed land use, low taxation, inhabitants engaged both in rural and urban occupations, lack of urban utilities, high population growth and density but less than in central city (Andrews, 1942; Kurtz and Eacher 1958). The proper taxonomy of RUF is very complicated, although many urban researchers have classified RUF into various zones such as suburb fringe, urban fringe, rural fringe and urban shadow. Suburb fringe is a contagious area to the central city with high proportion of non-farm land use; maximum residents engaged in city occupation and provide a few municipal services (Jindrich, 2010; Kurtz and Eacher, 1958). Urban fringe includes the low rurality in nature and high urbanity in approach, intermediated between the suburb and rural fringe (Lal, 1973; Mukherjee, 1963; Myers and Beegle, 1947; Sharp and Clark 2008) whereas rural fringe includes high rurality and maximum lands occupied by farm activities with a

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lower rate of land conversion (Pryor, 1968; Sinclair, 1967; Singh, 1967). Urban shadow is somehow similar to the rural area and is known as 'rural hinterland' (Piorr, 2011).

The indicators and methods used for fringe delineation are very much diversified just as the multiplicity of fringe definitions (Mustak et al., 2018; Pryor, 1968). The indicators used for the delineation of fringe not only vary from developed to developing nations but also vary from city to city in the same country. Variables for the delineation of rural-urban fringe are usually based upon functional linkage of the city with its surrounding area. Several authors have worked on the rural-urban fringe delimitation taking a variety of indicators (Table 1). Non-village population, rural non-farm population (Myers and Beagle, 1947), farm size, internal migration, public utilities, land value (Golledge, 1960), population density (Fesenmaire et al., 1979; Sharp and Clark, 2008) etc. are used for fringe delimitation in developed countries. Along with India, most of the developing countries have used built-up area, house type, pattern of streets (Singh, 1966), children school, population density, population growth rate, gender ratio, electricity consumption, water supply (Alam and Khan, 1972), isochrones, urban influence (Sinha, 1974), milk supply and vegetable supply (Nisha, 2015) and bus service (Arif and Gupta, 2018) etc. for fringe delineation. In developing countries, delineation of RUF depends on census data and functional relationship between the city centre and its rural hinterland (Doan and Oduro, 2012; Khan and Munir, 2017). Detroit fringe was delineated and classified into two groups based on NV-RNF (non-village, rural non-farm) population (Myers and Beegle, 1947). Land use data (from aerial photos) and census data (1951 and 1966) used for delineation of Melbourne urban fringe and also delineated outer suburb from the urban fringe (Pryor, 1969).

The RUF of Patna city in Bihar and Indore in Madhya Pradesh were delineated by using 'Urbanity Index' and 'Scale of Urbanity'. Accordingly, the RUF was classified into two groups, i.e. inner fringe and outer fringe by applying upper quartile (Q3), median quartile (Q2) and lower quartile (Q1) (Saxena and Vyas, 2016; Singh and Vyas 2014; Sinha, 1980). Superimposing of a series of maps based on several indicators is used to delineate the fringe region of KAVAL towns and Hyderabad metropolitan (Alam and Khan, 1972; Dube, 1976; Singh, 1966). Fringe areas of Delhi metropolitan were demarcated by using various heterogeneous factors and a 'stage model' also prepared to show the transformation of village into a metropolis (Nangai, 1976; Srivastav and Ramachandran, 1974). Based on the administrative unit, five fringe zones of Calcutta Metropolitan (now Kolkata Metropolitan; 1st of January, 2001) are delineated (Ganguli, 1967). The primary and secondary fringe of Jammu city has been delineated by applying Mean±Standard Deviation (SD) method (Nisha, 2015). Occupational, socio-cultural, spatial, structural and ecological characteristics of sub-urban, fringe area and rural area are examined to distinguish the inner and outer portions of the RUF (Carter, 1972; Newman and Applebaum, 1989; Sharp and Clark, 2008). Economic and social characteristics in the fringe zone were also considered adequate indicators for delineating the RUF (Duncan and Resse, 1956; Rao, 1982). Moreover, urban demand for agricultural land of RUF is an important criterion for fringe delineation (Hady, 1970; Hushak, 1975; Kumar, 1980; Relph and William, 2001; Sullivan et al., 2003; Zasada, 2011). Land use structure and land use policy in the RUF are examined in order to delineate the fringe zone and also considered as having particular importance for urban morphological planning, urban land use planning and sustainable management of land resources (Ban and Hu, 2007; Lawrence and Jeff, 2003; Wehrwein, 1942). Arif and Gupta (2018), Khan and Munir (2017), Mustak et al. (2018), Saradar and Hazra (2014) etc. also delineated the fringe region of different non-primate urban settlements such as: Aligarh, Raipur, Burdwan in India. In this regard, internet cafe services, market availability, accessibility of metalled road are recently taken into consideration as useful indicators in delineating non-primate cities' fringe. As a result, these indicators have been used in this paper along with Uluberia municipality's sphere of influence, which determined the exterior boundary of its RUF.

In addition to these indicators, a variety of methods for RUF delineation were also carried out. Most of the earlier studies in developed countries used statistical techniques (Fuzzy analysis, Cluster analysis etc.). The applicability of this method is very complicated for developing countries and needs enormous statistical knowledge and expertise. But most studies in developing and underdeveloped nations applied two methods, i.e. superimposed maps one over other (sieve method) and the urbanity index method. The significant drawback of the sieve method is the fact that the external fringe boundary is not fixed; it varies from researchers to researchers by using the same set of indicators and study area (Singh, 1980). On the other side, the urbanity index and composite urbanity index have the convenience of easily identifying the intensity of urban way of life around the urban area, cultural dimension and infrastructural growth of the cities (Mustak et al., 2016; Singh, 1980). The term 'urbanity' is understood as degree of urbanization, mostly used to measure the relative urban nature of a place (Karg et al., 2019; Saksena et al., 2014). This method also accurately identified the proper rural-urban gradation. The parameters of urbanity index are usually related to demographic data, socio-economic data and different rural-urban services, although country-specific diversification may also exist.

Table 1 List of indicators used for fringe delineation in different countries

Types of Country	Author(s)	Study area	Criteria used for fringe delineation
Developed countries	Myers and Beagle (1947)	Detroit, USA	Non-Village population, Rural Non-Farm population (NV-RNF) and earlier minor civil division units
	Golledge (1960)	Sydney, Australia	Farm sizes, population density, internal migration from inner city areas to the outer suburbs, housing density, non-urban land, provision of public utilities (water, gas, electricity, sewerage, public transport, paved roads, footpaths and street lighting), land values
	Mukherjee (1963)	Orlando, Florida, USA	Intensity of urban land use
	Pryor (1969)	Melbourne Metropolitan, Australia	Build-up area & density (collected from aerial photographs, 1951-1966), the construction of radial lines or vectors originating from the C.B. D
	Fesenmaire, Goodchild and Morrison (1979)	City of London, Ontario, Canada	Population density, proportion of non-farm residents, percentage of land in non-farm ownership, accessibility to the central city
	Sharp and Clark (2008)	Ohio, USA	Demographic indicators: population, density, population change, housing value, age of population, poverty, education, and income attributes; Occupational structure: employment in industries such as construction, manufacturing, agriculture, or professions
Developing countries	Hart and Partridge (1966)	Johannesburg (South Africa)	Land value, land utilisation, size of land, pattern of residential land development and its availability, accessibility of the land, household density, transportation facility
	Browder a, Bohland and Scarpaci (1995)	Bangkok (Thailand), Jakarta (Indonesia), and Santiago (Chile)	Basic migratory flows: direct rural to-peri-urban migration, step-wise interurban migration and intra-metropolitan migration; Employment Characteristics: sector of employment (agriculture, industry, construction etc.), gender of workers; Income generation: average monthly income, workplace location; land use data
	Zhao (2012)	Beijing, China	Migrant patterns, percentage of non-built-up area, growth rate of the population, transport and communication, growth rates in employment, housing price
	Yuhong (2016)	China	Non-agricultural households, quantity of industrial employees, non-agricultural permanent population, identify the village type, industrial enterprises.
	Singh (1966)	KAVAL towns, India	Built-up area and house types, types and patterns of streets, occupational structure of the inhabitants, site for large institutions and industrial establishments, presence of lime and brick-kilns, limit of essential services and distribution of children schools.
	Alam and Khan (1972)	Hyderabad metropolitan, India	Population density, population growth rate, gender-ratio, ratio of working population, electricity consumption, transport service, water supply, retailing, telephone and postal service.
	Sinha (1974)	Patna, India	Isochrones (time taken to reach corporation boundary of Patna), urban influence, Public utility services, land value, non-agricultural activities, number of families per house, population density, gender ratio, daily commuter, literacy, primary activities, agriculture activities, built-up area.
	Srivastav and Ramacharadran (1974)	Delhi Metropolis	Occupational structure, land-use pattern, interaction with the city, urban amenities and location characteristics.
	Lal, 1987	Bareilly, India	Ratio of non-agricultural workers, population density, rate of change in density, population growth, gender structure, literacy
	Singh and Vyas (2014); Saxena and Vyas (2016)	Chennai metropolitan, India; Indore City, India	Density, gender ratio, literacy rate, decadal growth, percentage of working population, percentage of main worker, percentage of marginal worker, percentage of cultivators, percentage of agricultural labour, percentage of other worker, number of household, size of household, distance from city centre, percentage of agricultural land, average land value, number of BPL families.
	Nisha (2015)	Jammu City, India	Economic Services: milk supply zone, the vegetable supply zone, mini bus service zone, commuters' zone, brick kilns zone; Demographic determinants: density of population, gender ratio, literacy rate; Occupational structure: ratio of non-agricultural workers.
	Mustak et al. (2016)	Raipur, India	Socio-economic data: population density, population growth, literacy, gender ratio; Occupational
			structure: non-agricultural workers; percent of urban land, accessibility (bicycle, auto, motorbike and city busses)
	Khan and Munir (2017)	Aligarh city, India	Economic determinants: milk supply, vegetable and fruit supply, daily commuters, transport services, educational services, medical services; Occupational structure: ratio of non-agricultural workers; Demographic determinants: population growth, population density, literacy, gender ratio, household density, pucca houses.
	Arif and Gupta (2018)	Burdwan city, India	Population density, decadal growth rate, literacy rate, female workers, non-agricultural workers, market availability, black topped road, bus services
Underdeveloped countries	Tabor (2013)	Finfine (Addis Ababa), Ethiopia	Population growth, net migration, housing density, land use, value of land, transport routes
	Karg et al. 2019	Tamale, Ghana	Urban built-up area, urban land use change, frequency of visits to city centre, non-farm employment, services: electricity, water, sanitation; Access: public transport, road density, distance to roads.

Source: author's processing from various literatures

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Study area

Uluberia municipality is a part of Kolkata Metropolitan Development Authority (KMDA) and is closer to Howrah Municipal Corporation. The municipality is located on the left bank of the river Hooghly (Fig. 1). Since 1982, it is the head-quarter of Uluberia subdivision and Uluberia C.D. block. The total geographical area of the Uluberia municipality is 33.72 square kilometers with a population of 230,000 inh. in 2011 (District census handbook, 2011). National Highway-6, railway lines (South-Eastern Railway) and state highway go through the municipality.

The fringe area of the municipality which covers a geographical area of 274.22 square kilometers and serves about 780,000 inhabitants is extended from 22º22′30″N to 22º36′30″N latitude and 88º0′0″E to 88º14′30″E longitude. The present study analizes 111 fringe villages and 44 census towns along the fringe area.

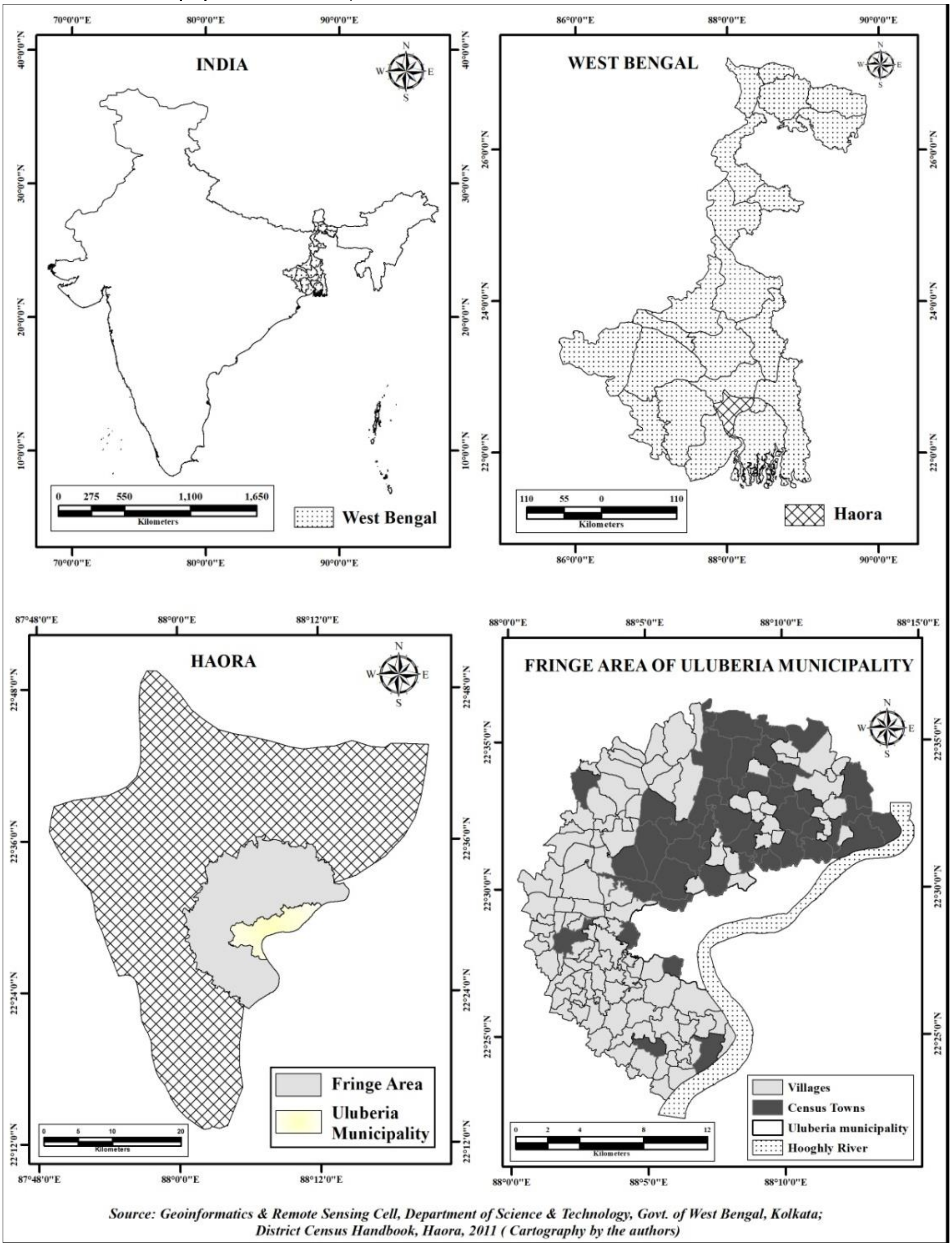

Fig. 1: Location of the study area

The studied municipality provides administrative, medical as well as educational services to its neighbouring region. Due to its contiguousness to Kolkata conurbation and Howrah municipality as well as Santragachi Railway junction, the municipality attracts important flows of migrants from different districts of West Bengal, Odisha, Bihar and Jharkhand fostering rapid growth of medium and small-scale industries. This huge influx of migrants from different parts of the nation significantly refuels the unorganised urbanisation process in the peripheral area with their heterogeneous socio-cultural traits. Without an appropriate infrastructural development and planning, the fringe area became ground of constant problems such as traffic congestion, land use, pollution, high population density etc. This persistent slum development impedes the progress of the settlement. To solve all those aforesaid problems, Uluberia municipality has immense responsability in delineating the rural-urban fringe (RUF) which could help the policymakers and urban planners for planning a smart urban growth and development in a more organised manner.

Data base and methodology

Socio-economic and demographic data were collected from District Census Handbook-Haora, District Statistical Handbook-Haora, Uluberia Municipality office and concern Block Development Authorities of Haora for the delineation of the sphere of influence and RUF zones of Uluberia municipality. Also, several essential thematic maps were obtained using Remote Sensing data and GIS tools.

a) The zone of influence or intermediate point between two cities i.e. Uluberia municipality and Howrah Municipal Corporation was demarcated by applying Converse's 'breaking point model'.

b) In order to delineate the RUF of Uluberia municipality the following methods were used:

- *Urbanity Index* (UI) - calculated for all sample villages and census towns, based on 11 variables. The value of the indicators decreases with the increasing distance from the central point of municipality as well as from fringe to the villages. Given these conditions, the formula of the urbanity index is:

UI = (F-V)/(T-V) ×100 (...............ii)

The calculated indicators' value increases as we move towards the villages and the index value also increases from fringe to village. In this situation, the formula of urbanity index stated as:

UI=(V-F)/(T-V)×100 (...............iii) where T, V and F are index value of factor for sample towns, villages and fringe, respectively.

- *Composite Urbanity Index* (CUI):

$$Composite\ Urbanity\ Index = \sum_{i=1}^{n} UI$$

(...............iv), where: n = number of variables and UI = Urbanity index.

Results and discussion

Identification of Uluberia municipality's sphere of influence

The sphere of influence of Uluberia municipality has been delineated by using P. D. Converse's 'breaking point model' (1949). By applying this model, 11 kilometers influence area of Uluberia municipality has been considered as study area. Total 111 villages and 44 census towns from seven blocks (Uluberia-I, Uluberia-II, Panchla, Sankrail, Amta-I, Jagatballavpur and Shyampur) are considered for the present analysis of RUF within 11 kilometers radial buffer zone from the central point of the municipality (Fig. 2).

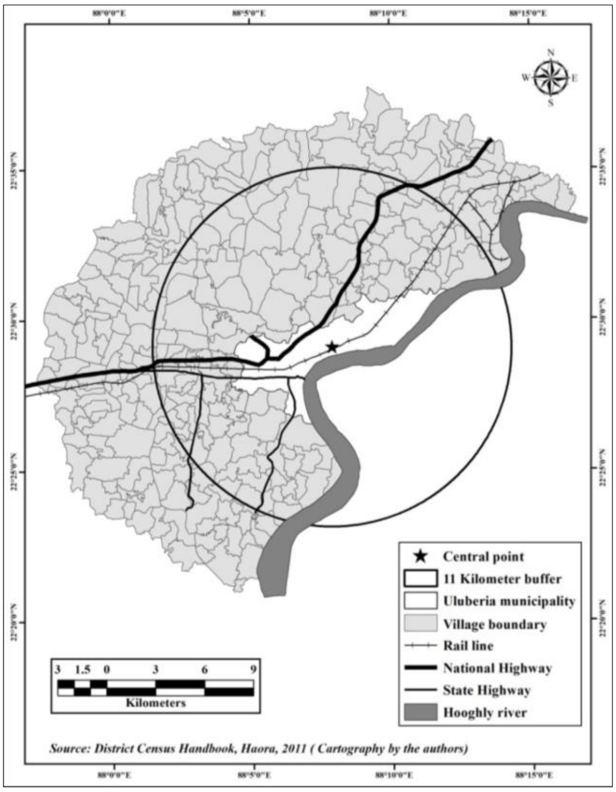

Fig. 2: Delineation of Uluberia municipality's sphere of influence (Source: District Census Handbook, Haora, 2011)

Delineation of Rural-Urban Fringe of Uluberia municipality

Considering the vast literature review, it is obvious that the indicators used for rural urban fringe delineation vary from developed nations to underdeveloped nations. Moreover, there are some common indicators

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used for the fringe delineation within the same country. But the nature and patterns of urbanisation are not the same for all. So, it was considered better not to tackle the indicators which were used to delineate the urban fringe of developed countries such as the western urban centres. Unlike developed countries, the land use pattern of developing countries is highly mixed in nature. Just as in India, most developing countries have used: land value, land use, plot size, household density, transport, migration, income etc. as indicators for fringe delimitation. The indicators should be based on the functional interaction of urban centres with their countryside and of course, the availability of data. A pilot survey in the study area helped us understand the functional interaction of Uluberia municipality with its surrounding villages and census towns. In fact, this helped out to set the indicators for delineation of rural-urban fringe of the study area. These indicators have been categorized into two groups, as following:

A. *Demographic determinants:*

i. Population density (persons per square kilometer)
ii. Population growth rate (percent)
iii. Household density (number of houses per square km)
iv. Gender ratio (number of females to 1000 males)
v. Literacy rate (percent)

B. *Occupation structure and economic services:*

i. Number of non-agricultural workers to the total workers (percent)
ii. Number of female workers to the total number of workers (percent)
iii. Availability of bus service (within 1 kilometer)
iv. Metalled road availability (within 1 kilometer)
v. Market availability (within 1 kilometer)
vi. Availability of internet cafes (within 1 km).

The Urbanity Index (UI) was calculated for all sample villages and census towns within the identified influence zone. Based on the UI value of eleven variables, four zones of the rural-urban fringe were identified for each variable by applying the mean ± standard deviation (SD) techniques i.e. suburb fringe (above mean + 1 SD), urban-fringe (mean + 1 SD), rural-fringe (mean - 1 SD) and urban shadow (below mean - 1 SD). A Composite Urbanity Index (CUI) has been estimated using the composite value of each variable to delineate the final fringe zones of Uluberia municipality.

A. Demographic determinants

Demographic indicators are very much useful for the delineation of rural-urban fringe. The following demographic determinants were selected to delineate the rural-urban fringe of Uluberia municipality:

i. Population density

Population density is one of the most valuable factors to determine the city's sphere of influence. Uluberia Municipality acts as a pull factor for both skilled and unskilled rural population due to its self-generating employment opportunities, education and other utility services. Immigrants from the remote corners of the municipality are unable to afford the higher house rent within the municipal area. Under these circumstances, the centrifugal force of urbanization plays a great role to force people reside outside the municipality's boundaries within a commutable distance and increases the pressure of population density.

The average population density in the fringe belt is 2956 persons per sq. km. Villages and census towns having the UI value above mean + 1 SD (> 47.09) and mean to mean + 1SD (29.27 to 47.09) are considered as the suburb fringe and urban fringe respectively. These two zones are mainly extended towards north-east due to the influence of Kolkata conurbation. Villages and census towns with UI value of mean to mean - 1 SD (29.26 to 11.43) and below mean – 1SD (<11.43) are termed as rural fringe and urban shadow respectively. Maximum villages of the south-west and north-west part of the study area come under the rural fringe and urban shadow zone due to its lower degree of urban influence.

ii. Decadal population growth

The population growth rate is a combined function influenced by fertility, mortality and migration. In Uluberia municipality's case, migration is the most significant factor for the population growth. Growth of the population in the Uluberia municipality and its surrounding areas follow the Ravenstein distance decay law (Ravenstein, 1889; Tobler, 1995) i.e. decrease of population growth with increasing distance.

It is obvious that the population growth rate is very unevenly distributed (Fig. 3); three villages within suburb region have a growth rate of above 56.32 percent and UI of 26.27 (Table 2). The high growth rate of population from 2001 to 2011 is registered towards north, west, south-west part of the fringe zone and fall into the urban fringe (UI, 18.49 to 26.27) (Fig. 4). Besides migration, illiteracy, poverty and traditional beliefs are also key determinant factors for the higher natural growth of the population. The north-eastern part of the fringe belt has been considered as rural fringe due to the minimum population growth, i.e. - 13.57 to 21.37 percent.

iii. Household density

A household is a fundamental unit of a settlement where persons are ties with a co-residential relationship regardless of kinship bonds. Demographic factors, kinship rules and socio-economic conditions of a society play an influential role in an individual household. Household density and size not only change with the urbanization process but also change the design and architectural pattern of the buildings. The population of the city's peripheral zone continuously increased due to the huge number of migrants. As a result, new buildings are constructed to accommodate the new migrants. Thus, there is a clear gradation of household density from the immediate surrounding fringe area to the rural area (Table 2) and household density gradually increased in every zone of RUF in the course of time.

Maximum villages and census towns of the north-eastern part fall within the suburb and urban fringe due to the tremendous concentration of households. Rural fringe (mean to mean – 1 SD) and urban shadow (below mean – 1 SD) are extended towards the north-west and south-west portion of the municipality's fringe where household density is below 615. The built-up area has been increased over a comparatively small space in the western part of the fringe area. In this zone, households are extended parallel to the railway and national highway. As a result, a few census towns (Kendua, Osmanpur, Basudebpur and Brindahanpur) and villages (Gudar, Kasipur, Gauripur, Kajiakhali) are fallen under the urban fringe, having household density 616 to 961 household per sq. kilometer.

iv. Gender ratio

The gender ratio is a fundamental element of geographical study because it has a profound effect on other demographic criteria like population growth, age of marriage, migration rate, occupational structure etc.

A large number of male workers migrated to Uluberia municipality from the countryside to get better jobs. Gender ratio increases from city centre to the rural area and vice versa. Low paid unskilled and semi-skilled migrants prefer to live in the peripheral areas of Uluberia municipality due to cheaper residential rent and availability of other urban facilities and services.

The huge influx of male migrants into the fringe area creates disparity of gender structure. The villages and census towns having low gender ratio (below 920) are found in northern, western and south-western parts of the RUF which are termed as suburb fringe and urban fringe. The female population exceeded the male population in the north-western part of the fringe (Fig. 3) which integrated them in the rural fringe and urban shadow category.

v. Literacy rate

Literacy is a significant determinant of social well-being as well as human development. The present study reveals that literacy rate decreases from suburb fringe to rural fringe (Table 2) and based on literacy rate, the maximum villages and census towns of suburb fringe and urban fringe are located in the periphery of RUF.

So, the relationship between the distance from the city centre and literacy is positive i.e. 0.44 (Table 3). The literacy map (Fig. 3) proved that people living in the north-eastern and south-western part have higher literacy rates (> 67.78 percent), termed as suburb fringe and urban fringe. In these parts, some of the scattered villages also fall under rural fringe and urban shadow group. From the northern to the western part of the fringe, villages are considered as part of the rural fringe and urban shadow because of the lower literacy rates (less than 67.77 percent).

B. Determinants of economic structure and economic services

Economic structure and services are important attributes taken into consideration in order to find out the degree of urban influence in peripheral regions.

i. Ratio of non-agricultural workers

The villages closer to the city change their rural character more than those situated farther from it. The higher percentage of non-agricultural workers to the total workers is an important feature of the fringe population. Increasing of non-agricultural workers is a remarkable changing phenomenon in the rural-urban fringe zones.

Uluberia municipality offers multifarious employment opportunities to its rural hinterlands. Surplus labour, low paid workers and unemployed persons of the surrounding villages migrate towards the city centre to get these diversified opportunities. The workers engaged themselves in the various secondary and tertiary economic activities like household and manufacturing industry, construction, trade and commerce, storage, communications and other services.

Rural-non-agricultural workers are concentrated in the north-eastern fringe zone (Fig. 3) because of the nearness to the Howrah-Hugli industrial zone, Kolkata metropolis and easy accessibility of transport for various purposes term as suburb fringe. North-western and south-western part of the rural-urban fringe lies in the urban shadow and rural fringe zone because of its higher rural character (UI is below 71.74) (Fig. 4). In these zones, almost 45 percent of the people are working on different primary activities such as agriculture, fishing, which are located far away from the city centre.

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Table 2 Categories of rural-urban fringe based on urbanity index of selected indicators

Indicators	Categories of Rural-urban Fringe	Range of the Urbanity Index	Range of the indicators	Number of villages	Number of census towns	Total number of villages and census towns
Population density	Suburb fringe	Above Mean + 1 SD (> 47.09)	>4643	8	17	25
	Urban fringe	Mean + 1SD to Mean (47.09 - 29.27)	4643 to 2956	23	16	39
	Rural fringe	Mean to Mean - 1SD (29.26 - 11.43)	2955 to 1268	62	11	73
	Urban shadow	Below Mean - 1SD (< 11.43)	<1268	18	0	18
Population growth rate	Suburb	Above Mean + 1 SD (> 26.27)	> 56.32	3	0	3
	Urban fringe	Mean + 1SD to Mean (26.27 - 18.49)	56.32 to 21.38	34	15	49
	Rural fringe	Mean to Mean - 1SD (18.48 - 10.70)	21.37 to -13.57	71	29	100
	Urban shadow	Below Mean - 1SD (< 10.70)	< -13.57	3	0	3
Household density	Suburb fringe	Above Mean + 1 SD (> 50.89)	> 961	6	15	21
	Urban fringe	Mean + 1SD to Mean (50.89 - 32.02)	961 to 616	23	17	40
	Rural fringe	Mean to Mean - 1SD (32.01 - 13.13)	615 to 271	64	12	76
	Urban shadow	Below Mean - 1SD (< 13.13)	< 271	18	0	18
Gender ratio	Suburb fringe	Below Mean - 1SD (< 39.53)	< 920	19	3	22
	Urban fringe	Mean to Mean - 1SD (39.53 to 52.58)	920 to 954	40	20	60
	Rural fringe	Mean + 1SD to Mean (52.59 to 65.64)	955 to 9989	34	20	54
	Urban shadow	Above Mean + 1 SD (> 65.64)	> 989	18	1	19
Literacy rate	Suburb fringe	Above Mean + 1 SD (> 77.64)	> 74.48	16	3	19
	Urban fringe	Mean + 1SD to Mean (77.64 to 63.75)	74.48 to 67.78	42	22	64
	Rural fringe	Mean to Mean - 1SD (63.74 to 49.85)	67.77 to 61.07	39	14	53
	Urban shadow	Below Mean - 1SD (< 49.85)	< 61.07	14	5	19
Non-agricultural workers	Suburb fringe	Above Mean + 1 SD (> 94.12)	> 94.54	9	20	29
	Urban fringe	Mean + 1SD to Mean (94.12 to 71.75)	94.54 to 75.40	36	22	58
	Rural fringe	Mean to Mean - 1SD (71.74 to 49.37)	75.39 to 56.25	38	2	40
	Urban shadow	Below Mean - 1SD (<49.37)	< 56.25	28	0	28
Female workers	Suburb fringe	Above Mean + 1 SD (>50.80)	> 25.90	17	6	23
	Urban fringe	Mean + 1SD to Mean (50.80 to 35.26)	25.90 to 18.65	32	24	56
	Rural fringe	Mean to Mean - 1SD (35.25 to 19.73)	18.64 to 11.39	42	12	54
	Urban shadow	Below Mean - 1SD (< 19.73)	< 11.39	20	2	22
Availability of bus service	Urban fringe	Above Mean (> 62.52)	2	73	27	100
	Rural fringe	Mean to Mean - 1SD (≤ 62.52)	1	38	17	55
Metalled road availability	Urban fringe	Above Mean (> 70.32)	2	77	32	109
	Rural fringe	Mean to Mean - 1SD (≤ 70.32)	1	34	12	46
Market availability	Urban fringe	Above Mean (> 62.52)	2	68	32	100
	Rural fringe	Mean to Mean - 1SD (≤ 62.52)	1	43	12	55
Availability of internet cafes	Urban fringe	Above Mean (> 57.42)	2	61	28	89
	Rural fringe	Mean to Mean - 1SD (≤ 57.42)	1	50	16	66

(Source: Computed from District Census Handbook, Haora, 2011)

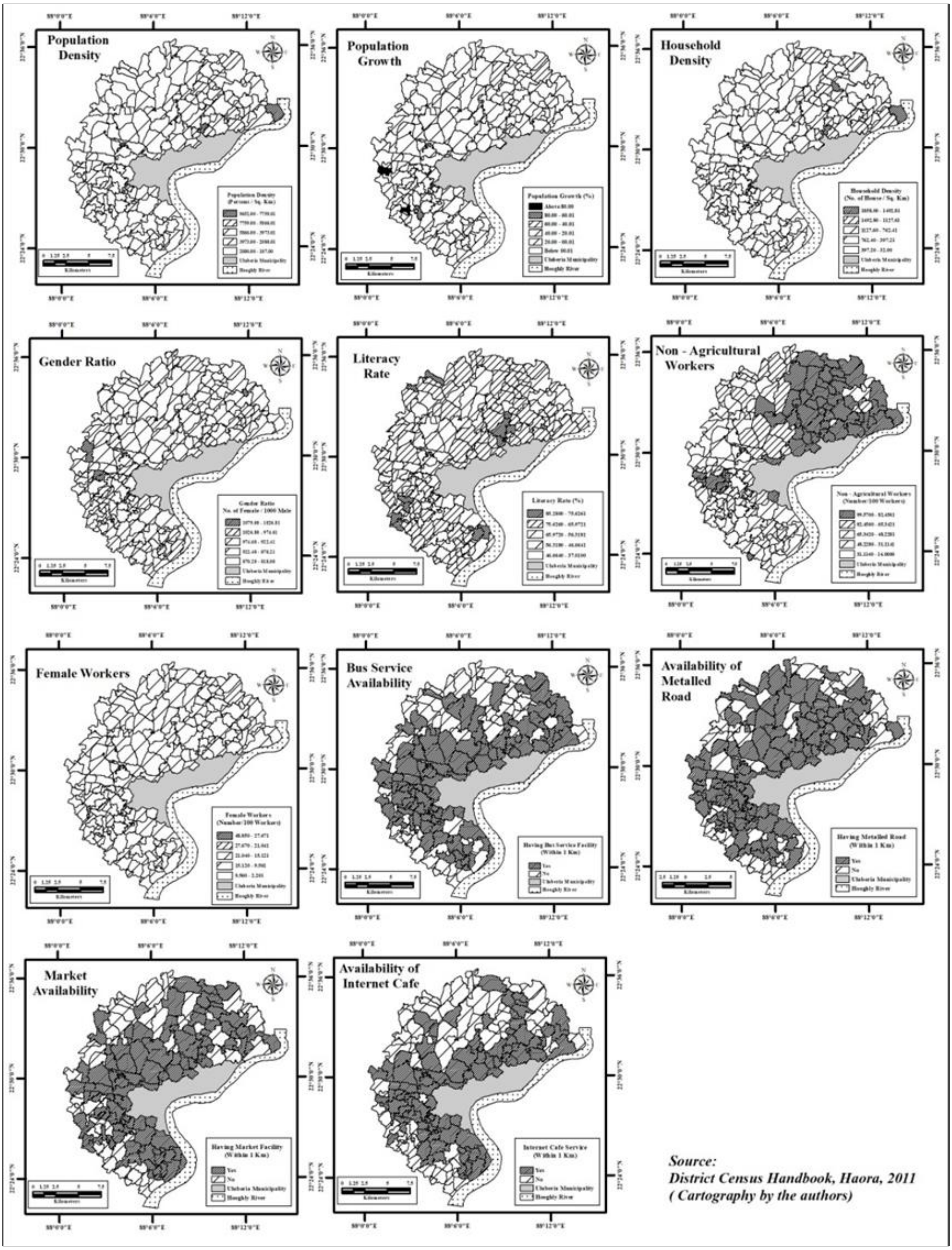

Fig. 3: Spatial distribution pattern of selected indicators, 2011

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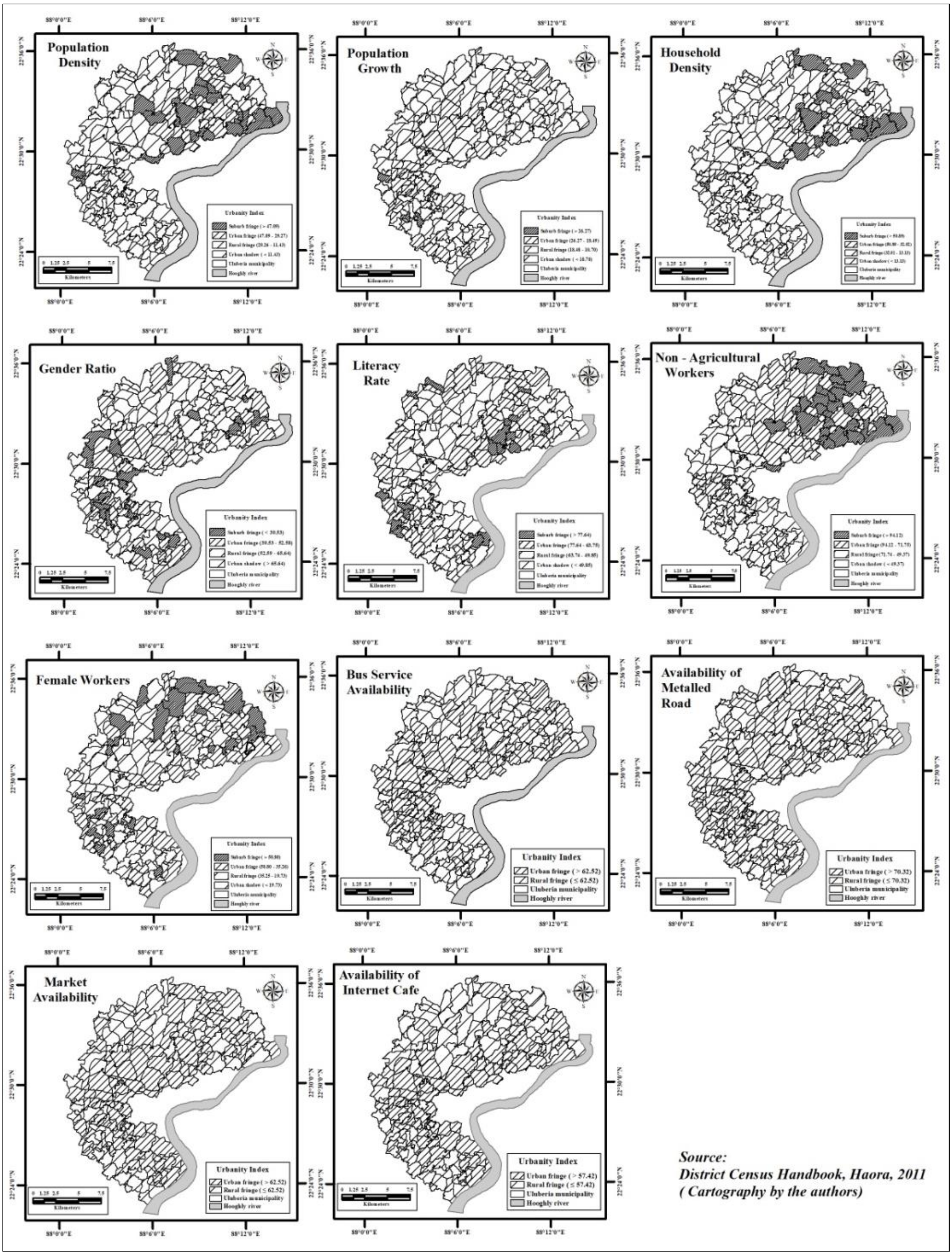

Fig. 4: Urbanity index of selected indicators used to delineate RUF

ii. Female workers

The number of female workers is one of the key determinants to delineate the rural-urban fringe area of Uluberia municipality. Female participation in the workforce creates a better economic environment for the individual family and village as a whole because women are socio-economically and politically empowered. Villages and census towns having high literacy rate may engage more females to the workforce.

Urbanity Index based on female workers' percent have the most peculiarity in terms of the spatial distribution of Uluberia municipality's RUF. The distribution of female workers to the total population are maximum towards the peripheral zone of north-east and west, considered as the suburb fringe (above 25.90 percent) and urban fringe (18.65 to 25.90 percent) (Fig. 3). A large number of villages and census towns in the north-western and south-western part of the fringe belt integrate in the rural fringe and urban shadow zone due to the higher assemblage of male workers. Thus, a total of 23 villages and census towns are part of the suburb fringe, 56 of the urban fringe, 54 of the rural fringe and 22 of the urban shadow zone (Table 2).

iii. Availability of bus service

Rapid urbanization with the increasing trends of administrative, business and commercial activities demand a high mass transit system of Uluberia municipality. Uluberia-Howrah-Kolkata, Uluberia-Jagatvallavpur-Arambag, Uluberia-Shyampur, Uluberia-Amta, Uluberia-Panchala, Uluberia-Bagnan-Mecheda are the important bus routes which radiate from Uluberia bus terminal. The studied administrative units possessing bus services (within one kilometer) are found along the inner crescent of the municipality which denotes the urban fringe zone. The radial distributional pattern of the road network is responsible for the development of the urban fringe. Peoples living in the villages and census towns adjacent to the boundary of the municipality are daily commuters and regularly cross the distance from their place of residence to the urban centre.

iv. Availability metalled road

The patterns of city development are greatly influenced by its transportation system. It actually bridges between the urban and the rural community. There is a positive correlation between levels of connectivity and suburbanization development. The connectivity through the metalled roads is important for the daily movement of people to the city centre. New residential colonies developed along the metalled road. So, transportation development intensified the suburbanization process and became a larger exterior frontier to the urban system of Uluberia municipality. Maximum villages and census towns have effective facilities of the metalled road within one-kilometer radius. Metalled roads of Uluberia municipality are extended parallel to the railway track, state highway and National Highway-6. Very few villages are settled without metalled road access around the end limit of rural-urban fringe.

v. Market availability

Markets play an important role in the formation of the urban fabric. Market centres are always a focal point for the economic activities which act as the central place for services and functions. Through employment generation, markets create a variety of ancillary jobs (suppliers, hospitality, security, delivery vehicles) and empowered low-income peoples. The characteristics of these markets are hierarchically lower order and retail in nature within communicable distance. A good transportation facility, agricultural and industrial development helps to increase the size and number of markets nearer the city centre. Fringe villages and census towns with a higher percentage of non-agricultural dwellers are economically capable to buy a variety of commodities. To serve the dwellers, different kind of shopping centres and higher-order markets are developed in the rural-urban fringe of Uluberia municipality. From an economic point of view, market availability denotes opulence to both sellers and buyers as well as the consumption level of the dependent population.

vi. Internet café availability

The internet café, commonly known as the cyber café, is a place where people can use a computer with internet access at a minimum cost per hour. The villages and census towns which have at least one internet cafe within one-kilometer distance is termed as urban fringe. Villages which do not have any internet cafes within one-kilometer radius are considered part of the rural fringe, being located at the extreme boundary of the urban fringe. At the edge of the fringe area, lagging economic and infrastructural services discourage the development of internet cafe facilities. The distance from the urban centre also plays a significant role in the availability of internet cafes among the villages and census towns.

Correlation analysis

In order to measure the intensity of relationship degree between distance from the city centre and selected variables, the Pearson product movement correlation coefficient (r) method has been used in this study. This correlation coefficient value has an immense significance to the application of UI formulas (Table 3). Equation-2 has been applied, for the negative correlation between two variables and equation-3 is used for the positive correlation. Thus, UI of the selected variables like population density, population growth, household density, non-agricultural workers, availability of bus service, metalled road availability, market availability and availability of internet cafe are calculated by using equation-2 whereas equation-3 has been taken for gender ratio, literacy rate and female workers.

Table 3 Relationship between the distance from central point of Uluberia municipality and selected indicators

No.	Name of the indicators	Value of Correlation Coefficient
1	Population density	-0.81
2	Population growth rate	-0.53
3	Household density	-0.78
4	Gender ratio	0.23
5	Literacy rate	0.44
6	Non-agricultural workers	-0.56
7	Female workers	0.26
8	Availability of bus service	-0.92
9	Metalled road availability	-0.86
10	Market availability	-0.94
11	Availability of internet cafes	-0.89

Composite Urbanity Index for the delineation and classification of Uluberia municipality's rural-urban fringe

The crescent-shaped fringe area of the Uluberia municipality is extended up-to 11 kilometers radius from the central point. Based on the eleven selected variables, the Composite Urbanity Index (CUI) has been calculated for the entire study area and plotted on the map (Fig. 5) for the delineation of rural-urban fringe. Finally, four zones of the RUF have been identified based on Mean ± Standard Deviation of CUI, described in Table 4.

Suburb fringe

The suburb fringe is placed just beyond the municipality boundary of Uluberia. This zone has a more pronounced urban character (> 63.43 CUI) with the higher concentration of non-farm dwellings, possessing better municipal facilities in comparison to the other three zones. The suburb fringe comprises 12 villages and 11 census towns within an area of 32.87 sq. km (11.99 percent of the total fringe area) (Table 4). Land-use is corporate in nature and exclusively urban. Both demographic and household density are very high. People who reside in the suburb fringe are migrating to the urban centre and engaged in different factories, offices and commercial centres. Land value is very high and most of its territory is occupied by industries, large residential apartments and multistoried houses. In this zone, vertical expansion of the houses is preferable to the horizontal one. Due to the favourable location, this zone is continuously expanding to the north-east and west direction along the axial transportation network.

Table 4 Categories of rural-urban fringe based on Composite Urbanity Index (CUI)

Categories of rural-urban fringe	Ranges of CUI	No. of villages	No. of census towns	Total number of census towns and villages	Area (sq. Km)	Population (2011)
Suburb fringe	Above Mean + 1 SD (> 63.43)	12	11	23	32.87	134414
Urban fringe	1SD + Mean to Mean (63.43 to 50.91)	39	22	61	106.32	383268
Rural fringe	Mean to Mean - 1SD (50.90 - 38.37)	37	9	46	89.4	184878
Urban shadow	Below Mean - 1SD (< 38.37)	23	2	25	45.63	81458
Total		**111**	**44**	**155**	**274.22**	**784018**

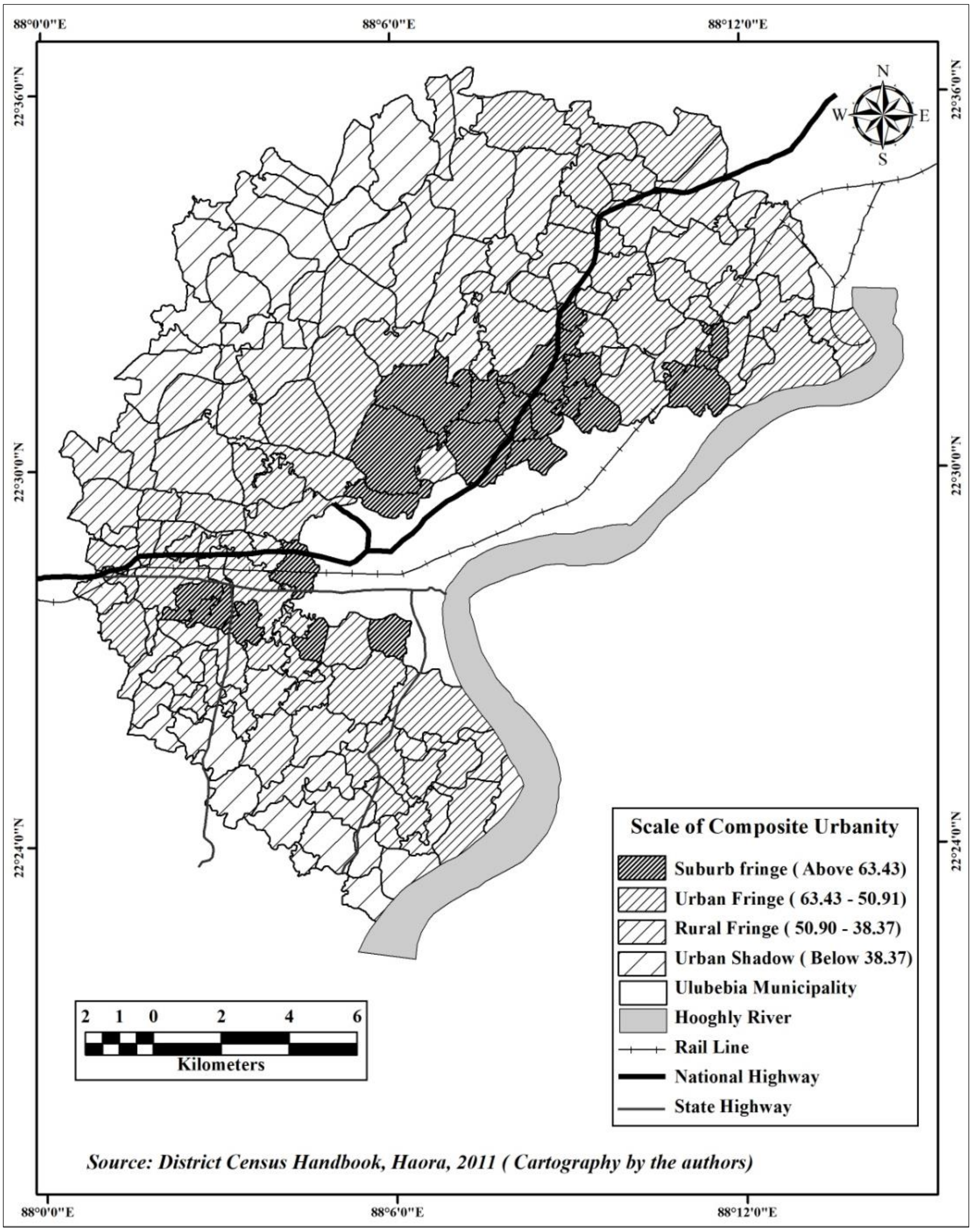

Fig. 5: Delineation of RUF, Uluberia municipality, 2011 (based on Composite Urbanity Index)

Urban fringe

Urban fringe is located beyond the suburb fringe boundary and surrounded by the rural fringe in all directions except for the north-east and west. This zone consists of 34 villages and 22 census towns with an area 106.32 sq. km. (33.77 percent of the total fringe area) (Table 4). The urban fringe is an area having a higher population growth rate due to the huge influx of rural migrants. There are still some open places owned by the farmers but they want to sell it at higher prices. The settlements are semi-urban in nature and urban land uses dominate. The workers within the urban fringe are engaged in the non-agricultural activities and most of them are employed in different industries. Presence of Howrah-Hugli industrial zone, national highway and railway track affect the shape of the urban fringe zone with a clear elongation in north-east and west directions. The high concentration of population density, non-agricultural workers, bus service and high growth rate of population characterize this zone. The villages and census towns in the urban fringe underwent tremendous transformation in terms of demographic and economic structure. Unplanned and haphazard growth of built-up area creates problems of traffic congestion, sewerage etc.

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Rural fringe

The boundary of rural fringe starts from the outward side of the urban fringe. Rural fringe covers 89.40 sq. km area (32.60 percent of the total fringe area) with 37 villages and 9 census towns. This area acts as an agricultural hinterland (38.37 to 50.90 CUI value) (Fig. 5) and has strong linkage with the Uluberia municipality in terms of supply of labourers, vegetables, milk and other daily commodities for the urban dwellers. A mixed rural-urban character prevails and most of the area is dominated by agricultural activities. The percentage of agricultural land and open space are relatively higher than in the suburb and urban fringe. Only a few urban amenities such as water supply, transportation, sewerage, markets and internet cafes are available in this zone. The percentage of farmers is very high, followed by a part-time-farmers, agricultural labours and non-farmers. Restaurants, gas-stations and cottage-based industries are randomly distributed along the major arterial roads.

Urban shadow

This zone is located far away from the centre of Uluberia municipality and it actually begins from the outer edge of the rural-urban fringe belt. A total 25 villages and census towns belong to the urban shadow zone with an extension of 45.63 sq. km geographical area (16.64 percent of the total fringe area). The urban encroachment into rural land is the dominant characteristic of this region. Presence of urban characteristics is very low in the area with <38.37 CUI value (Fig. 5). This zone experiences low population density with a lower rate of migration which indirectly establishes greater availability of open space. Unplanned commercial establishment and residences are common and of course, the mixture characteristics of rural-urban land uses. Dwellers are mainly engaged in different primary activities like farming, fishing, forestry etc. The residential form of the urban shadow is isolated and developed as interstitial growth.

Conclusion

The rapid expansion urban areas act as powerful centres having economic opportunities with high potential to multiply various economic activities beyond the municipal boundary. Uluberia municipality could not support itself without interaction to its surrounding fringe; there is actually a strong interdependence between the two areas. Furthermore, complex relationships between the urban centre and its surroundings are established based on several criteria such as: supply of vegetables, food-grains, fruits, milk or facilities such as: banking, education, medical and bus services etc. The centre and its periphery interact with each other by extensive transport and communication network. The industrial (rice and jute mills, biscuits and cakes industry, light vehicle production centres, furniture industry, etc.), commercial expansion (retail and market centres), the growth of manufacturing and service activities, the increasing number of educational institutions (Uluberia College, Tata Institute of Social Sciences, Calcutta Institute of Technology, Fuleswar Paramedical College, etc.) and healthcare facilities (sub divisional hospital, ESI hospital, Sanjibani Multi-specialty hospital and other private nursing home) have also made a significant contribution for the economic and fringe development of the town. The urban area performs as administrative headquarter, the extension of brick kilns in the fringe region, rapid construction of housing complexes along transportation routes, the establishment of recreation and local tourist centres on the bank of the river Hooghly and in the proximity of Kolkata metropolitan area contributed to the process of urbanization in case of Uluberia municipality and the suburbanization in its fringe zone. Along with these, the Hooghly river has an imprint on the shaping and development of Uluberia municipality's RUF. It also fulfilled the recreational and water demands of the city's inhabitants and entrepreneurs.

The RUF of Uluberia is a mixed zone situated at the municipal boundary exerting a strong urban influence on its periphery. All selected indicators have individually delineated different extensions of the rural-urban fringe zone and were superimposed into one to find out the combined effects of these indicators. Thus, the limit of the rural-urban fringe extended 9 kilometers in the north, 7 kilometers in the north-east, 6 kilometers in the south-west and west of the municipality boundary of Uluberia. Built-up area in the fringe zone is discontinuous and haphazardly located over agricultural land. There is no distinct physical boundary between fringe zones of Uluberia municipality, but all are interrelated and interconnected. In fact, the levels of socio-economic development have developed the gradation of fringe villages and census towns.

The north-eastern and western part of the fringe belt has a greater urban character due to the location of small and medium scale industries along the transportation route. Land-use transformation is very rapid in this part and mainly engulfed by administrative headquarters, residential and commercial buildings, educational and health centres and industries. Maximum rural characteristics have been found in the south-western and northern part of the RUF. This sector is mainly used for agricultural purposes, but also consists in unproductive fallow land. Farmers are usually ready to sell these lands with higher prices to businessman, industrialists and stockholders. Uluberia municipality's fringe has a crescent spatial pattern. The fringe belt has not expanded towards the east and southeast because of the barrier the Hooghly river represented. If only a bridge is built over the Hooghly river near the municipality, this barrier would be alleviated and it may have a great impact on the physical shape of the fringe area in the near future.

The RUF areas of growing cities in developing countries are experiencing a rapid urbanization process which has improved the quality of life, developed mixed communities and a pluralist culture. But this rapid urbanization process may have also determined a complex socio-economic and environmental development. Urban sprawl in the RUF region, dynamic land use patterns and urban demands for agricultural land are important issues which need further detailed research. Until then, the appropriate socio-economic and demographic variables used to scientifically delineate the RUF, but also the spatial extension of Uluberia municipality's fringe zones may provide useful information to policy-makers, urban and regional planners for city planning and smart design of urban growth.

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Status of housing condition, household amenities and assets in rural-urban fringe of Faizabad city, India

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Abstract

The main aim of this paper is to examine the effect of urbanization on housing conditions and access to basic amenities in rural urban fringe of Faizabad city. Food, clothing and shelter are the basic needs for the survival of human beings. Although food and clothing have their own importance, however, the need of better housing conditions cannot be ignored. The inadequacy of housing conditions affects the quality of life and social well-being. Rural-urban fringe generally has unique characteristics. The mixture zone is characterized by both traditional and new houses with all facilities. This study is mainly based on secondary sources of data collected from the village directory and housing listing tables from the census of India. The paper reveals that the overall better housing conditions and housing amenities exist only in primary fringe. Thus, this paper suggests some remedial measures for improving the overall housing conditions in rural-urban fringe of Faizabad city.

Keywords: *rural-urban fringe, housing conditions, amenities, urbanization.*

Rezumat. Situația condițiilor de locuit, a dotărilor și a facilităților domestice din franja rururbană a orașului Faizabad, India

Scopul principal al acestei lucrări este de a examina efectul urbanizării asupra condițiilor de locuire și a accesului la facilitățile de bază în periferia rururbană a orașului Faizabad. Hrana, îmbrăcămintea și adăpostul sunt nevoile de bază pentru supraviețuirea ființelor umane. Deși alimentele și îmbrăcămintea au propria lor importanță, totuși, nevoia unor condiții de locuit mai bune nu poate fi ignorată. Starea inadecvată a condițiilor de locuit afectează calitatea vieții și bunăstarea socială. Franja rururbană are, în general, caracteristici unice. Această zonă mixtă este caracterizată atât prin prezența unor case tradiționale, cât și a unor case noi cu toate facilitățile. Acest studiu se bazează în principal pe surse secundare de date colectate din arhivele rurale și din statisticile legate de locuire de la recensământul național. Lucrarea relevă faptul că doar în franja primară condițiile generale de locuit și dotările locuințelor sunt mai bune. Astfel, această lucrare sugerează câteva măsuri ameliorative pentru îmbunătățirea condițiilor generale de locuit în periferia rururbană a orașului Faizabad.

Cuvinte-cheie: *franjă rururbană, condiții de locuit, facilități, urbanizare.*

Introduction

Urbanization is the process of transformation of rural landscape into urban landscape. It has become a global phenomenon. The world has been urbanizing rapidly in the last decades. Nowadays, more population globally lives in urban areas than in rural areas. In 2018, more than half the world's population resided in urban areas. Overall, 4.2 billion people reside in urban settlements as compared to 3.4 billion in rural areas (United Nations, 2018). Developing countries of the world have experienced rapid rate of urbanization. India is a developing nation and urbanization is taking place rapidly in the country. Indian cities are urbanizing either due to migration or to natural growth, but migration is one of the dominant factors. Due to rapid urbanization, Indian cities are expanding beyond the physical boundary and cause a new phenomenon i.e. rural-urban fringe. Rural-urban fringe is a mixed zone between well-recognized urban areas and purely rural landscapes. Arif et al. (2019) define the rural-urban fringe or periurban zone as a place where urban and rural activities coincide, which is economically and socially heterogeneous and subject to rapid change. This rapid expansion does not only affect the city itself but also the peripheral areas of the city. Based on spatial determinants i.e. distance gradient, rural-urban fringe zone has been divided into primary fringe, secondary fringe and rural fringe. Primary fringe is to be found very close to the city and characterized by rapid rate of transformation. On the other hand, rural fringe is characterized by a more dominant rural occupance than urban and it is very close to pure rural areas.

The mixture zone has unique characteristics because it is characterized by both traditional and new houses with all facilities. It is obvious that the share of inhabitants engaged in non-agricultural activities is quite high in primary fringe. So, the income level is also higher in the villages of primary fringe. Access to adequate housing and basic amenities are related to higher economic and social status (Srinivasan and Mohanty, 2004; Huang and Jiang, 2009; Ahmad, 2012). Housing conditions and availability of housing amenities such as source of lighting, safe drinking water, housing facility, separate kitchen, toilet facility reflect lifestyle and socio-economic status. Accessibility of basic amenities such as drinking water, electricity, toilet facility and clean fuel are important factors that affect the quality of life in most developing countries like India. Housing conditions, availability of drinking water, sanitation facilities affects the health of people and determines the quality of life for the entire society (Nayyar, 1997). Housing and availability of household amenities as well as assets is considered to be the most important indicator of lifestyle and socio-economic status of society. Although in the 21st century, the majority of Indian people have been deprived of standard housing, safe water supply, toilet facilities and electricity facilities which remain major challenges in rural and urban India. Housing is one crucial basic need of human beings, but certain disadvantaged groups of the society still do not have access to it. The use of safe drinking water and sanitation facilities is target of Goal Seven (7) of Millennium Development Goals (MDG's) in India. Shortages of adequate housing and inequity in the availability of household amenities and assets have become serious problems that need to be addressed. The present research paper analyzes the spatial variations of housing conditions, household amenities and assets in respect of availability of safe drinking water, improved sanitation, clean cooking fuel and drainage facility in rural urban fringe of Faizabad city. Also, the study tried to assess the relationship between housing conditions, household amenities, assets and the distance from the city centre.

Literature review

Access to adequate housing, household amenities and assets, is essential for human development. In India, the access to basic amenities and quality housing is unequally distributed and remote areas as well as poorest communities in the society still lack adequate housing facilities. According to the Census of India (2011), "the household is usually a group of persons who normally live together and take their meals from a common kitchen unless the exigencies of work prevent any of them from doing so." The house not only provides shelter and a place to eat and sleep, but it also provides the base for family and social activities. Housing provides privacy and security against any kind of interferences, both physical and emotional (Nicholas and Patrick, 2015). However, the term "basic amenities" refers to drinking water supply, sanitation, electricity and so on (Shaw, 2007). The quality of housing is considered as households having basic amenities and assets which are meant to be necessary for living. Lack of quality of housing, without basic amenities, is a major rising problem across India in both rural and urban areas, because of low incomes, poverty and unemployment. Quality housing and availability of household amenities like electricity, drinking water, toilet facility and clean fuel is considered to be the critical determinants of quality of life as well as socio-economic status. The amenities like electricity, water, sanitation and clean fuel are the critical determinants of living conditions and health of the urban people (Indongo, 2015). Access to basic amenities like drinking water, sanitation, electricity, housing, drainage and others are crucial to well-being (Kumar, 2014). Quality housing with availability of household amenities plays a crucial role to the health status of the population. Pawar et al. (2015) stated that health promoting factors such as housing conditions, availability of drinking water, sanitation facility, light, affect the health of people and sometimes such conditions are more important than health services. Sources of clean water and sanitation facilities are considered as the backbone of an effective public health system. Marsh et al. (2000) collected data in Great Britain and observed that poor housing conditions both affect current as well as future health status. The deprivation of drinking water, sanitation and toilet facilities is most obvious in rural areas and also in small and medium towns. Poor sanitation and inadequate access to safe water are public health concerns because they create such conditions which are favourable to the spread of diseases (Bhagat, 2011). Living conditions in the absence of basic household amenities such as safe water supply, sanitation and toilet become miserable and unsafe for everybody's health. Karn et al. (2003) studied the environmental conditions and health of slum dwellers in Mumbai and they observed that income, literacy, sanitation and personal hygiene affect the morbidity of the people.

Housing, access to household amenities and assets are directly or indirectly related to the economic status of population. Sadaf and Munir (2017) assessed the household environmental conditions like house types, kitchen, electricity and sanitation facilities of groups having different income (high, medium and low) in the residential suburbs of Faizabad city and observed that level of income is highly correlated with housing conditions. Infrastructural facilities such as roads, water electricity, telecommunications and safe disposal of waste play very important roles in achieving societal welfare, socio-economic and political growth of urban and rural areas (Gabriel and Abraham, 2009). Some studies also pointed that shelter, basic amenities and assets not necessarily reflect the income of the population, it may also be due to social, cultural and political factors. Kundu et al. (1999) have different views; it was pointed out that poor housing conditions and lack of basic household amenities is not necessarily related to non-availability or deprivation of a particular amenity, it could be due to natural, social and cultural factors. Recent increase in poverty and rapid population growth have created substantial pressure on housing and availability of household amenities in developing countries. Similar to the other developing countries, India is also experiencing inequality in housing and basic amenities (Edelman and Mitra, 2006). There is unequal distribution of housing conditions and access to basic amenities in rural as well as in urban areas. Pal et al. (2015) analyzed that access to drinking water, toilet facility and electricity is better in urban areas as compared to the rural areas in most states of India. The basic services, such as drinking water, sanitation and toilet are unequally distributed, particularly in the rural areas. Chandoke (1977) mentioned that villages suffer from health problems. The area outside the houses is insufficiently planned and badly maintained, making it a poor environment. The rural-urban fringe is a heterogeneous zone and it is an amalgamation of pucca, semi pucca and kutcha houses. The urban fringe is heterogeneous in its social composition and it constitutes the habitat of diverse communities including lower income groups, who are particularly vulnerable to negative externalities of both rural and urban systems such as risks to health, life and physical hazards related to the occupation of unsuitable sites, lack of access to clean water and basic sanitation and poor housing conditions (Amao and Ilesanmi, 2013). The share of non-agricultural workers is comparatively low in rural fringe than the adjoining areas of the city. So, the percent of low income households is even greater in the rural fringe. Moreover, the access to basic amenities and adequate housing is highly correlated with economic status of population. Therefore, this paper is to examine the relationship of distance from city to the housing quality, household amenities and assets in a rural-urban fringe.

Study area

Faizabad city is located in the eastern Uttar Pradesh state in Northern India. The city lies between 27°53′ N latitudes and 78°4′ E longitudes. This city is located on the south bank of the Saryu (Ghaghra) river in Faizabad district (Fig. 1). It is medium sized class I city. It is a very old city, its history is 250 years old as Faizabad city was the capital of the Nawabs before Lucknow city. The total population of Faizabad was 144705 in 2001 and it has increased to 165228 in 2011. Faizabad and Ayodhya cities are known as twin urban centers. Faizabad is at a 6 km distance from Ayodhya city.

The whole area is well connected by roads and railway network. National highway 28 connects the city to Nepal and it is connecting with Lucknow (capital of Uttar Pradesh). The city is well connected with Azamgarh, Allahabad (Prayagraj), Raibareli, Basti, Gonda, Balrampur, Bahraich and Gorakhpur. Faizabad railway connects the city with many big cities such as Mumbai, Surat, Ahmadabad and Delhi. The city is the district headquarters related to administration, transportation and education. All administrative offices, hospitals, universities and colleges are located in Faizabad city.

The rural-urban fringe of Faizabad city of extends over 115.8 sq. km. The total area of rural-urban fringe zone lies within 10 kilometers from the center of Faizabad city. The primary fringe has 56,614 inhabitants and 9,568 households, whereas secondary fringe has 55,466 inhabitants and 9,132 households and rural fringe consists of 54,122 inhabitants and 8,793 households (Table 1). Total population as well as number of households is decreasing with the increasing distance from the city centre.

Data base and methodology

The study is based on the secondary sources of data obtained from the Primary Census Abstract and house listing table (Census of India, 2011). For the delineation of the rural-urban fringe, the study area has been divided into three zones with a radius of 5, 7.5 and 10 km from the city center. A village has been considered as a smallest unit for the study. Village wise housing conditions, household amenities and assets in rural urban fringe have been depicted with the help of simple percentage. Regression analysis has been used to analyze the relationship between urbanization and housing conditions, household amenities and assets (Fig. 2). ArcGIS 10.2.1 software has been used for obtaining adequate cartographical products.

Table 1 Number of households and population in rural-urban fringe of Faizabad city

S.I. No.	FRINGE ZONE	Zone (distance from the city centre)	Number of villages	Number of households	Total population	Area [sq. km]
1.	Primary Fringe	0-5 km	22	9,568	56,614	29.22
2.	Secondary Fringe	5-7.5 km	23	9,132	55,466	42.52
3.	Rural Fringe	7.5-10 km	24	8,793	54,122	44.14
Total			69	27,493	166,202	115.8

Source: author's processing

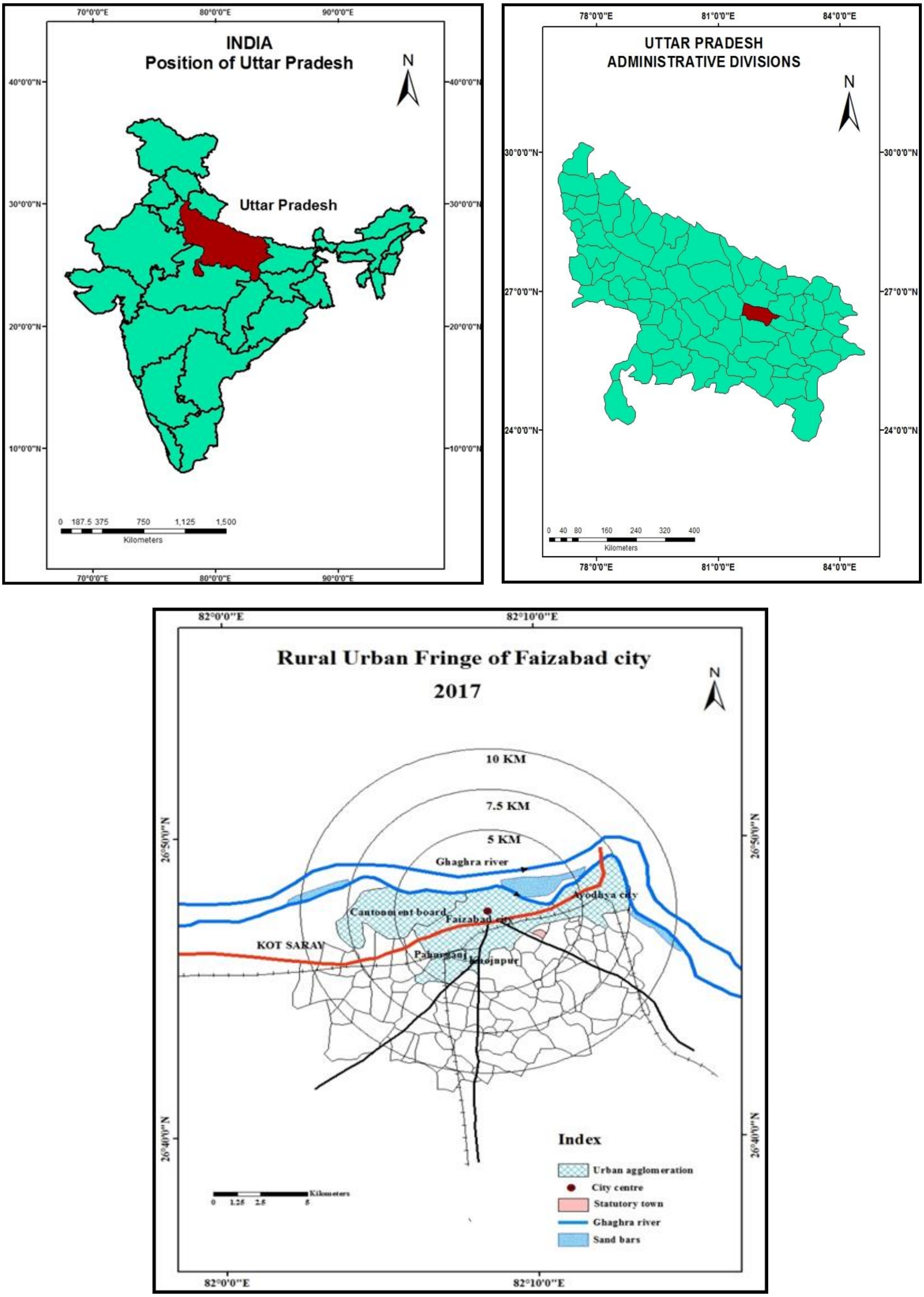

Fig. 1: Location of the study area (based on the Census of India, 2011)

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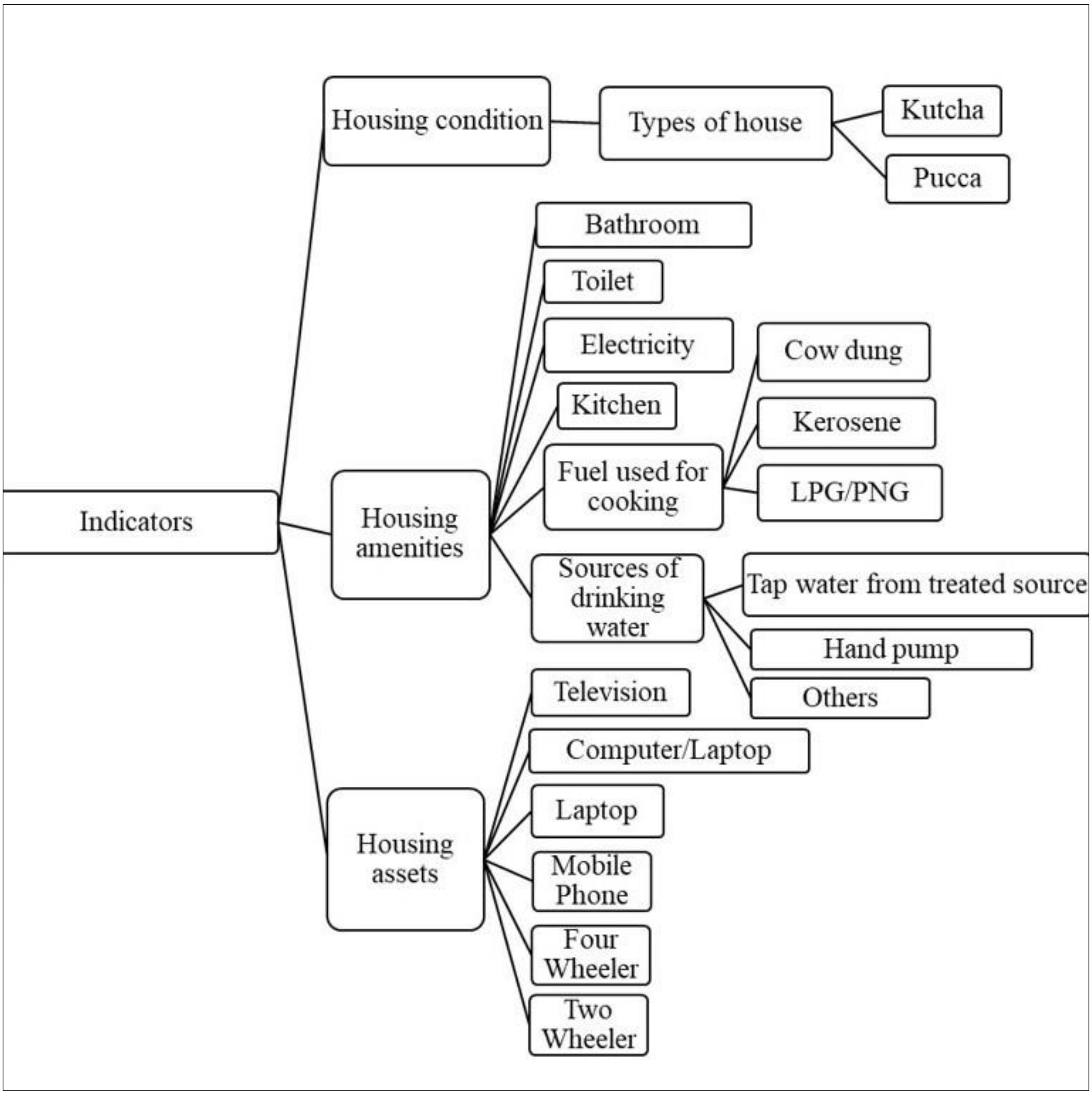

Fig. 2: Indicators used for Housing Condition, Household Amenities and Assets

Results and discussion

Housing conditions in rural-urban fringe of Faizabad city

Housing is one of the basic needs of every human being. A house is the place where we can cook food, take rest and sleep. Housing is not only a necessity, but it also affects all aspects of our life.

Lawrence (2004) said that "housing is meant to provide shelter and security and is considered a fundamental development process, in which the built environment is created, used and maintained for the physical, social and economic well-being and quality of life of individuals and households". Housing conditions are related to standard of living and quality of life.

According to census of India, "pucca houses are those houses made up of Burnt brick, stone, slate, G.I./metal/asbestos sheets and concrete". A Kutcha house is made of mud walls, mud roof and has an earthen floor. It is very obvious that pucca house provides more durable shelter than Kutcha house. Available data revealed that higher proportion of the population is living in pucca houses in the primary fringe (Table 2). Primary Fringe records 79.6% Pucca Houses and it decreases in secondary fringe (75.93%) and rural fringe (70.54%). The percentage of Kutcha houses is lower in adjoining villages of the city while the percentage of Pucca houses is decreasing with increasing distance from the city (Fig. 3, Fig. 4).

Table 2 Types of House in Rural Urban Fringe, in percentages (2011)

S.I. No.	Fringe Zone	Kutcha house	Pucca house
1.	Primary Fringe	20.40	79.6
2.	Secondary Fringe	24.07	75.93
3.	Rural Fringe	29.46	70.54

Source: author's processing

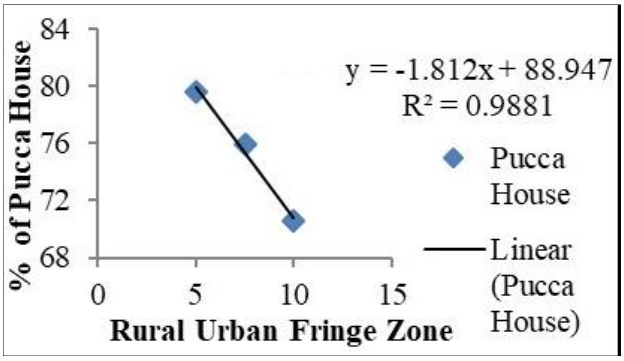

Fig. 3. Pucca house in rural-urban fringe of Faizabad city (2011)

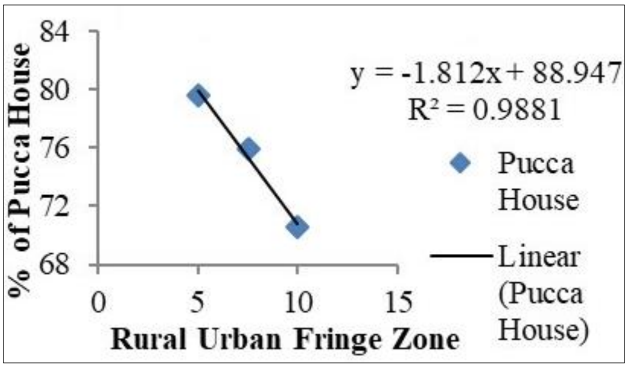

Fig. 4: Kutcha house in rural-urban fringe of Faizabad city (2011)

The access to basic amenities like electricity, bathroom, toilet, kitchen, drinking water and clean fuel are critical indicators of quality of life in most developing countries like India.

Bathroom facility is considered critical determinant of quality of life and social equity. More than 60% households having bathroom facilities (both inside and outside the house) in primary fringe, it goes on declining in secondary fringe (60%) as well as in rural fringe (56.58%) (Fig. 5).

Available data revealed that 43.08% of the households have a toilet facility in the primary fringe (Table 3). Proportion of toilet facility is very low (21.28%) in the rural fringe. Most of the people in villages defecate in open areas. Open defecation is one common practice in rural India.

More than 59 per cent of the villages within the primary fringe have electricity connections. In contrast to that, the distant villages from the city have low rates of electrification such as 50.48% of villages in secondary fringe have electricity and villages in rural fringe having 45.93% electricity. The number of households that have access to electricity is decreasing away from the city centre (Fig. 7).

Generally, pucca households preferred separate kitchen arrangement within the dwelling whereas in Kutcha households cooking is done in open area. The kitchen facility is better in primary fringe (94.08%) and less developed in secondary fringe (91.66%) and rural fringe (91%) (Fig. 8).

Table 3 Household amenities in rural-urban fringe, in percentages (2011)

S.I. No.	Fringe Zone	Bath-room	Toilet	Elec-tricity	Kitchen
1.	Primary Fringe	60.45	43.08	59.67	94.08
2.	Secondary Fringe	60	23.51	50.48	91.66
3.	Rural Fringe	56.58	21.28	45.93	91

Source: author's processing

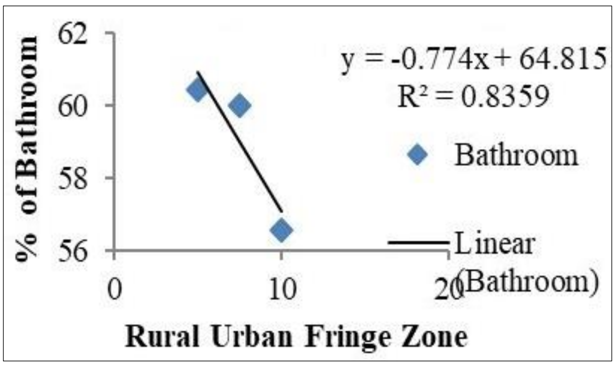

Fig. 5: Bathroom facility in rural-urban fringe of Faziabad city (2011)

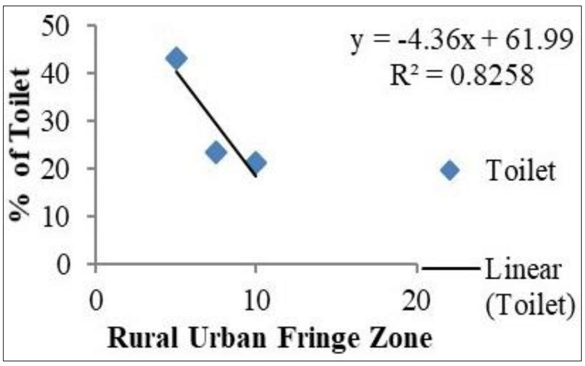

Fig. 6: Toilet facility in rural-urban fringe of Faziabad city (2011)

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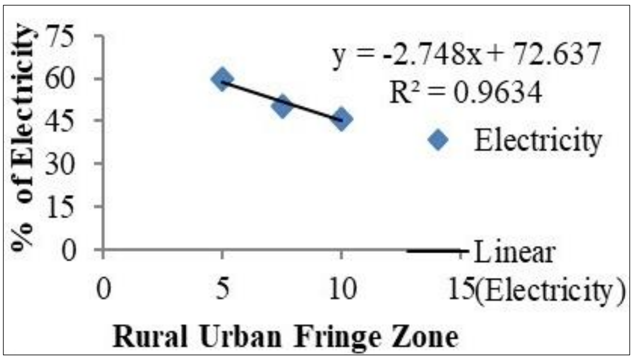

Fig. 7: Electricity facility in rural-urban fringe of Faziabad city (2011)

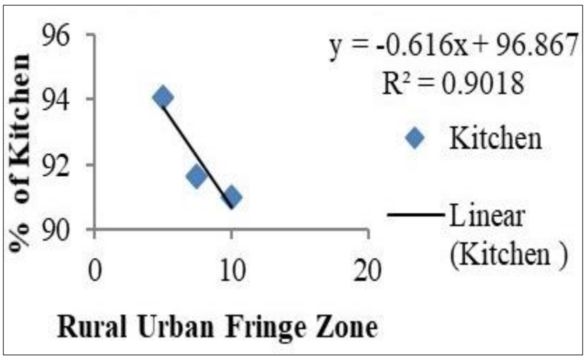

Fig. 8: Kitchen facility in rural-urban fringe of Faziabad city (2011)

Quality of cooking fuels is major factors in determining the quality of life. Prosperous households have better access to quality to household fuels. The use of solid fuels for cooking in households usually results in the emission of hundreds of compounds, some of which may cause cancer and other health problems and it also produces greenhouse gases that is responsible for global climate change. The type of fuel used in cooking is the most important source of indoor air pollution.

Solid fuel such as crop residue and cow dung cake are the most important cooking fuels for cooking in the households of rural fringe while kerosene followed by LPG/PNG are the primary source for cooking in the households of primary fringe (Table 4, Fig. 9, 10, 11). Almost 32% households of primary fringe are using LPG/PNG as a source of fuel that goes on decreasing in secondary fringe (16.13%) and rural fringe (11.52%). Cow dung cakes are the second most common cooking fuel used by 10.54% of the households in primary fringe, 10.56% of the households in secondary fringe and 24.73% of the households in rural fringe. The other biomass fuel used for cooking is crop residue and 2.50% of the households in primary fringe, 5.98% of the households in secondary fringe and 6.02% of the households in rural fringe are using crop residue.

Table 4 Fuel Used for Cooking in rural-urban fringe, in percentages (2011)

S.I. No.	Fringe Zone	Crop Residue	Cow Dung Cake	Kerosene	LPG/PNG
1.	Primary Fringe	2.50	10.54	0.75	31.29
2.	Secondary Fringe	5.98	10.56	0.40	16.13
3.	Rural Fringe	6.02	24.73	0.35	11.52

Source: author's processing

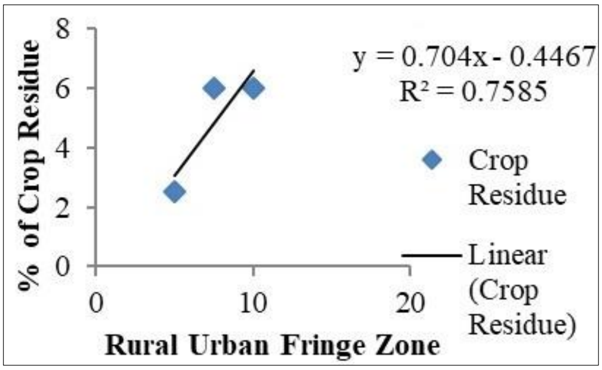

Fig. 9: Crop residue in rural-urban fringe of Faziabad city (2011)

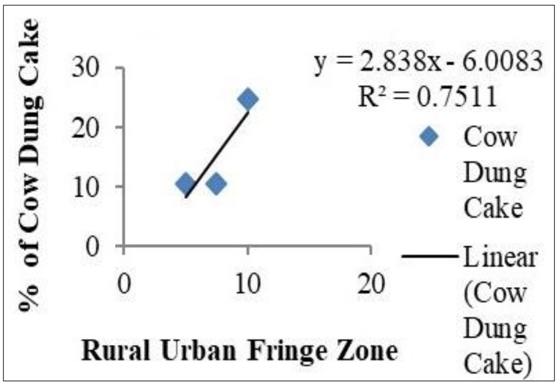

Fig. 10: Cow Dung Cake in rural-urban fringe of Faziabad city (2011)

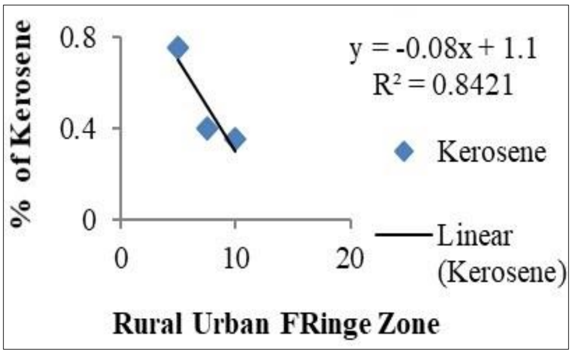

Fig. 11: Kerosene in rural-urban fringe of Faziabad city (2011)

Sources of clean water enrich the effective public health system. Basic hygiene provided by safe drinking water is related to the health status of the population. Safe drinking water facilities not only reduce morbidity and mortality, but it increases worker productivity and overall well-being. Sources of water supply determine the quality of drinking water.

Main source of drinking water in rural-urban fringe is hand pump followed by tap water. More than 83% of primary fringe households get hand pump water from treated sources in their homes, 81.29% households get hand pump water in secondary fringe and 75.77% households get hand pump water in rural fringe (Table 5).

Table 5 Sources of drinking water in rural-urban fringe, in percentages (2011)

S.I. No.	Fringe Zone	Tap Water	Hand Pump	Others
1.	Primary Fringe	17	82	2
2.	Secondary Fringe	13.92	81	5.08
3.	Rural Fringe	13	75.77	6.23

Source: author's processing

Only 15.41% of households with tap water from treated source are available in primary fringe records due to the influence of the city. Only 2% households get drinking water from other source (river, ponds, well, tube well/borehole and canals) in primary fringe. Sources of drinking water such as tap water from treated sources and hand pump are declining away from the city centre (Fig. 12, Fig. 13, Fig. 14).

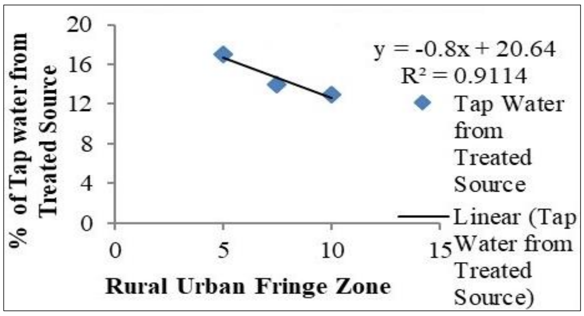

Fig. 12: Tap water from treated source in rural-urban fringe of Faziabad city (2011)

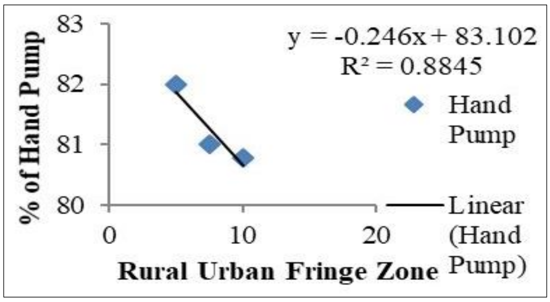

Fig. 13: Hand pump in rural-urban fringe of Faziabad city (2011)

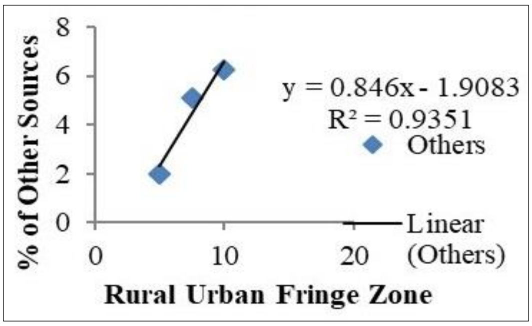

Fig. 14: Other sources of drinking water in rural-urban fringe of Faziabad city (2011)

Household assets in rural-urban fringe of Faizabad city

Household assets like television, computer, laptop and telephone are the modern information and communication technologies. These modern communication technologies are the important instruments in the process of development. In the era of digitalization, use of information communication technologies has increased in urban as well as in rural areas. With the help of telephones, computers and internet people can exchange their experiences and learn from each other. People can also help to overcome traditional barriers and update their day to day life.

Table 6 Household assets in rural-urban fringe, in percentages (2011)

S.I. No.	Fringe Zone	Television	Computer, Laptop	Two Wheelers	Four Wheelers
1.	Primary Fringe	47.44	8.00	28	3.54
2.	Secondary Fringe	37.21	7.39	23.08	3.52
3.	Rural Fringe	30.42	7.37	20.90	3.28

Source: author's processing

The most common asset is television, which is available for 47.44% in the households of primary fringe, 37.41% in the households of secondary fringe and 30.42% in the households of rural fringe (Table 6). The use of computers/laptops is still very reduced and it is reserved for extremely small pockets of population in rural urban fringe. The asset like computer/laptop is uneven in different zones of rural urban fringe. Only 8% households have computer/laptop in primary fringe and it goes on decreasing with distance from the city centre (Fig. 16). Mode of transportation is also very important factor for level of development. Two wheelers is the one of the most important mode of transportation in rural urban fringe and 28% households have two wheelers in primary fringe, 23.08% households in secondary fringe and only 20.90% households have two wheelers in rural fringe (Fig. 17).

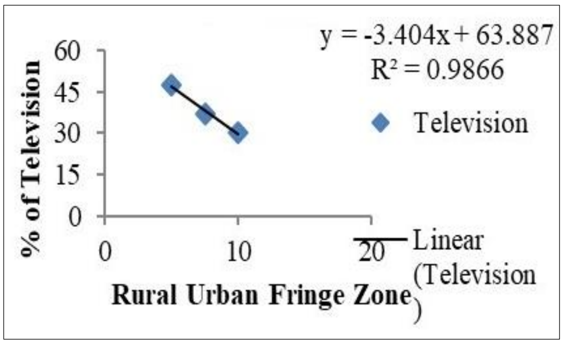

Fig. 15: Television in rural-urban fringe of Faziabad city (2011)

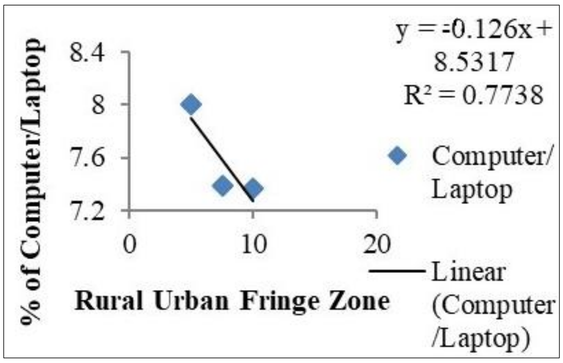

Fig. 16: Computer/laptop in rural-urban fringe of Faziabad city (2011)

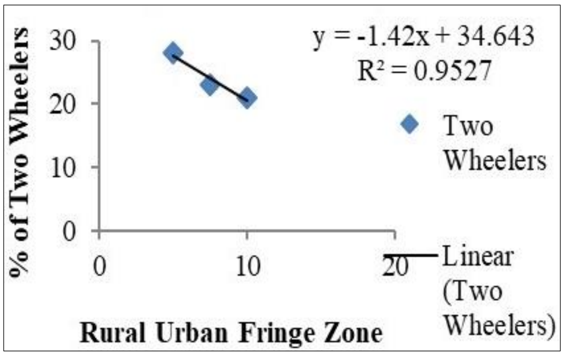

Fig. 17: Two wheelers in rural-urban fringe of Faziabad city (2011)

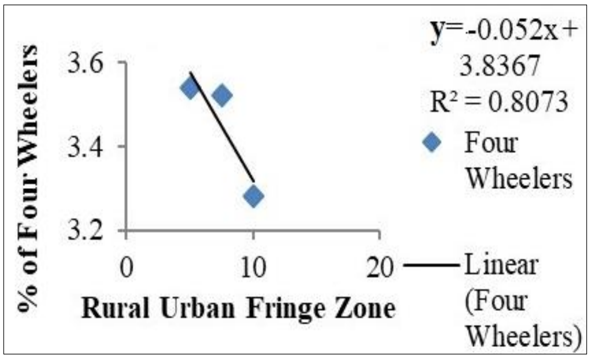

Fig. 18: Four wheelers in rural-urban fringe of Faziabad city (2011)

Conclusion

Using the census data of 2011, it is found that the distribution is unequal with rural fringe having lower access to basic amenities. This analysis suggests that access to basic amenities, such as drinking water and sanitation is highly correlated with the economic status of households. This finding is also supported by the regression analysis which examines the determinants of housing conditions in rural urban fringe.

Economic and social backgrounds of the household are major determinants of housing conditions in both rural and urban India. The villages of the analyzed primary fringe possesses good quality of housing condition and housing amenities in rural-urban fringe of Faizabad city. Whereas, the villages of rural fringe are not in good condition and the villages of secondary fringe are having moderate conditions. The study shows that the housing condition and availability of housing amenities decreases from high in primary fringe to low in the rural fringe. There is a declining trend in availability of household assets from the city centre to the rural-urban fringe of Faizabad city.

All in all, despite the existing various schemes for rural development such as PURA (provision of urban amenities to rural area), Pradhan Mantri Adarsh Gram Yojana, Sansad Adarsh Gram Yojana (SAGY) and Shyama Prasad Mukherji rurban mission (SPMRM), rural-urban gap in terms of housing and basic amenities remains high. At present, lack of proper policy funding, corruption within the programmes at different levels, lack of people’s involvement hinders the completion of any programmes in India.

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A model of CBT networks and organizations: an African perspective and beyond

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Abstract

Community-based tourism networks (CBT-N) are important both locally and globally. However, few studies are dedicated to CBT-N. This paper fills this gap and includes an examination of two CBT networks/associations (CBT-N) to validate their role and service in CBT. The two African CBT-Ns examined in this paper show the real need for partnerships and collaborations with various entities and the multiple services that the CBT-N offers for training, funding, marketing, capacity building and empowerment. This paper reviews related literature and the African CBT-N as a case study and proposes a CBT-N model. The model, while not claiming to be all-inclusive, attempts to illustrate the variety of possible collaborators within CBT-N and the wide range of services and activities that the various entities, in primis the CBT-N itself, can propose, harness and manage.

Keywords: *tourism; community-based tourism; community-based tourism network; community-based tourism organisation; community-based tourism association*

Rezumat. Un model de rețele și organizații de turism bazat pe comunitate (CBT): o perspectivă africană și nu numai

Rețelele de turism bazate pe comunitate (CBT-N) sunt importante atât la nivel local, cât și la nivel global. Cu toate acestea, puține studii sunt dedicate CBT-N. Această lucrare aduce o contribuție la această lipsă de cercetări și include un studiu asupra a două rețele/ asociații CBT-N pentru a valida rolul și serviciul lor în CBT. Cele două CBT-N-uri africane analizate în această lucrare arată necesitatea reală de parteneriate și colaborări cu diverse entități și serviciile multiple pe care CBT-N-ul le oferă pentru formare, finanțare, marketing, consolidarea capacităților și împuternicirile. Acest articol analizează literatura de specialitate și CBT-N-ul african ca studiu de caz și propune un model CBT-N. Modelul, deși nu se dorește a fi atotcuprinzător, încearcă să ilustreze varietatea posibilelor colaborări din cadrul CBT-N și gama largă de servicii și activități pe care diferitele entități, în primul rând CBT-N-ul în sine, le pot propune, valorifica și administra.

Cuvinte-cheie: *turism; turismul bazat pe comunitate; rețea turistică bazată pe comunitate; organizație turistică bazată pe comunitate; asociație turistică bazată pe comunitate*

Introduction

Tourism has assumed profound global relevance and pre-eminence for development in various settings (Tolkach et al., 2012:3). The tourism sector is currently a well-acknowledged economic sector that is supporting the economic growth and development around the world (Stankova and Kaleichev, 2013:50). Simultaneously, community-based tourism (CBT) has been identified as an appropriate development model that is able to enhance the socio-economic benefits derived from tourism (Tolkach and King, 2015:386). Networks in CBT are also an important matter such that in various "parts of the world, community tourism networks or knowledge hubs play a key role in supporting CBT, sustainable tourism, rural and eco-tourism" (Asker et al., 2010:85). Moreover, it has been argued that "a networked, collaborative approach to CBT offers better prospects for delivering effective and sustainable tourism development" (Tolkach and King, 2015: 386).

Despite the recognition and relevance of the CBT network (CBT-N) model, little research is available on the matter of networks in CBT (Tolkach et al., 2011:3). This paper contributes to filling this research gap by enhancing research and knowledge on CBT-N using cases from Africa. The paper aims to examine two CBT networks/associations (CBT-N) to verify their role and service in CBT.

Methodology

The paper is based on a desk research. Therefore, besides literature and documents, the case study is based on the services offered and presented on the two CBT-N websites. These include capacity building/training, marketing and booking (and, if offered, how to book and pay), partnership, standardization and accreditation. The case studies are about the Kenya Community-Based Tourism Network (KECOBAT) and Uganda Community Tourism Association (UCOTA). Content analysis was performed to tease out these matters in a systematic manner. The next section presents the literature review.

Literature Review

The literature review is a general summary of issues in CBT, such as capacity building and training, marketing, partnership and standardization and accreditation. Thereafter, a section is dedicated to CBT-N. A CBT-N model is subsequently suggested to better visualise possible contexts and roles of CBT-N.

Community-based tourism

This paper does not present specific aspects related to ownership, control and management of CBT venture/projects. These are important and lie at the heart of CBT. Indeed, it is important to mention that a genuine CBT venture should be owned, managed and controlled by disadvantaged community members. Ideally, CBT should be linked to local control of the tourism sector (Giampiccoli and Saayman, 2016). Thus, "CBT highlights the importance of community empowerment and 'ownership' in tourism development as a means to sustain the community growth" (Abdul Razzaq et al., 2012:10). In contrast, the KwaZulu-Natal Province (South Africa) has a Community Tourism Organisation (CTO) strategy that "does not appear to be specifically dedicated to comprehensively facilitating CBT in disadvantaged communities but leans more towards the typical private sector" (Giampiccoli, Saayman and Jugmohan, 2014:1146). The Kenya Community Based Tourism Network (KECOBAT), on the contrary, emphasises the need for community control and benefits by disadvantaged community members to the exclusion of private companies (see Box 1).

Thus, this paper focuses on specific features, services, facilities and supporting actions that the CBT-N can offer and will engage the debate concerning ownership and management characteristics of the CBT ventures/projects. Networks can be established at various geographical levels (from local to global level), in both public and private domains and include various types of entities such as communities, NGOs, government agencies, intergovernmental organizations, international financial institutions and private firms (Trejos et al., 2008:17). "A 'network' describes a formal relationship that has been consciously and purposefully established to connect multiple actors" and differentiated by the level of integration, centralization and interdependence (Tolkach and King, 2015: 389).

Box 1.
Eligibility of membership

For the purpose of determining whether an enterprise is a CBTE, the following criteria will be considered:

- Should be owned and operated by a community, community – organisation or by a resident individual who is a member of the local community and shall not include enterprises controlled by private companies;
- The tourism enterprise should be significantly benefiting the disadvantaged communities;
- There should be clear evidence of a community-benefit fund or other form of community benefit coming from the CBTE; and
- Whether in the opinion of KECOBAT, the proposed CBTE can be viable (reasons must be given).

Source: KECOBAT, (online, b)

Community-based tourism has been implemented in some developing countries with some success as well as with some challenges in some circumstances (Lenao, 2015:580). Even if the debate is raging about the success of CBT, unsuccessful stories have also been recorded (Kontogeorgopoulos et al., 2014). For example, a case in Botswana presented challenges including "poor accessibility during the rainy season, poor or inadequate marketing of the project, lack of capacity especially within the Trust Board, low income generation and the resultant heavy dependence on external funding" (Lenao, 2015:585). This indicates that issues such as marketing, funding and training can be challenges in CBT development. Mentoring and extension support as is done in agriculture can be considered to be necessary in tourism. Skilling and capacity development are crucial in the formative stages of the venture. By virtue of the fact that these ventures are usually initiated in rural areas where the people are usually less skilled and poorly resourced, support is needed in terms of training in packaging their final offerings (home stays, dances, food and ceremonies) and products (crafts and artefacts), costing for their services and products, marketing (to the domestic and international clientele) and so on.

Capacity building can be viewed as a basic requirement to be emphasized in CBT. Capacity building should be seen as an essential pre-condition in the implementation of CBT projects (Suansri, 2003:12; Giampiccoli et al., 2014a:659) and the need to skill and develop capacity in CBT was emphasised in a case in Uganda (Victurine, 2000). Moreover, capacity building in CBT takes some uniqueness because it should serve as an empowerment and self-confidence building tool, to learn business and tourism management and so on (Twining-Ward, 2007:14). Community-based tourism capacity building should be understood and implemented as a tool to impart new community capacities to be utilized beyond the sole tourism milieu (Hamzah and Khalifah, 2009:14; Giampiccoli et al., 2014a:659). Capacity building is important to increase community participation and to deepen the community's understanding of the tourism sector. While training and capacity building can take time and need to be context specific, they "are key components of capacity building and courses including hospitality and tourism management at the community level, as well as general business skills such as marketing, communication, finance, and governance are imperative for success" (Dodds et al., 2018:1550). Training is necessary to allow the people involved to manage their enterprises and in various guiding, English language and the production of crafts are necessary (Dodds et al., 2018:1550). Education, capacity building and training can "give the communities a foothold in facing the open, competitive market and empowers people to begin to transform from beneficiaries to business managers" (Dodds et al., 2018:1550). We also add that training in the basics of foreign languages for communication is important in the same way as the tourists may want to casually learn local languages and some cultural habits and behaviour as part of the tourism experience.

CBT standards (CBTS) have been recognised as valuable and at the same time challenging for the Association of Southeast Asian Nations (ASEAN). For example, as a consequence of the expansion and spread of CBT in the region, tourism ministries of these countries made a call for standardisation of CBT during planning and development in pursuit of sustainable development (Novelli et al., 2017:261). As indicated in the ASEAN CBT Standard Scope, the standards provide common performance indicators for managing tourism offerings available in communities under the auspices of a CBT Committee (ASEAN, 2016:3). It is to be noted that the aim is not to exclude communities but to provide communities with minimum standards of the quality of services expected and as a way to assure tourists of uniform service across countries that are in the ASEAN (ASEAN, 2016:3).

In that Asian context, the increase in the tourism sector and its linked factors such as competiveness and product quality have stimulated "the demand for CBTS", so that in 2013 the Thai Community-Based Tourism Institute (CBT-I) introduced standards mostly in relation to community rights (Novelli et al., 2017:266). In addition, CBTS which would bestow pride to the community, increase stakeholder confidence and improve access to markets as the standards 'remain a self-assessing, benchmarking and guiding tool rather than a certification' (Novelli et al., 2017:266). The CBTS derived from STS [sustainable tourism standards] to improve the CBT sub-sector but their relevance, practicality and effectiveness is not clear (Novelli et al., 2017:263). It could be said that work in CBTS still remains to be done. Standards have their pros and cons. The pros include consistency and compatibility in service provision, they provide an idea of what to expect and pitching value. The cons include the fact that standards may stifle innovation and while things change, standards tend to keep things static/constant because the ambition is to achieve consistency. Additionally, those who cannot meet the standards will lose out thus making standards exclusionary in disadvantaged communities where inclusion is necessary for justice and fairness.

A collaborative effort is fundamental in establishing and implementing CBTS. From the ASEAN case, members considered that a multi-stakeholder approach should be used to speedily harmonize national standards followed by the adoption of ASEAN-CBTS in the region for good practice in CBT (Novelli et al., 2017:276). This implies the need for collaboration undergirded by a proper national CBT network that coordinates and guides the task related to the establishment, promotion and implementation of CBTS. By implication, should standards be found to be desirable, CBT-N could be the appropriate platform to spearhead standardization given its wide communication capabilities and capacities to reach many players.

Marketing has been another key challenge in CBT. Communities often lack the capacity to launch effective marketing campaigns, let alone to produce their own marketing material for use both domestically and globally (Ashley and Garland, 1994:37). The marketing factor is essential for the success of their ventures upon which depends the number of tourists they will be able to attract (Dodds et al., 2018:1552). Communities need to be taught how to market their product (marketing skills) to expose their CBT enterprises to potential tourists using promotional activities such as posters, radio stations, signs and billboards and television shows (Vallabh et al., 2017:7). It is then imperative to evaluate the partnerships and it invokes the need for networks in CBT. This implies that communities will need the skills and technological know-how to market themselves both locally and globally, otherwise no one will know about their existence and the attractions they have to offer.

It is fundamental to consider the way CBT is implemented as various researchers "claim that the problems encountered in the community-based tourism approach stem from the methods and techniques employed in its implementation" (Sakata and Prideaux, 2013:882). Within the global context of value chain and local impacts on livelihoods, a case study on CBT observes that CBT seems to contribute to empowering communities and improving livelihoods as opposed to traditional tourism in which the tour operator appropriated to himself the lion's share of the tourism earnings (Lapeyre, 2010:769).

The establishment of specific CBT-N at global levels is proposed when advocating "in favour of the establishment of an international body specifically related to all aspects of CBT" (Giampiccoli and Saayman, 2016:8). A CBT-N that upholds equality and equity would be the ideal model to promote these virtues. In this context, collaboration and partnerships are crucial but they also need specific characteristics that favour CBT. For example, in marketing and CBTS, cooperation "lowers the risk of failure for CBT and it is rare to find CBT initiated and controlled entirely by the community. External advice and links are a necessity to ensure success" (Dodds et al., 2018:1551). Models of partnership and collaboration in CBT can include joint ventures and various private-public partnerships which are debatable because some people think that external parties should be excluded. Various entities can be involved in CBT collaborative effort and include the private sector, the government and non-governmental sector for purposes of training, marketing, technical resources and funding (Dodds et al., 2018:1556). These efforts have been undertaken by international development agencies (IDAs) including NGOs which promote CBT by selling the concept in communities and unpacking its benefits as well as potential challenges during implementation (Novelli et al., 2017:260).

While partnership and collaboration are important in CBT projects involving various entities, it is equally important to remember that the type and purpose of the partnership is key in deciding the success or failure of a CBT venture. It is also important to establish the modalities upfront of how to break the dependency of the CBT project itself from external entities. In Kenya, the current model of CBT enterprises is based on the neo-colonial model which favours foreign investors and reinforces dependency while not working towards community empowerment, emancipation, independence and benefit (Manyara and Jones, 2007). The structuring of the ownership and management landscape of the venture should favour the local community if any significant benefits are to accrue to them in earnest. Window dressing will not help communities achieve their socio-economic emancipation and empowerment. Many authors have criticized external funding from foreign donors because this has created dependency and a lack of financial sustainability of many CBT projects (Kontogeorgopoulos et al., 2014:115).

A possible direction to take in partnerships is to ensure that it is temporary but only 'long-term' for capacity building and empowerment but the CBT venture itself should not be part of the partnership (Mtapuri and Giampiccoli, 2016:163). Collaboration amongst CBT ventures should be embraced for the greater empowerment of the communities in the CBT sector. Limitations and difficulties in CBT can be mitigated through a collaborative network approach (Tolkach and King, 2015: 389). This is in line with the creation of the CBT-N.

Community-based tourism networks / association

CBT-N are fundamental in assisting CBT development, because they can provide the moral support, impetus, resilience and reach in the long-haul which an individual entity may not be able to maintain (Asker, et al., 2010:77).

Partnerships and other forms of networks can provide critical support for CBT initiatives. A CBT venture that is well networked will be more successful and resilient than one that is internally focused and solely reliant upon CBT managers to build and sustain the CBT venture. Relationships between community tourism managers and external organizations/individuals can be invaluable for many aspects of tourism management from product development through to marketing, resourcing and the development of knowledge and capacity to ensure delivery of a quality CBT experience to visitors. Support can come in many forms, including financial assistance, training in tourism service delivery, networking community managers with other local providers and assistance with marketing (Asker, et al., 2010:78).

A CBT manual (Asker, et al., 2010:77; bold in original) proposes the following fundamental issues in relation to CBT-N:

- **Building positive relationships** between CBT management teams and other tourism stakeholders to **build a strong foundation for CBT**. Identifying, developing and managing positive relationships provides a strong foundation for effective and sustainable CBT;
- CBT, in many contexts, requires engagement with the private sector. Appropriate **relationships between communities and the private sector** can benefit community-managed initiatives;
- **Collaboration between communities and tourism authorities** (including peak industry bodies) can provide benefits around branding and positioning the CBT operation within the wider tourism marketplace; and
- **Regional community tourism hubs** can be a great source of support to CBT managers. These knowledge and networking centers can assist by

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providing information, facilitating learning and connecting communities with private operators and government agencies, and aid agencies.

Community-based tourism networks "have potential to assist the socioeconomic development of less developed countries, especially in the case of Small Island Developing States (SIDS), where tourism is often associated with colonial and neo-colonial activities that contributed inadequately to local livelihoods […] CBT networks may also provide an opportunity for rural development by strengthening fragile individual business operations" (Tolkach and King, 2015: 386). Community-based tourism networks have been proposed and can be useful in various contexts, as the few examples below illustrate. Thus, in relation to CBT and rural tourism, it is indicated that, in the competitive context of rural tourism locally and internationally, rural destinations "must also create networks among small enterprises in order to get noticed, and build capacity in terms of business skills, marketing, advertising and promotions, etc., and create partnerships with the private sector (e.g. tour operators and other accommodations) as well as alliances with national CBT associations where available" (Dodds et al., 2018:1562). A research on exploring models of CBT Network [CBT-N] in Timor-Leste conclude that the growth "of a CBT network should help build a strong national CBT tourism product in Timor-Leste that offers benefits to the wider population. It should also advance existing knowledge about the benefits of networking and of coordinating community-based tourism initiatives" (Tolkach et al., 2011:4). A case from Sarawak (Eastern Malaysia) proposes the possible role of CBT-N in training and marketing when mentioning generating "support networks with other CBT ventures in the region increases potential exchanges including 'look and learn' visits, which may serve to increase staff confidence and motivation. Such networks can also provide collaborative marketing opportunities and other benefits from collaboration (e.g. setting standards and making a particular CBT product stand out in a specific region)" (Asker, et al., 2010:58). In the context of Thailand, "regional or national network can assist not only with marketing efforts, but also funding capabilities and knowledge-exchange between parishes and/or individual communities would be strengthened" (Dodds et al., 2018:1552). A case study about community-based tourism network in Jordan concludes that producing "NGOs will allow communities to work together transcending tribal differences and allowing people to become integrated into the socio-economic development process in Badia" (Al-Oun and Al-Homoud, 2008:50).

Given their possible potential, CBT-N are present around the world. Costa Rica presents two main CBT-N: the Costa Rican Association of Community-Based Rural Tourism (Asociación Costarricense de Turismo Rural Comunitario, ACTUAR) and the Cooperative Consortium - National Ecotourism Network (Consorcio Cooperativo Red Ecoturística Nacional, COOPRENA). ACTUAR and COOPRENA have 23 and respectively 13 members (Trejos et al., 2008:17). The study from Costa Rica concludes that the "research has shown the importance of support networks in the development of CBRT in Costa Rica" (Trejos et al., 2008:23). Table 1 presents an example of some CBT-Ns around the world, demonstrating how the global growth and 'networking' of CBT entities is much a reality in spite of the challenges. However, much remains to be done to mainstream and internationalise CBT concepts and practices for tourism to become just, equitable and sustainable (Giampiccoli and Saayman, 2016:8).

Thus, the need remains to work towards "internationalise/mainstream CBT concepts and practice […] together with possible options on how to establish a CBT international body with decentralised 'branches'" (Giampiccoli and Saayman, 2016:8).

Table 1: Examples of CBT-N around the world

Network/Organisation/ Association	Geographical area	Website
Kyrgyz Community Based Tourism Association "Hospitality Kyrgyzstan" (KCBTA)	Kyrgyzstan	http://cbtkyrgyzstan.kg/
Thailand Community Based Tourism Network Coordination Center (CBT-N-CC)	Thailand	http://cbtnetwork.org/
Bali Community-Based Tourism Association (Bali CoBTA)	Bali	http://balicbt.org/
REDTURS: Latin America Community-based Tourism Network.	Latin America (various countries)	http://www.redturs.org/nuevaen/index.php
Uganda Community Tourism Association (UCOTA)	Uganda	http://ucota.or.ug/
Tajik Community Based Tourism Association (TCBTA)	Tajikistan	http://cbttajikistan.tj/en/

CBT Vietnam	Vietnam	http://www.cbtvietnam.com/
The Kenya Community Based Tourism Network (KECOBAT)	Kenya	http://kecobat.org/
Cambodia Community-Based Ecotourism Network (CCBEN)	Cambodia	http://crdtours.com/cambodia-community-based-ecotourism-network/
Costa Rican Association of Rural Community Tourism and network (ACTUAR)	Costa Rica	http://actuarcostarica.com/?lang=en

It is also relevant to note from a different approach of networks at a more global level and wider/mainstream tourism sector that CBT-N and CBT itself need to be contextualised in the global framework and mainstream tourism. In this context, the possible "inability of small CBTEs [community-based tourism enterprises] to be included in mainstream distribution networks limits their potential to attract significant tourist numbers and generate revenues" (Lapeyre, 2010:767). Recent researches have moved from the micro-level approach to the more global milieu, therefore "tourism activities, including CBTEs, are now rightfully regarded as being part of a network of local, regional, national and international actors, and as a result tourism impacts are increasingly analyzed through the lens of the global commodity chain (GCC) theoretical framework" (Lapeyre, 2010:759). Networks allow the sharing of experiences, ideas, know-how; the expansion of the product offerings and value chains (from a micro to a global level) as well as providing a platform for learning and co-learning. By cooperating together through these networks, communities adopt and adapt new things from elsewhere while opportunities to innovate based on what has been learnt widen. These networks can help ventures to improve their bottom-line – profits in win-win circumstances.

CBT-N in Africa

This section proposes the case study of KECOBAT (KECOBAT, online, a) and UCOTA (UCOTA, online, a), two CBT-N currently present in Africa. The aim is to examine what roles, features and services the two CBT-N have in order to assist CBT ventures in their development efforts. In Uganda, the origin of UCOTA is the result of an international (USA) programme and local support. UCOTA was established and officially launched in 1999 (Victurine, 2000). Specifically, a programme workshop promoted "the decision to create UCOTA in 1998" (Victurine, 2000:226). The establishment of UCOTA was a collaborative effort, as participants of the workshop "established a committee charged with creating and legalizing the association. They also acquired a commitment of technical support for the process from the North Carolina Zoo and from the Namibian Community-Based Tourist Association, whose representative attended the training to assist in forging the new organization" (Victurine, 2000:226). Finally, UCOTA's ambition is to "represent the interests of various individuals and community-based tourism initiatives, hotels, and craft makers to ensure application of standards and quality control to enhance visitors' tourist experience and ensure that members benefit economically from Uganda's ecotourism" (Victurine, 2000:226). The UCOTA's own website presents the organization as "the official umbrella body that brings together and advocates for the interests of community tourism groups in Uganda to ensure that the local tourist host communities benefit from tourism" (UCOTA, online b). In addition, "UCOTA describes the emphasis on crafts as a useful strategy for keeping interest alive (through exports) until tourism recovers" (Ashley and Roe, 2002: 77). It is important to note that, in Uganda, there is another CBT organization (Community Based Tourism Initiative – COBATI), curiously and practically of the same age (1998) of UCOTA and working in favour of CBT ventures and products. COBATI seems focused on CBT training and projects implementation, such as the Bombo Community Tourism Initiative that is also financially supported by external private donors (COBATI, online b).

In Kenya, the CBT-N is more recent, in fact "KECOBAT was launched in August 2003 as a membership umbrella organization representing the interest of Community Based Tourism (CBT) organizations in Kenya" (KECOBAT, 2017). It is mentioned that "KECOBAT Network can be regarded as a "trade association" representing the poorest sections of tourism. Most of the members are based in communal land areas where a majority of them are poor and depend on subsistence livelihoods. By being the central point of contact, KECOBAT Network links these, often-inaccessible communities with the government, the private sector, NGO's, donors, and training institutions thereby making it easier and less time consuming to work with" (KECOBAT, 2017). Thus, the role of KECOBAT is proposed to "create a forum that afford communities grappling with tourism challenges work with one voice and purpose through empowering communities to mobilize their own capacities, learn from each other, effectively manage their resources and thereby make informed decisions to control activities that affect their lives and their

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environment. This will make them actors rather than passive subjects in the tourism industry" (KECOBAT, 2017; KECOBAT, online g). Moreover, the KECOBAT plan is to "actively create appropriate mechanisms and incentives to open-up opportunities for rural communities to enhance their participation in the tourism industry especially in planning and running of enterprises on their land" (KECOBAT, online g).

The Kenyan KECOBAT has a collaborative approach stating that it "aims at meeting its goals by working with regional associations, group, CBOS [community-based organisations] and other like-minded bodies that work to the benefit of communities through tourism" (KECOBAT, online c) and its partners include National partners, national Associations, national NGOs, and Governments such as (see KECOBAT, online c):

- Ministry of Tourism;
- Tourism Regulatory Authority;
- Western Circuit Tourism Association;
- Uganda Community Tourism Association (UCOTA);
- Tanzania Association of Cultural Tourism Organizers (TACTO);
- Fredskorpset;
- East Africa Wildlife Society;
- Kenya Utalii College;
- Lake Victoria Tourism Association (LVTA);
- Mount Kenya Tourism Circuit Association; and
- Mombasa and Coast Tourism Association (MCTA).

The KECOBAT website (KECOBAT, online c) also shows possible links with more international entities presenting logos such as the European Union (European Union flag) and the SNV Netherlands Development Organisation. In the context of programmes, services or activities offered, KECOBAT includes (KECOBAT, online d): policy advocacy, marketing, homestays development, CBTE's training, capacity building and economic empowerment, accreditation and standardization, market access for CBTE's, central reservations for CBTE's, Fredkopset Norway (fk), research and consultancy, and certification. On the other hand, the Ugandan UCOTA offers capacity building, marketing, advocacy, networking, conservation, resource mobilization and consultancy (UCOTA, online b).

In terms of training, both CBT-N offered various training opportunities. Training is specifically seen as a core activity in UCOTA and the organization offers training in (see UCOTA, online b):

- Community enterprise concept development;
- Community business plan development;
- Community operations planning;
- Community interpretive guiding and tour planning;
- Community product sales and marketing;
- First Aid;
- Ecology;
- People of Uganda/ ethnicity; and
- Product development (Tourism and handcraft).

UCOTA boasts that in "Capacity building: UCOTA trains her members in various fields of tourism development such as business skills, interpretive guiding, bird watching, hospitality, handcrafts, group dynamics, site management, conservation of natural and cultural resources" (UCOTA, online b, bold in original).

The Kenyan side is also active in training and it is noted that "KECOBAT provides training opportunities to communities, local people and the informal sector who are interested in understanding the basics of community tourism and how to fully exploit the employment and business opportunities presented by tourism to their communal area [...] KECOBAT conducts training at both local and regional levels to help the local communities develop sustainable community tourism enterprises" (KECOBAT, online f). In Uganda, the above-mentioned CBT-N (COBATI) also focuses highly on training. Thus, COBATI training offers include topics such as (see COBATI, online b):

- Community Tourism as a tool for income generation and poverty alleviation in rural areas;
- Agritourism – Linking tourism to agriculture;
- Cultural Heritage – Linking tourism to local people and their cultures;
- Heritage Trails – Developing scenic and historical trails;
- Handicrafts and Tourism – Promoting ethnic designed crafts and tapping indigenous knowledge;
- Homestead Tourism – Linking tourism to rural hospitality, local lifestyles, and village environment as attractions;
- Support small and emerging local tourism businesses in rural Uganda; and
- Conservation of unique rural features and historic sites as community tourism attractions.

This variety of training possibilities lean towards what is proposed in CBT that training should be as much as comprehensive to give possibility to be applied beyond strict tourism needs. There is a need to attempt to consolidate all these features, service and products of CBT-N towards a model to establish a possible starting framework within which a CBT-N should be established and work.

Towards a CBT-N model

Without claiming to be fully comprehensive, the present section illustrates a CBT-N model that assembles various aspects related to CBT-N. This model can be viewed as a starting point upon which specific CBT-N could take inspiration. Specific local contexts, resources, capacities and capabilities will also influence the final CBT-N model to be established in each case. As a background, it can be noted that, as proposed in a Timor-Leste case study, success of the CBT-N will depend on strength of the steering and management committees, funding sources and whether or not CBT practitioners are keenly involved in the network (Tolkach and King, 2015: 396).

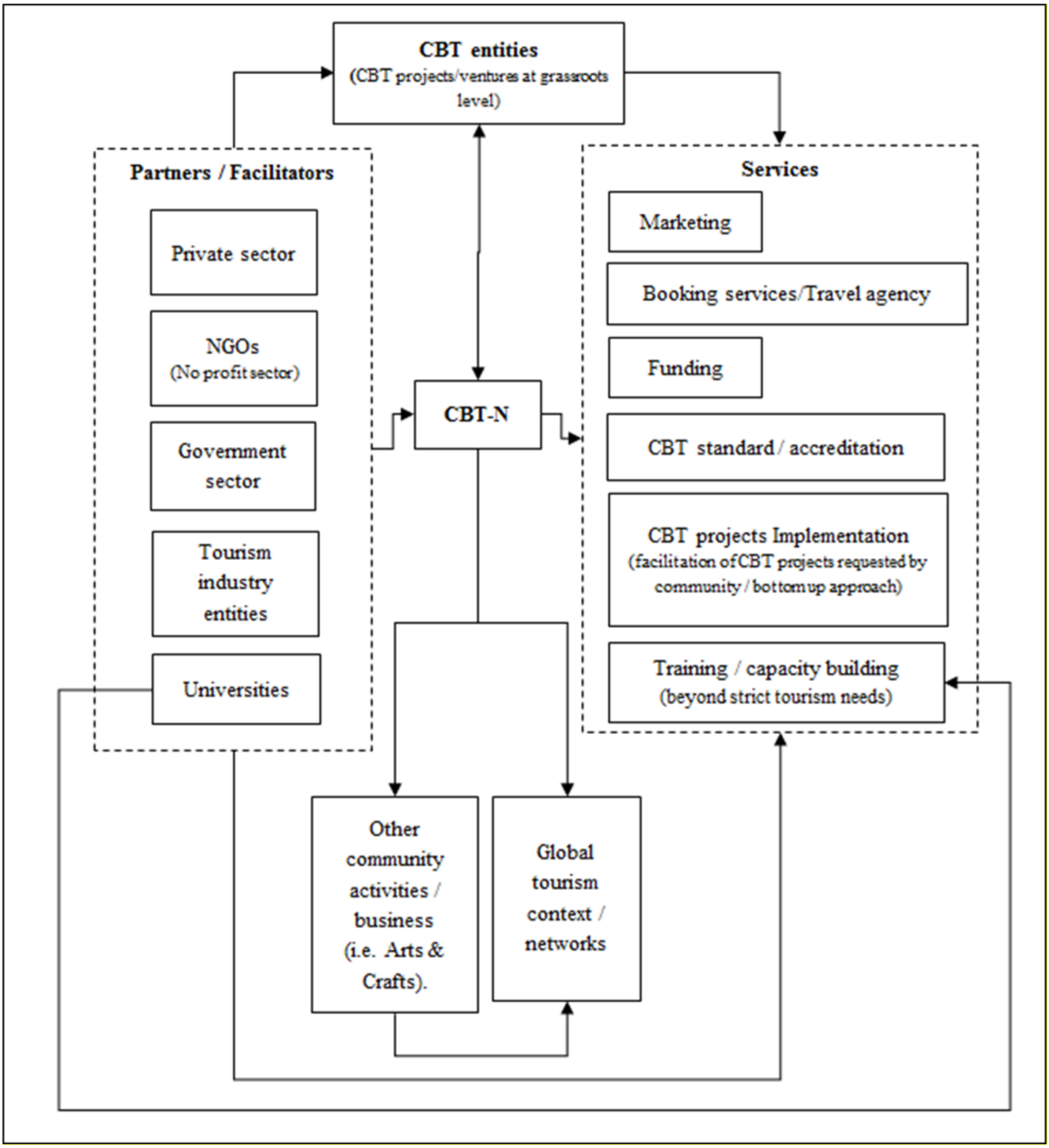

Fig. 1: CBT-N model (source: Authors)

Collaboration and partnership are fundamental and present in current CBT-N. However, while partnerships with various entities can be beneficial, it is important to recall that partnership between CBT venture and the external entities, should be temporary but 'long-term', as proposed; "partnerships, whether informal or formal, should have two specific characteristics: firstly, the partnership should be 'temporary' but in long term in cases where it is deliberately directed towards capacitating and empowering the community to gain greater independence and bargaining power in relation to external entities; and, secondly, the CBT venture itself should not be part of a partnership" (Mtapuri and Giampiccoli, 2016:163). For example, a case study on CBT in a Bedouin's context proposed that "Bedouins sharing their heritage with outsiders is encouraged, as long as they remain in control of their culture and are socially and economically empowered by working in tourism in partnership with government agencies and NGOs" (Al-Oun and Al-Homoud, 2008:51). This issue is fundamental. The need of independence and control is well recognized. For example, "KECOBAT is in the process of developing a community tourism Central Reservation system that will afford community members in Kenya low cost yet powerful and effective way to market their products and services locally and internationally" (KECOBAT, online e). While eventual technicality and methodologies related on how the reservation system work could be debated, it is fundamental to underline the need to have a centralised booking reservation system for CBT ventures. In this sense, KECOBAT seems to be following the right direction. In this context, the leading independency (break of dependency) in Uganda, UCOTA, aims "to become a self-financing membership association as well as an organization that will raise funds to continue with the capacity building initiated by the GMU [Grants Management Unit]" (Victurine, 2000:226). Thus, the model (Figure 1) presents an array of possible entities that could partner and facilitate/assist the CBT-N. The facilitators could work directly with the CBT-N entity, but also be involved with the specific CBT ventures or provide themselves some of the services. Whatever involvement is present, the aim should always be to work towards community empowerment, independence and greater community control and benefits from the tourism/CBT sector.

Universities, with their wide range of expertise, their local long-term presence and their variety of way of possible engagements, could be seen in a positive light, especially, for training purposes (Giampiccoli, Saayman and Jugmohan, 2014). Moreover, while many types of entities can be involved, preference leans towards "government entities, envisioning a more complementary role for the private sector and NGOs" (Giampiccoli et al., 2014a:1141). Figure 1 shows that the CBT-N should be the central coordination entity and the main unit involved in the various services. While the list of services offered could be seen as endless, based on the possible needs of specific circumstances, the model proposed a list of services seen as usually required and valuable. This list includes: marketing, booking service/travel agency, funding, CBTS and accreditation functions, implementation of CBT projects, training and capacity building in various aspects of CBT and beyond them. The booking system, while not presently common in many CBT-N, is, instead, considered as very relevant to work towards the CBT-N (and its members) independence. Within this aim towards increased empowerment, independence, long-term sustainability, the CBT-N should facilitate the link – but not the assimilation – with the global tourism context in order to increase their weight and relevance locally and internationally and maintain their value and benefits for the members involved. At the same time, the CBT-N should also favour the link with (and when possible, the facilitation and establishment of) other businesses, such as art and craft that can be connected to the main CBT ventures. All the above should move towards greater empowerment and independence of the CBT ventures and CBT-N. Looking at CBT enterprises in a Kenyan study, there was mentioned that: "The paper concludes that CBEs reinforce a neo-colonial model, with foreign control of tourism resources and heavy reliance on donor funding reinforcing dependency, and it advocates an urgent review of the support framework for community tourism development in Kenya in order to integrate the principles of sustainable development" (Manyara and Jones, 2007:630). Community-based tourism networks (associations or organizations) could greatly contribute towards the emancipation, independence, empowerment and growth of the CBT sector.

Conclusion

The relevance of CBT within the tourism sector is growing. Community-based tourism is aimed at disadvantaged community members and remain within the general context of alternative development proposing issues such as empowerment and self-reliance. Community-based tourism networks are currently present globally and their importance has been recognised. However, few studies are dedicated to CBT-N. Two CBT networks/associations (CBT-N) that were used in this paper show their role and mandate and the power of working together in partnerships for the common good.

Based on the literature review and the case study, this paper proposes a CBT-N model. The model, shows the possible collaborators in a CBT-N to reflect what the CBT-N can offer. Specific local contexts, resources, capacity and so on will also influence the final CBT-N model to be established in each case. The final aim should be to consistently work for the enlargement enhance the relevance of CBT, locally and internationally – while also boosting and supporting more multinational and global CBT-Ns – to contribute towards a fair tourism sector, thus, supporting "the need for the establishment of a CBT body present at various geographical levels and rooted in the values, concepts and practices of CBT's original meaning and understanding and opposing neoliberal tourism for social justice and sustainability" (Giampiccoli and Saayman, 2016:8); therefore, CBT-Ns have value.

Author contribution

The authors have developed an equal contribution in this research and in the article production.

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