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FORUM GEOGRAFIC

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XVIII**, Issue **1** (**June** 2019)

Professor Constantin Savin, Life and Activity

Lecturer univ. Ph.D Diana SAVIN[1]

[1] Faculty of Mathematics and Informatics, Ovidius University of Constantza

Constantin Savin was born on February 24th, 1937, in the village Hangu, commune Hangu county Neamt, Romania. From 1951 to 1954, he was a student at "Petru Rares" High School, in Piatra Neamt. In 1959, he graduated the "Alexandru Ioan Cuza" University of Iași, Faculty of Natural Sciences and Geography, Department of Geology-Geography, institution where he also got his Ph.D in Geography, in 1976, under professor Constantin Martiniuc, with the thesis "The geohydromorphological study of the Jiu lowlands in the Getic Plateau and the Plain of Oltenia". Through his thesis, the author delivered an original and important contribution to the study of the Jiu river's meadow and river bed dynamics.

During the doctoral and post-doctoral periods, Constantin Savin graduated the following courses:

- "The draining of rivers. Hydrological calculations" postgraduate course, organized by UNESCO at the Lomonosov University in Moscow, part of the "International Hydrological Programme (IHP)", between June and July 1969;
- "Applications of mathematics in hydrology" course, organized by the Meteorology and Hydrology Institute (MHI), Bucharest, in May, 1973;
- "Hydrology" course organized by the Civil Engineering Institute, Faculty of Hydraulic Engineering, Bucharest, in the 1979-1980 school year. At the course's final exam, Constantin Savin presented the article "The characteristics of flash flood rays in the drainage basin of river Jiu";
- "Applied hydrology" course, organized by the Meteorology and Hydrology Institute (MHI) Bucharest, in 1986, over the course of nine months.

The professional evolution of Constantin Savin was remarkable:

- First, he was a secondary school teacher in commune Rediu, Neamț county during the school year 1959-1960, then in commune Buda, Bacău county, between 1960 and 1961;
- Between 1961 and 1964, Constantin Savin worked as a hydrologist (responsible over station) at the Hydrological Station Bacău (part of Iași Water Directorate). Between 1964-1966, he worked as Chief Hydrologist within the same unit;
- He functioned as chief hydrologist at the Hydrological Station Craiova between 1966 and 1968;
- At the establishment of the Meteorological and Hydrological Sector (MHS), Craiova (later Jiu Water Directorate, Craiova), Constantin Savin was promoted to Chief Hydrologist over the entire country of Oltenia (which was the target of his transfer from Bacău). He remained within the unit as Chief Hydrologist for 8 years (1967-1975), for 14 years as Chief of Hydrology-Hydrogeology (following the unification of the two departments) between 1976 and 1990, for one year as Chief Hydrometeorologist (1990-1991), then for 8 years as CTO of the Craiova Branch of "Apele Române" Autonomous Management;
- In the school year of 1967-1968, Constantin Savin joined the University of Craiova, Faculty of History-Geography, as a assistant professor and, later, as lecturer, teaching Hydrology (course and seminary). Afterwards, after the promulgation of the law banning cumulating functions, during the summer of 1968, Constantin Savin decided to give up the job. Sometime later, the Geography Department of the Faculty was dissolved;
- Between 1975 and 1978, due to the delegation of wife Elena Savin (Mathematics teacher) to the Kingdom of Morocco, part of the technical and scientific collaboration between countries, Constantin Savin was also delegated to work as an engineer in Hydrology-Hydrogeology, also in Morocco, part of Public Administration and Communications Ministry,

Hydraulic Directorate, Water Resources Division, Regional center of Tadla in the town of Beni Mellal;

- Between 1991 and 1992, Constantin Savin taught Hydrology at Post-secondary School of Hydrometeorology in Craiova. At the same time, he was an associate professor, teaching Hydrology-Hydrogeology (course, workshops, exams), at Faculty of Ecobiotechnology, in Caracal, Romania;
- Between 1992 and 1993, Constantin Savin functioned as associate professor at University of Craiova, Faculty of Sciences, Geography-Geoecology Department, for Hydrology (course, workshops, seminaries, exams, field work) and at "Lower Danube" University of Galați, Faculty of Letters-Sciences, History-Geography Department, for Meteorology-Climatology (course, workshops, exams) and Hydrology (course, workshops, exams) – despite functioning as an associate professor, he was paid as a lecturer only.
- Between 1994 and 1995, Constantin Savin was an associate professor at University of Târgoviște, Faculty of Sciences;
- Between 1994 and 1997, Constantin Savin was a lecturer at University of Craiova, Faculty of Sciences, Geography-Geoecology Department;
- In 1997, his activity at Jiu Waters Directorate comes to an end, after which he obtains the associate professor position at University of Craiova, Faculty of History, Philosophy and Geography, Geography Department;
- In 2002, Constantin Savin wins the position of Professor (titulary) at University of Craiova, Faculty of History, Philosophy and Geography, Geography Department;
- Between 1999 and 2008, at the same time with his work at the Faculty of History, Philosophy and Geography, Constantin Savin also teaches at Faculty of Horticulture, at University of Craiova;
- At the end of the school year of 2007-2008, Constantin Savin retires.

Professor Constantin Savin wrote the following works (treaties, monographies courses):

- Constantin Savin, Jiu meadow water resources, Scrisul Românesc Publishing House, Craiova, 1990;
- Constantin Savin, Scientific Polyglot Dictionary, Tipored Publishing House, Bucharest, 1996;
- Constantin Savin, Scientific Polyglot Dictionary - Glossary, Tipored Publishing House, Bucharest, 1997;
- Viorica Tomescu, Vasile Pleniceanu, Constantin Savin, General physical geography (Tests for admission in higher education forms), Universitaria Publishing House, Craiova, 1990;
- Constantin Savin, Underground waters of Craiova, Tipored Publishing House, Bucharest, 2000;
- Constantin Savin, Hydrology of Rivers – theory and applications, Reprograf Publishing House, Craiova, 2001;
- Constantin Savin, Physical geography of Romania, course for students, University of Craiova, Craiova, 2003;
- Constantin Savin, Ion Marinica, Synoptical Meteorology (course support for the students of Faculties of Geography and Environment Engineering), published on CD, University of Craiova, Autograf Publishing House MJM 2007, ISBN 973-8989-13-2 (Romania), ISBN 978-973-8989-13-9 (E.U.), 2003, 2007 respectively;
- Constantin Savin, Rivers of Oltenia. Hydrological phenomena of high risk, Sitech Publishing House, Craiova, 2004;
- Constantin Savin, Hydrology and the protection of water quality, Sitech Publishing House, Craiova, 2006, University of Craiova, Faculty of Horticulture;
- Constantin Savin, Special meteorology and hydrology problems – course for students, University of Craiova, Craiova, 2006;
- Constantin Savin, Rivers of Oltenia – hydrological monography, vol. I – The dynamics of river drainage, Sitech Publishing House, Craiova, 2008.

Constantin Savin had been interested into scientific research and theoretics (apart from his work obligations) since 1965-1970, interest which had taken a variety of forms: research articles, synthesis, studies, books, participation (with or without holding a discourse himself) in scientific conferences, both national and international, participation in courses, local press interviews, interviews and discussions over scientific matters, at the territorial Radio Craiova studio, reviews of certain books (as a scientific reviewer), reviews of Ph.D thesis (also as a scientific reviewer to some).

Professor Constantin Savin wrote over a hundred research articles, studies and pages of synthesis (out of which thirteen abroad, two in France and eleven in Morocco), over 85 of which were published in magazines with reviewers. To mention a few:

1. Guessab Driss, Constantin Savin, La possibilité d'eméttre des previsions d'apports d'été au reservoir de Bin El Ouidane, published in Notes techniques de l'hydrauligue - Série Hydrologie, March 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);
2. Constantin Savin, Exploitation des mesures de débit d'étiage des rivières aux fins de prévision de fourniture d'eau pour l'irrigation, published in Notes techniques de l'hydrauligue - Série Hydrologie, May 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);
3. Constantin Savin, Etude des débits au maximum de l'oued Ourbia (Akka N'Khelifa), publicata in Notes techniques de l'hydrauligue- Série Hydrologie,

December 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);

4. Constantin Savin, L'étude hydrologice de l'oued Ikaben, published in Notes techniques, no.4/1976 (MTPC, DH, DRE, Centre Régional du Beni Mellal, Maroc);

5. Constantin Savin, Contributions to the hydrological study of the Craiova area (partial results), published in Lucrarile Seminarului geographic "D. Cantemir", nr. 3/1982, Univ. Iasi;

6. Constantin Savin, The characteristics of flash flood rays in the drainage basin of river Jiu – detailed study, published in Hidrotehnica, nr. 9/1983, CNA, Bucharest;

7. Constantin Savin, Contribution à l'étude de la dynamique des versants à base des measures hydrotopométriques, Symposium the role of geomorphological field experiments in land water management, August 25-September 3, 1983, Bucharest (University of Bucharest, Institute of Geography of the Romanian Academy), published in the volume Geomorphological research for land improvement, under ISPIF, Bucharest, University of Bucharest, Institute of Geography of the Romanian Academy, Bucharest, 1985;

8. Nicolae Ghigiu, Constantin Savin, Hydro-meteorological data valorification towards rational exploitation of water volumes from the "Valea de Pești" Dam, published in Hidrotehnica, nr. 11/1994, RAAR, Bucharest;

9. Constantin Savin, L'écoulement minimum sur la riviére de Jiu pendant la période de sécheresse 1992-1993, 3-èmes Rencontres Hydrologigues Franco-Roumaine, Montpellier, September 6-8, 1995 (special volume);

10. Constantin Savin, L'asssèchement des rivières dans l'espace hydrographique Jiu-Danube. Etude de synthèse, published in Les travaux de 3-èmes Rencontres Hydrologigues Franco-Roumaine, Montpellier, September 4-8, 1995 (special volume);

11. Constantin Savin, Elena Savin, Climate of Oltenia towards aridity, published in Hidrotehnica, nr. 6/1995, RAAR, Bucharest;

12. Constantin Savin, Contributions to the analysis of the aquiferous layers with free level within the Craiova Area, published in Analele Universitatii din Craiova, sectia Geografie, nr. 3/1999;

13. Constantin Savin, Viorica Tomescu, Human-induced Changes of the Danube alluvial plian. Landscape within Drobeta Tr. Severin-Corabia Area, published in Analele Universitatii din Cluj-Napoca, Facultatea de Geografie, nr.3/1999;

14. Constantin Savin, Contributions towards determining the underground water quality in the Craiova area, published in Hidrotehnica, vol. 46, nr. 1/2001, p. 16-22, CNAR, Bucharest;

15. Constantin Savin, The hydrometrical method of evaluation of the minor riverbed dynamics. Applied to river Jiu, published in Analele Universitatii din Craiova, sectia Geografie, nr.4/2001;

16. Constantin Savin, The evaluation of underground water resources in the perimeter of the Craiova area, published in Geoforum, nr.1/2001, Univ. din Craiova, sectia Geografie;

17. Constantin Savin, The variation of the annually drain of water for the main rivers of Oltenia, published in Hidrotehnica, vol. 47, nr. 12/2002, p. 11-16, Bucharest;

18. Ion Marinica, Constantin Savin, Canicular days, climatic risk, phenomenon in Oltenia, published in Ovidius University Annals of Geography, vol. 2/2005, p.111-124;

19. Constantin Savin, Ion Marinica, Brussels - Craiova – a climatic parallel, published in Ovidius University Annals of Geography Volume 2/2005, p. 135-144;

20. Constantin Savin, The variation of medium water deposits drainage on the rivers of Oltenia in the past 50 years, published in Lucrarile Seminarului geographic "D. Cantemir", nr. 25/2005, Univ. Iasi, p.77-85.

The books and articles of professor Constantin Savin have been quoted not only in many Romanian journals, but also abroad, in Journal Cold Regions Science and Technology (Elsevier), in Central European Journal of Geosciences (Versita), etc.

In 1975, Constantin Savin was among those who contributed to the transformation of Meteorological and Hydrological Sector (MHS), Craiova, into Jiu Water Directorate, Craiova. After the revolution of 1989, he was among those who contributed to the reestablishment of the Geography-Geology Department at Faculty of Sciences, University of Craiova. Also, he was one of the founders of the Hydrological Sciences Association of Romania.

Professor Constantin Savin was the Romanian hydrologist who introduced the notion of "exceptional hydrological risk", as an effect of the current climatic changes.

For many years, Constantin Savin was a board member of the following journals: Romanian Journal of Hydrology – Water Resources (edited in 1994 by MMHI, Bucharest), the "Hidrotehnica" journal, Annals of the University of Craiova (the Geography series), the Geographical Phorum.

Professor Constantin Savin was a scientific reviewer of the following books:

- Elena Gavrilescu, Ion Olteanu, The environmental quality (II). Monitoring the water quality, Universitaria Publishing House, Craiova, 2003;
- Elena Gavrilescu, Ion Olteanu, The environmental quality (III). Air analysis and monitorization methods, Universitaria Publishing House, Craiova, 2003;
- Elena Gavrilescu, Water Quality: Vol. 1: Aquatic environment pollution, Sitech Publishing House, Craiova, 2006;

- Elena Gavrilescu, Water Quality: Vol. 2: Aquatic ecosystems evaluation, Sitech Publishing House, Craiova, 2006;
- Elena Gavrilescu, Pollution sources and environmental polluting agents, Sitech Publishing House, Craiova, 2007;
- Elena Gavrilescu, General notions of Ecotoxicology, Sitech Publishing House, Craiova, 2008;
- Elena Gavrilescu, Bogdan Filip Gavrilescu, The characteristics and the source of used industrial waters and their influence, Sitech Publishing House, Craiova, 2009;
- Elena Gavrilescu, Ecotoxicology: Aspects and problems, Sitech Publishing House, Craiova, 2011;
- Elena Gavrilescu, Gilda Diana Buzatu, Environment-depolluting methods, Sitech Publishing House, Craiova, 2013.

Professor Constantin Savin had professional connections to various colleagues in Romania: Faculty of Hydrotechnics, University of Bucharest, "Spiru Haret" University, Romanian Academy Geography Institute, INMH, ICIM, C.N.A.R. in Bucharest, the universities of Iasi, Cluj-Napoca, Timisoara, Oradea, the colleagues from Water and Environment Management System and „Apele Române" National Company, from numerous cities. Professor Constantin Savin had professional connections to various colleagues from abroad: France (Paris School of Mines, University of Sorbonne, I.H.P. National French Committe), Switzerland (O.M.M.), Belgium (Royal Meteorological Institute), Israel (in Tel Aviv), Kingdom of Morocco (Hydraulic Directorate, Rabat, Beni Mellal), Ukraine (University of Cernivtsi), Moldova (State University of Tiraspol, Hydrometeorological Directorate in Chisinău).

Professor Constantin Savin was member of the following prestigious scientific societies, in Romania and abroad:

1. Founder of the Romanian Hydrological Sciences Association, Headquarters at MMHI Bucharest;
2. Member of Geographical Sciences Society of Romania;
3. Member of Geomorphological Association of Romania;
4. Member of the Romanian National Committe of the International Hydrological Programme.

Professor Constantin Savin wrote appreciative reviews for 14 Ph.D thesis at I.P. Bucharest, I.C. – Faculty of Hydrotechnics, Bucharest, Universities of Cluj-Napoca, Iasi, Bucuresti, Romanian Academy Geography Institute, MMHI Bucharest.

Professor Constantin Savin had an intensive collaboration with the mass-media, the press, Radio Craiova, Teleuniversitaria Studio, Regional Craiova Studio of the Romanian TeleVision: until 1998, as the Spokesperson of Water Directorate Craiova,and then of Geography Department of University of Craiova.

For his professional activity, professor Constantin Savin was awarded the following medals:

- Honorary Medal and Diploma, awarded by C.N.A. and I.N.M.H. on the occasion of celebrating the „Romanian Meteorology and Hydrology Institute Centenary", for exceptional contributions to the named disciplines in Romania;
- Medal for „Exceptional activity during the floods of October 1972", awarded by State Council;
- Medal for „special merits in the development of Hydrological and Meteorological activities in Romania", in 1974;
- Diploma awarded by ROMAG Dobreta Turnu Severin, on the occasion of the 10th Anniversary of the water factory establishment, „for his contribution to the development of nuclear energy in Romania";
- Honorary diploma, issued by University of Bucharest, Faculty of Geography, on the occasion of a century of geographical studies at University of Bucharest;
- Honorary diploma, awareded by the Romanian Geography Society on the occasion of its 125th Anniversary.

On 26th of August 2017, professor Constantin Savin passed away.

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English translation of
Alexandra Pasparuga

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Climate parameters relevant for avalanche triggering in the Făgăraș Mountains (Southern Carpathians)

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Abstract

The climate conditions may contribute significantly to the generation of several hazards in mountain areas, such landslides, wildfires, flash floods and avalanches. This study examines the variation of the main meteorological parameters with impact on avalanche triggering conditions at Bâlea-Lac Meteorological Station. At the best of our knowledge, this is the first overview of the basic climate parameters which are potentially avalanche triggers in the Făgăraș Mountains (Southern Carpathians). The study is based on data from only one weather station (Bâlea-Lac) from the period 1979-2017, assuming it is consistently relevant from climatic point of view for avalanche occurrence in the area. The results demonstrate that the theoretical circumstances for avalanche triggering (e.g. snow pack, fresh snow or wind) can be captured. This paper briefly describes the nivologic monitoring system run by the National Meteorological Administration and emphasises its utility for avalanche forecasting and alerts.

Keywords: *avalanche hazards, avalanche triggering factors, mountain climate, Făgăraș Mountains*

Rezumat. Parametrii climatici relevanți pentru declanșarea avalanșelor în Munții Făgăraș (Carpații Meridionali)

Condițiile climatice pot contribui semnificativ la apariția mai multor hazarde naturale în zonele montane, precum aluncări de teren, incendii de vegetație, inundații și avalanșe. Acest studio analizează variațiile principalilor parametrii meteorologici care favorizează declanșarea avalanșelor la stația meteorologică Bâlea-Lac. Din câte cunoaștem, acesta este primul studiu al prametrilor climatici de bază are pot constiti factori declansatori pentru avalanșe în Munții Făgăraș (Carpații Meridionali). Studiul utilizează datele de la o singură stație meteorologică (Bâlea Lac) în perioada 1979-2017, considerând că este relevant din punct de vedere climatic pentru producerea avalanșelor în zonă. Rezultatele demonstrează că circumstanțele teoretice pentru declanșarea avalanșelor (stratul de zăpadă, zăpada proaspăt cazătă sau vântul) pot fi surprinse. Lucrarea descrie succinct și sistemul de monitorizare nivală condus de către Administrația Meteorologică Națională, punând accent pe utilitatea acestuia pentru prevederea avalanșelor.

Cuvinte-cheie: *riscul de avalanșă, factori declanșatori de avalanșelor, climat montan, Munții Făgăraș*

Introduction

Snow avalanches represent a major natural hazard triggering significant damages and casualties in many mountain massifs, so that avalanche forecasting services function in many countries – France, Germany, Switzerland, Norway, Poland, Austria, Italy, Czech Republic, Scotland, Iceland, Sweden, United States of America, Canada - issuing avalanche warnings. Statham et al (2018) identify four avalanche characteristics that should be considered in the assessment of avalanche hazards, related to (1) problems derived, (2) location, (3) probability of occurrence, and (4) magnitude of the event, and one can associate equal weight to each of them. Such properties should be quantitatively assessed both for current conditions and upcoming weather, as basic information for avalanche bulletins at regional and local scales.

While snow avalanches are the result of the simultaneous occurrence of different conditions related mainly to topography, climate and human activity, the efficient monitoring and accurate forecasting should equally consider all the triggering factors. Complex approaches may always deliver complete results, but studies oriented to limited aspects are also valuable since they reveal one particular facet of the avalanche phenomenon. This study investigates the climatic factors which can lead to avalanche occurrence in the Făgăraș Mountains (Southern Carpathians).

The composition and stability of the snow layer and the derived avalanche risk are evaluated based on the European Avalanche Danger Scale, and the collected information consists of information about the place, time and probability of release for a specific type of avalanches (slab or sluff, large or small, wet or dry).

Within the Romanian Carpathians, avalanches occur each winter, with an increased frequency in areas above 2,000 m, covering about 4,000 km^2, with rough topography and not permanently inhabited. Skiing fields are usually not located in areas frequently affected by snow avalanches, but the increasing number of backcountry skiers brings up the necessity of a permanent service for monitoring snow parameters and avalanches in all the mountainous areas.

Snow avalanches have been registered since February 2004, when the Snow and avalanche monitoring network began the activity at four meteorological stations: Vârful Omu, Sinaia, Predeal and Bâlea-Lac, covering the Bucegi and Făgăraș

Mountains. Since 2018, the observational network was extended with seven meteorological stations covering most of the mountain area where avalanches frequently occur: Iezer, Călimani, Ceahlău-Toaca, Parâng, Țarcu, Vlădeasa 1800, Semenic (Figure 1).

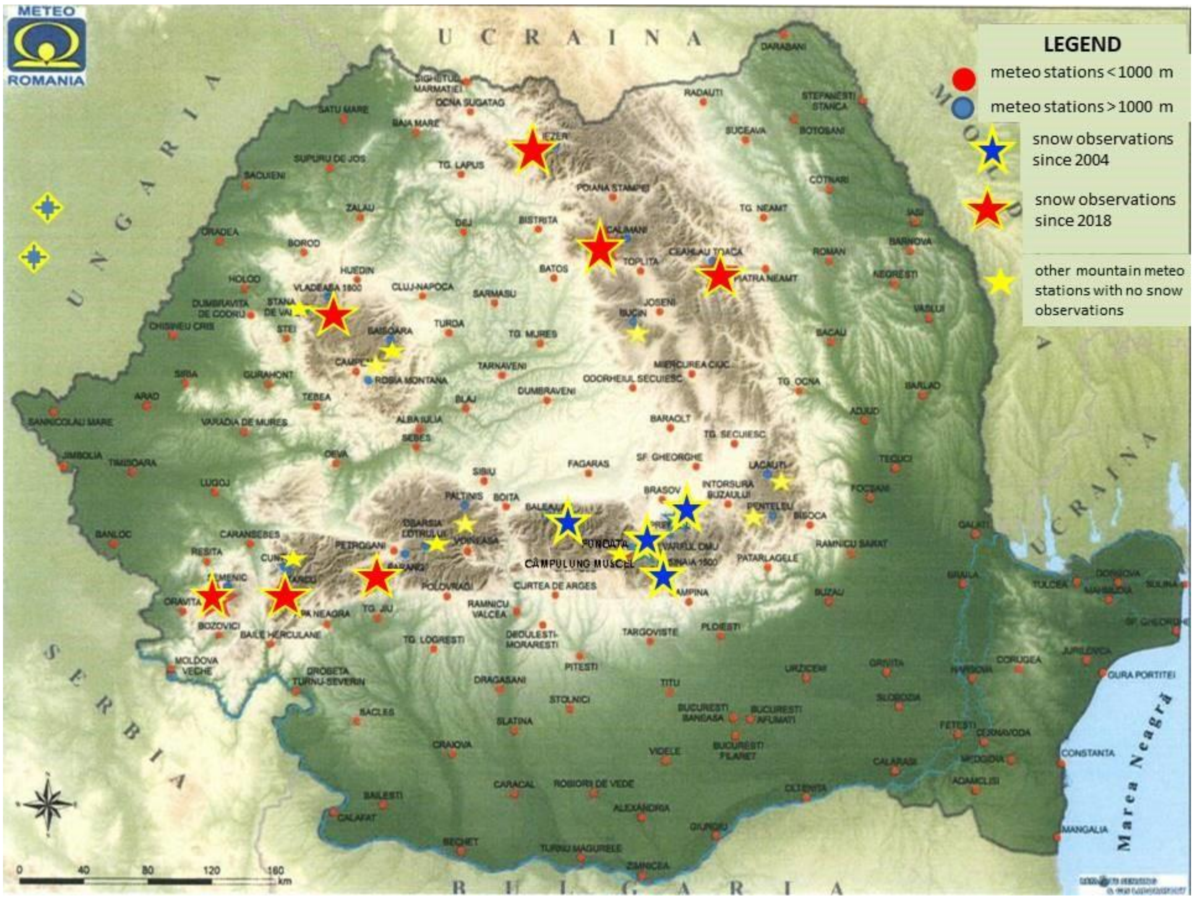

Fig. 1: Nivological network in the Romanian Carpathians

However, the information about avalanches is sparse and a consistent database covering the entire mountain area is under construction. Since January 2005, the operational work has been materialized in daily bulletins, which have been delivered to various stakeholders, e.g. Mountain Rescue Teams, District Councils, mass-media, touristic resorts and Town Halls.

While the avalanche monitoring action started in 2004, the first study about avalanches in Romanian Carpathians have been performed in 1964 and 1965 (Gaspar, 1968), following a burst of avalanches occurring at the beginning of 1963 blocking numerous roads and railway tracks in the forest massifs of the Southern Carpathians (Lotrului, Şureanu, Făgăraş) and Northern Carpahians (Maramureşului, Rodnei). The first study aimed to assess the conditions for avalanches, their characteristics, and techniques for prevention and combating.

As a result of the avalanche monitoring activity, the nivological bulletin is issued annually including information like the number, type and triggering conditions for avalanches (***, Bilanţul nivologic al sezonului de iarnă – Annual winter season report), as well as different research studies and other articles. Besides National Meteorological Administration, other research groups have analysed avalanches for specific Carpathian sectors and from different conditions, e.g. human triggering or terrain (elevation, aspect and slope angle) – (Voiculescu 2014).

This study examines the variation of the main meteorological parameters with impact on avalanche triggering conditions at Bâlea-Lac Meteorological Station, since 1979, when first observations were made, through December 2017. Bâlea-Lac is the only long-term weather station in the Făgăraș Mountains, and one can assume that the meteorological conditions are relevant for the climate of the entire mountainous area. After the introductory section (1), the paper presents (2) the triggering factors for avalanche hazards and forecast criteria, (3) meteorological data, avalanche database and climate settings at Bâlea-Lac, (4) a few climate characteristics relevant for avalanche triggering in the area of interest, and (5) concluding remarks.

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Triggering factors for avalanche hazard and forecast criteria

Most triggering factors leading to avalanche are related to the snowpack load and several classifications have been developed accordingly. Atwater (1954) proposed 10 weather and snow factors which contribute most to avalanche hazard in the Alta Ski Area, Utah, as follows: (1) old snow depth; (2) old snow surface; (3) fresh snow depth; (4) fresh snow type; (5) fresh snow weight; (6) state of accumulation; (7) wind force; (8) wind direction; (9) temperature developments; (10) snow coverage. The topography was not considered.

McClung and Tweedy, (1993), described five essential activating factors, including terrain, precipitation (especially fresh snow), wind, temperature (including radiation effects), and snowpack stratigraphy. The avalanche release probability can be assessed by estimating and weighting each contributing factor (Gubler, 1993).

Triggering factors may be stable (e.g. slope or morphology) or variable (e.g. weather conditions or snow properties) in time and they include (Ancey, 1998; de Quervain, 1981; Bernard, 1927):

• Mean slope, defined as the average inclination of avalanche starting zones, relevant between 27 and 50°;

• Roughness – a key factor in the anchorage of the snow cover to the ground;

• Shape and curvature of the starting zone. The stress distribution within the snowpack and the variation in its depth depend on the longitudinal shape of the ground. Convex slopes are generally associated with a significant variation in the snow cover depth, favouring snowpack instability;

• Slope aspect has a strong influence on the day-to-day stability of the snowpack;

• Fresh snow - an accumulation of 30 cm/day may be sufficient to cause widespread avalanching (Föhn et al., 2002; McLung and Tweedy, 1993; Ancey, 1998; de Quervain, 1981; Bernard, 1927; Gubler, 1993);

• Wind causes uneven snow redistribution (accumulation on lee slopes), accelerates snow metamorphism, form cornices which may collapse and trigger avalanches;

• Rain and liquid water content of the snow play a complex role in the snow metamorphism; i.e. the heavy rains induce a rapid increase in liquid water content, which results in a drop in the shear stress strength and leads to widespread avalanche activity (wet snow avalanches) (Conway & C.F., 1993).

• Snowpack structure. The stability of layer structure resulting from successive snow-falls depends on the bonds between layers and their cohesion. For instance, heterogeneous snow-packs, made up of weak and stiff layers, are more unstable than homogeneous snowpack (Schweizer et al., 2003).

Rapid warming leads to instability and slow warming derives snow-pack stability (according to (McClung and Schweizer, 1997)). For large (catastrophic) fresh snow avalanches, important snowfall is the strongest forecasting parameter ((Föhn et al., 2002)) and is closely related to avalanche danger (Figure 1).

Table 1: Weather-related indicators and associated greater avalanche potential (www.meted.ucar.edu/afwa/avalanche)

	Indicator	Greater avalanche potential
Precipitation	Snow accumulation rate	2.5 cm/h or more for more than 6 hours
	Water amount	25 mm or more in 24 hours
	Fresh snow density	More than 15 cm of 9% or greater density
	Storm trend	Begins cold, ends warm
	Rainfall	Any rain
Temperature	Increasing temperatures	Temperature rise >8°C in 12 hours, reaching values temperatures near or above the freezing point
	Rain/snow level	At or above avalanche starting zone elevations
	Warm temperatures	Above freezing at avalanche starting zone elevations > 24 hours
	Cold temperatures	▪ Very low temperatures (<-10°C) for long time (days) ▪ Shallow snowpack <1m deep and very low temperatures: <-10°C
Wind	Mean wind speed	▪ 9-27 m/s ▪ >27 m/s with snow density>10% ▪ 7-9 m/s with snow density<5%
	Mean wind direction	Consistent
Cloud cover	Nighttime sky cover	Clear skies with temperatures <-10°C and winds ≤ 5 m/s
	Daytime sky cover	Clear skies or thin clouds with warm temperatures and high sun angles, especially on sun-facing slopes

Accumulation of a fresh snow depth of about 1 m within a storm event is considered critical for the initiation of extreme avalanches; about 30–50 cm is critical for naturally released avalanches in general (Schaer, 1995) However, even with large amounts of

The avalanche forecast combines (1) information relevant for the snow conditions along the season of interest, and (2) short-term weather forecast for the area of interest. Avalanche forecasting is based on the joint assimilation of the weather conditions and snow coverage characteristics from the very beginning of the "winter" season. Meteorological data from the area of interest are currently used at daily scale and they should refer to:

a) Precipitation (snowfall and snow water equivalent - SWE)

b) Maximum and minimum temperatures

c) Winds near ridge-top level or at all forecast-area elevations

d) Average cloud cover

If detailed data from the past are not available, the regional weather data can be used cautiously and adapted to the area of interest. Most avalanches are associated with fresh snow falls, so that the following information should be available for any recent and/or ongoing precipitation event: (a) amount of fresh snowfall, (b) rate of accumulation, (c) SWE, and (d)

fresh snow, the combined release probability of a group of avalanche paths is frequently than 50% (Schaer 1995). This shows that the fresh snow depth alone is not sufficient to explain avalanche activity (Schaer 1995).

density of the fresh snow. Further, the avalanche potential is estimated based on a threshold exceedance procedure (Table 1).

Meteorological data, avalanche database and climate settings at Bâlea-Lac

Meteorological data and metadata

This study is based on daily meteorological records from Bâlea-Lac Meteorological Station (45°36'11"LN, 24°37'44"LE, 2044 a.s.l.) from 1 January 1997 to 1 December 2017. The location of the station is in the northern part of the Făgăraș Mountains, Bâlea glacial valley, in the vicinity of Bâlea Lake (Figure 2, 3), near the Transfăgărășan road. The station began observations since January 1978, after a huge avalanche stroke, when 23 victims died. Until august 1995, the meteorological platform was situated near Bâlea-Lake chalet, then, after the chalet burned, the station was moved into the Paltinul chalet (Figure 3).

Fig. 2: The Făgăraș Mountains, with Transfăgărășan Road and Bâlea Lac Meteorological Station position

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Fig. 3: Bâlea glacier Valley, the Făgăraș Mountains

Avalanche database

A number of 392 days with recorded avalanches have been collected from Bâlea-Lac meteorological station since January 1979, the beginning of the activity until January 2019. Most of the data have been collected since February 2004, when the programme of nivology began at the National Administration of Meteorology and mentioned since then into every Annual winter season report (***, Bilanțul nivologic al sezonului de iarnă). Until 2004, avalanche cases have been recorded from the literature and Mountain Rescue Services (Salvamont) – work of Walter Gutt and Reinhold, who collected informations from local papers, (as Neuer Weg, Hermannstädter Zeitung, Die Woche, Karpatenrundschau, Allgemeine Deutsche Zeitung für Rumänien, Jahrbuch der Sektion Karpaten des Deutschen Alpenverein, Kronstädter Zeitung, Clubul Alpin Român bulletins, Bukarester Tageblatt, Jahrbuch des Siebenbürgischen Karpatenvereins, Siebenbürgisch-deutsches Tageblatt). Some important avalanches happened before 1979, like the one from April 17, 1977, when 23 people were killed in an avalanche at Bâlea-Lac, but these will not be included in the study, due to the lack of meteorological observation data. All the information has been put together into a database in the Snowball project (http://snowball.meteoromania.ro/about/about-snowball).

Based on the data retrieved at the Bâlea – Lac Meteorological Station, from January 1979 through December 2017, synoptic conditions for the avalanche days have been studied and thresholds of several meteorological parameters considered to have an impact on this phenomenon has been made (Pașol et al, 2017).

Climate settings

The climate conditions at Bâlea-Lac Meteorological Station are very likely to be relevant for all the Southern Carpathians above 2,000 m, despite inherent differences related to local conditions, such as slope, exposure and land cover. The warmest period occurs during the summer months (i.e. June, July, and August) when the mean air temperature exceeds 9.0°C (e.g. 9.2°C in July and 9.5°C in August), and the maximum daily temperature reached almost 25°C (i.e. 24.8°C in 24 July 2007). The cold season (i.e. December, January, and February) has mean air temperature values around -7°C (i.e. -6.0°C in December, -7.6°C in January and February), while the lowest temperature over the period 1979-2017 was -31.7°C at 1 March 2005 (Fig. 4).

Fig. 4: Monthly average temperature (Tave), maximum (Tmax) and minimum (Tmin) daily air temperature, and mean monthly relative humidity (RH) at Bâlea-Lac meteorological station (1979-2017)

The average monthly relative humidity varies between 76-77%, in October and November, and 86-

87%, in June and July, in close correlation with the liquid precipitation influx over the area of interest (Fig. 5).

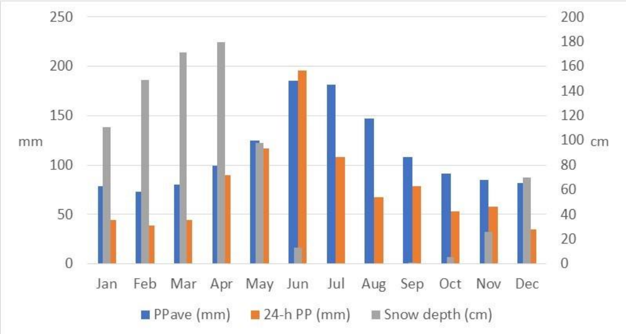

Fig. 5: Monthly average precipitation (PPave) and 24-h maximum amount (24-h PP), and mean snow depth at Bâlea-Lac meteorological station (1979-2017)

The highest precipitation amounts fall during JJA (150-190 mm as monthly average), and the highest 24-h precipitation amount was 195.6 mm, at 3 June 1988 (Fig. 5). From October to March the monthly amounts are below 100 mm. The snow cover is present almost all year round. The minimum values are in July (0.2 cm) and August (0.0 cm), and the largest snow depth occurs in April, with 179.6 cm, and March, 171.4 cm, as multiannual average values over 1979-2017 (Fig 5).

The monthly average wind speed ranges between 2.0 m/s, in August, and 3.6 m/s, in November, with a distinctive seasonal regime along the year (Fig. 6).

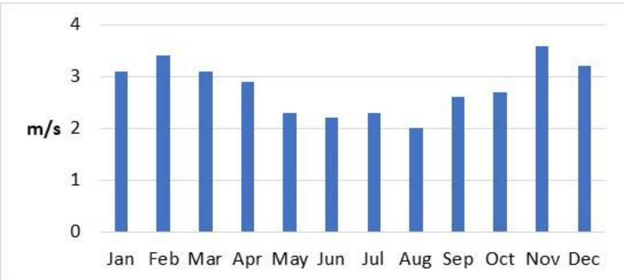

Fig. 6: Monthly average wind speed at Bâlea-Lac meteorological station (1979-2017)

Climate characteristics relevant for avalanche triggering

The climatic background enables specific climate characteristics which may favour the development of avalanches. This section depicts simple linkages between avalanche cases and (1) snow depth and water input, (2) air temperature, and (3) wind speed characteristics at Bâlea-Lac weather station. A more detailed study using this general setting is under preparation.

Snow depth and water input

There is an inherent relation between avalanche occurrence, snow depth and water input, as no snow avalanche can start without a snow cover, and the precipitation represent the main triggering mechanism. At Bâlea-Lac, the highest avalanche frequency is due to the consistent snow cover, generally exceeding 100 cm as an average for the days with avalanches during the period December-May, while the off-season avalanches (June, and September-November) depend more on the 24-h precipitation than on the existing snow cover (Figure 7).

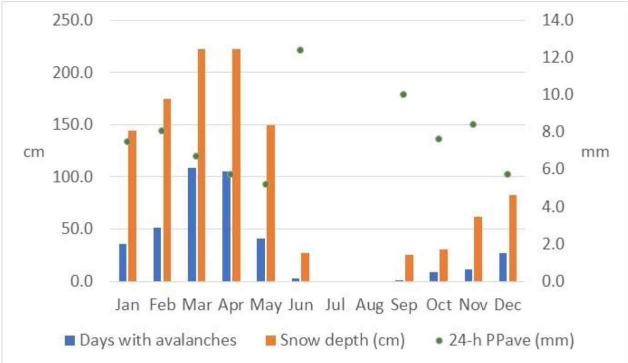

Fig. 7: Avalanche occurrence and corresponding snow depth and average 24-h precipitation (24-h PPave) at Bâlea-Lac meteorological station (1979-2017)

The snow accumulation rate and the amount of fresh snow in 24 hours is an important marker signposting potential avalanche activity, as 2.5 cm/h or more for over 6 hours and 30 cm or more in 24 hours are considered as a great avalanche indicator. (Föhn et al., 2002; McClung and Tweedy, 1993; Ancey, 1998; de Quervain, 1981; Bernard, 1927; Gubler, 1993).

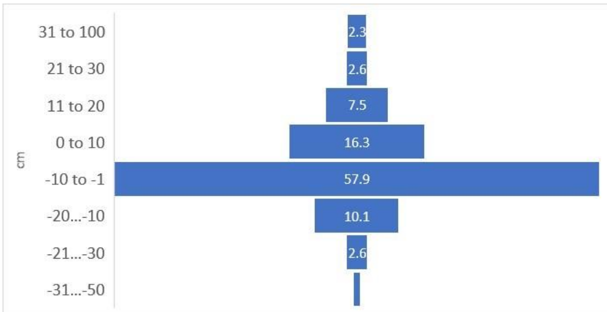

Fig. 8: Distribution of avalanche occurrence (%) depending on snow depth variation in 24-h

The distribution of avalanches based on snow depth is shown in Figure 8. Most cases occur when the snow depth decreases along 24 h with different rates (e.g. 57.9% for 1 to 10 cm decrease or 2.6% for 21 to 30 cm decrease), while snow addition over the existing cover generate avalanches in about 30% of cases (e.g.

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4.9% for 21 to 100 cm). The snow cover variations depend on the precipitation influx along certain time intervals. Over the Bâlea area high precipitation amounts lead to increasing snow depth (Figure 9), and the daily snow cover accumulation or shrinkage is well corelated with the 24-h precipitation amounts (R2 = 0.35). Temperature is also an important control factor for snow depth, explaining some negative snow depth variations along 24 h even when precipitation happen.

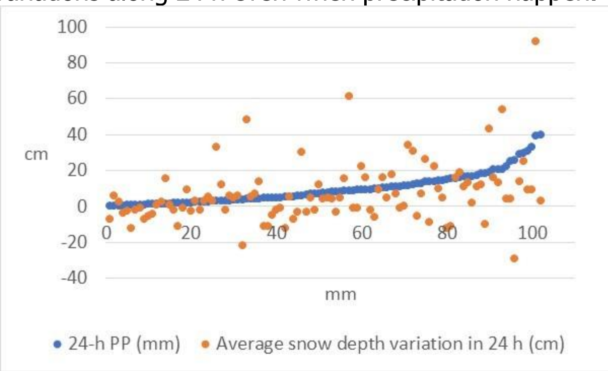

Fig. 9: 24-h precipitation amounts and corresponding average snow depth variations in 24 h for avalanche occurrence

The water amount input can increase the weight of the snow pack and 25 mm precipitation in 24 hours is considered a relevant threshold for triggering avalanches (Schweizer et al, 2003).

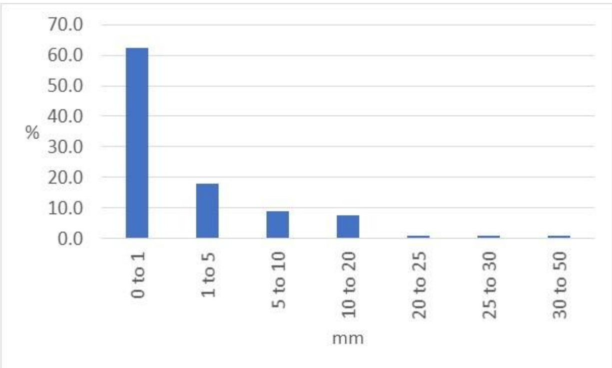

Fig. 10: Distribution of 24-h precipitation amounts (%) on different thresholds, for avalanche occurrence

Air humidity was high on most days with avalanche recordings, 53,3% at over 90% minimum relative humidity, 22,9% of cases for 70 to 90% relative humidity; 11,9% cases for 50 to 70% humidity and only 3,3% of cases for humidity lower than 50% (Fig. 4). An important number of days were recorded with fog (134) and mist (114) .

The avalanches are often associated with different weather phenomena illustrating certain humidity or temperature characteristics. For example, mist and/or fog were recorded in 319 days from the total 393 avalanche days (Fig. 11), illustrating a substantial bias of the air humidity in triggering avalanches over the Bâlea-Lac area.

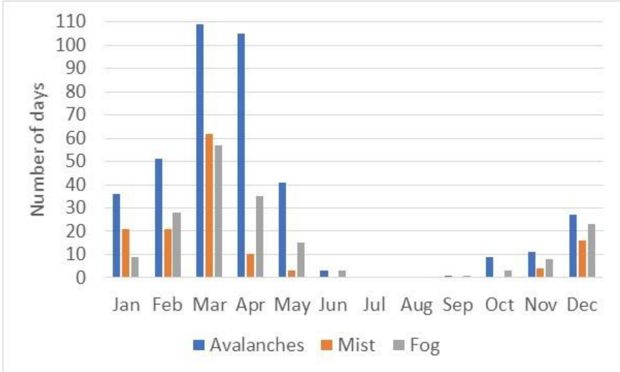

Fig. 11: Mist and fog frequency in days with avalanche occurrence

Air temperature

Near surface air temperature controls the precipitation type (e.g. rain, snow or sleet) and the persistence and steadiness of snow cover, which are basic ingredients for avalanche starting. The avalanches analysed in this study occurred between -24.0°C (daily minimum temperature 3 February 2010) and 15.9°C (daily maximum temperature 12 April 2015). The vast majority of cases are recorded in days when the minimum temperature was negative (81.7% of cases), but avalanches can also occur when the night time temperature remains positive (Fig. 12). As regards the maximum daily temperature, most avalanches happened in days with positive temperatures (60.8%). It is worth mentioning that the freeze-thaw processes are likely to play an important role for avalanches, i.e. 61.9% of the cases are noted with positive maximum and negative minimum temperature values during the same day. Moreover, the largest number of avalanches can be noticed in cold to warm season transition months (February to May), when the diurnal temperature range is higher (i.e. up to 25°C in March) (Fig. 13), and the frequency of freeze-thaw is eventually more important.

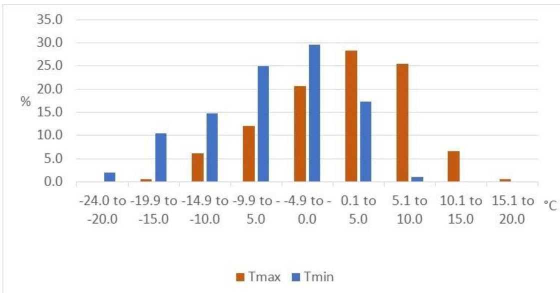

Fig. 12.: Distribution of avalanche days on maximum (Tmax) and minimum (Tmin) daily air temperature classes

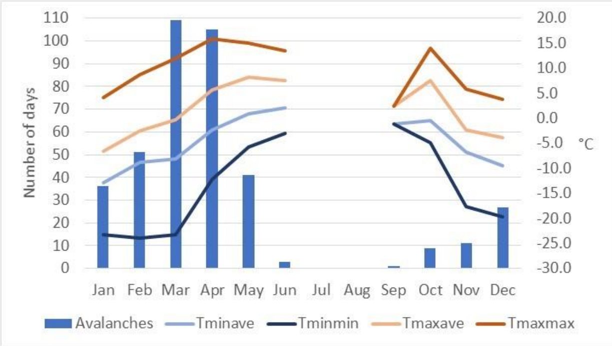

Fig. 13: Annual distribution of avalanche days and the corresponding average minimum (Tminave) and absolute minimum (Tminmin) daily temperature, and respectively average maximum (Tmaxave) and absolute maximum (Tmaxmax) daily temperature. Temperature values were computed only for days with avalanches

Wind speed

Wind can add relevant pressure on snow packs leading to avalanches. Figure 14 shows that, in the days with avalanches, the maximum wind speed measured at 10 m above the ground at Bâlea-Lac weather station is between 5 and 10 m/s in almost 75% of the cases. Sustained wind speeds are clearly an important factor in avalanche triggering processes.

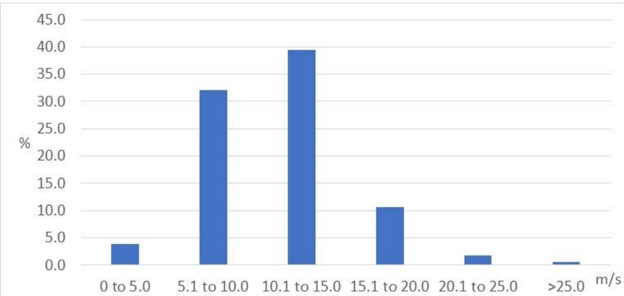

Fig. 14: Frequency of daily maximum wind speed (m/s) on different classes

Conclusions

This study reveals the value of continuous monitoring and careful collection of detailed avalanche information, which can support the research of the causes and possible impacts. At the best of our knowledge, this is the first overview of the basic climate parameters which are potentially avalanche triggers in the Făgăraș Mountains (Southern Carpathians). The study is based on data from only one weather station (Bâlea-Lac), assuming it is consistently relevant from climatic point of view for avalanche occurrence in the area. Even if such an assumption contains an inherent degree of confidence, which was not evaluated here, the results demonstrate that the theoretical circumstances for avalanche triggering (e.g. snow pack, fresh snow or wind) can be captured.

Most avalanches in the database (covering the Făgăraș Mountains) happen over steady snow depth while receiving supplementary water input, under temperature fluctuations and wind speed pressure.

Simple linkages between avalanche incidence and factors like (1) snow depth and water contribution, (2) air temperature, and (3) wind speed were evaluated and quantitative indications are provided, in good agreement with the theoretical premises for such phenomenon. Moreover, the results represent the background for more detailed investigations which are under preparation, and can contribute to enhanced avalanche forecasting in the Southern Carpathians.

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Tracing the development of weather radar technology in Romania and worldwide

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Abstract

Almost 90 years from the radar invention, the radar technology has evolved enormously and today it presents itself as an instrument of great importance in various research areas (meteorology, aviation, astronomy, air-ecology etc.). The main objective of the article is to identify the periods of development at the global level and also in Romania, as well as to identify the technology of most operational weather radars today. The article is based on publications from international journals and scientific books, covering the period of 1930-2018. The overview presentation demonstrates the reasons today's weather radar is a powerful tool for studies concerning the atmospheric precipitations prediction, wind speed and direction, rainfall risk assessment and implementation of weather forecasts. Knowing the technological development is needed for the construction of the new generation radar and for exceeding the actual limits with regard to the accuracy of the radar data and the limits of observation. The purpose of this article is to summarize the evolution of the weather radar, with emphasis on the first experiments carried out during the analogue and digital period.

Keywords: *weather radar, electromagnetic waves, microwaves, precipitation*

Rezumat. Urmărirea dezvoltării tehnologiei radarului meteorologic în România și la nivel mondial

La apropape 90 de ani de la invenția radarului, tehnica radar a evoluat extrem de mult, iar astăzi se prezintă ca un instrument de mare importanță în diferite domenii de cercetare (meteorologie, aviație, astronomie, aeroecologie, etc.). Obiectivul principal al articolului este de a identifica perioadele de dezvoltare la nivel global și în România precum și identificarea tehnologiei prezente în majoritatea radarelor meterologice operaționale. Articolul se bazează pe publicații din jurnale internaționale și cărți științifice, care acoperă perioada 1930-2018. Prezentarea de ansamblu demonstrează motivele pentru care astăzi radarul meteorologic este un instrument puternic pentru studiile privind estimarea precipiațiilor atmosferice, viteza și direcția vântului, analiza riscului pluviometric și realizarea prognozelor meteo. Cunoașterea evoluției tehnologice este necesară pentru construirea noilor generații radar și depășirea limitelor actuale în ceea ce privește precizia datelor radar și limitele de observare. Scopul acestui articol este de a rezuma evoluția radarului meteorologic, punându-se accentul pe primele experimente desfășurate în perioada analogică și digitală.

Cuvinte-cheie: *radar meterologic, unde electromagnetice, microunde, precipitații*

Introduction

The meteorological radar is one of the key instruments in weather forecasting and monitoring especially of convective storms producing severe weather (e.g., intense precipitation, large hail, tornadoes). The radar technology of today was developed over the last 90 years through the research efforts of engineers, meteorologists, and other scientists. Mostly, the use of radar for meteorological purposes is due to the intensive projects during the period of the Second World War and post-war, when the theoretical foundations of the meteorological radar were laid.

The development of the weather radar depended on the technology evolution. Therefore, although some theories were known, they could not be implemented (e.g. the Doppler Effect).

This article describes the history of the meteorological radar from the early stages of development until today. The aim of this paper is to highlight the main periods of development at global scale and in Romania, as well as to identify the current technology in most operational weather radars worldwide. Early research conducted by weather national agencies are discussed here, as well as the first experiments which lead to the construction of the first operational radars. A part of the early history of the radar is described in Marshall (1953), Atlas (1990), Zhang et.al. (2011), and Galati (2016). This paper focuses only on weather ground-based radar, and tackles the early experiments, the pioneer.

1. Early experiments

The term RADAR (RAdio Detection And Ranging) was used for the first time by the United States Navy in November 1940 (Swords, 2008), as suggested by two American officers, S.M. Tucker and F.R. Furth. In the United Kingdom the term was adopted in 1943, but before that they used RDF (Radio Detection and Finding), also known under the name of "Cuckoo", in the military circles. The Italians used the term RDT (Radio Detector Telemetro), the French DEM (Detection Electromagnetique) and the Germans "Funkmessgeraet" (Galati, 2016; Swords, 2008). After the

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Second World War, the term was used by the rest of the world as well.

In 1930, the radar technology was operational for the first time to detect and track aircrafts (Whiton et al., 1998). The first use of radar for meteorological purposes occurred in England in 1942 (Atlas, 1990). However, previous research had been already performed in the 19th century.

The first scientist with fundamental contributions to the development of the radar techniques was James Clerk Maxwell (1831–1879). He formulated the theory of electromagnetic radiation, and noted that, although mathematical approach of individual electric and magnetic phenomena existed, no general theory was proposed at that time. Therefore, in 1864, he published the theory of the electro-dynamic field, which included the four equations and macroscopic theory of electromagnetic field (Mahon, 2003). In 1893, Maxwell published a mathematical theory by which he predicted that the electromagnetic interference should propagate through space at the speed of light.

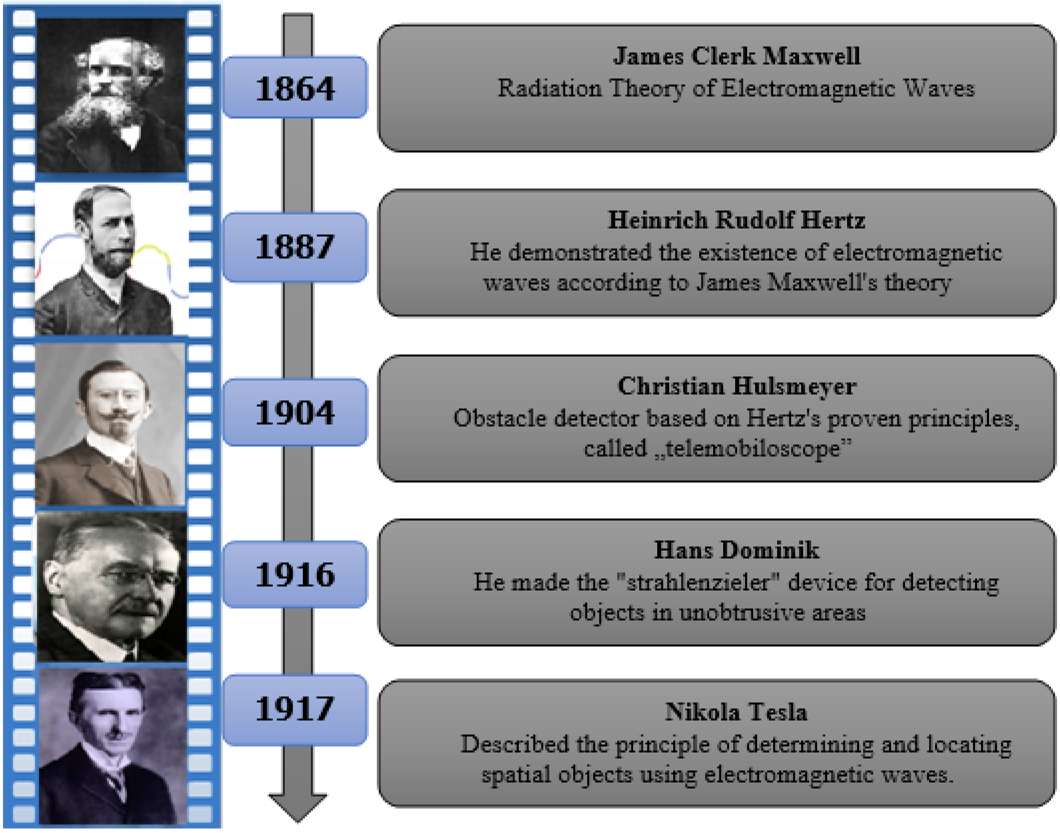

Fig. 1: The precursors of the development and emergence of the first radar (Maxwell, 1954; Garratt, 1995; Shaw, 1994; Dominik, 2007; Faccio et al., 2006)

Heinrich Rudolf Hertz (1857–1894) was the first to apply the mathematical theory of Maxwell on the transmitting and detection of the electromagnetic waves. In 1887, while he was Professor of physics at the Polytechnic University of Karlsruhe, Hertz designed a set of experiments to test Maxwell's theory. His work demonstrated the existence of electromagnetic waves, which reinforced Maxwell's conclusion, namely that light is an electromagnetic wave (Bevilacqua, 1984).

The first use of the principle of determination and location of spatial objects by electromagnetic waves is unclear. The first mention of this principle was formulated by Nikola Tesla (1856–1943). In august 1917, Tesla stated that "... we can produce, when needed, from a broadcaster, an electric effect, anywhere in the world; we can determine the relative position or course of a moving object, such as a ship at sea, the distance traversed and the speed ... "(Galati, 2016, p. 24). Tesla described the radar operation principle to locate metal objects, but he did not take into account other disturbing factors, such as the attenuation of the radio waves on contact with water. The system was called "electric ray" and, at that time, his idea was revolutionary.

On April 30, 1904, Christian Hulsmeyer (1881–1957) applied in Germany for a patent for the so-called telemobiloscope. The system consisted of a transmitter and a receiver meant to detect metal objects, using the electromagnetic waves. The system was intended to avoid collision of ships (Sengupta and Sarkar, 2003). The first demonstration of the telemobiloscope was held on 18 May 1904. Hulsmeyer's device was able to detect ships at a maximum distance of 3 km and operated at wavelengths between 40÷50 cm. However, the military and naval authorities did not show any interest, but during the WWI, experts became interested in using this device (Galati, 2016). Most of his devices were destroyed during the WWII (Sengupta and Sarkar, 2003).

Another contribution to the development of radar is due to the research carried out in 1916 by Hans Dominik (1872-1945). He built a device called "strahlenzieler", which could detect targets in places with no visibility (Galati, 2016). The location of these targets was based on the reflection of electromagnetic waves by metallic surfaces. On the 16th of February, 1916, Dominik received financial funds to advance his research and he succeeded to build a device with 10 cm wavelength. A month later, he was asked to build a device to be used during the WWI, but Dominik failed to finish it on time.

In 1936, Watson-Watt (1892-1973) managed to invent the first radar, and for this he is recognized as the "father of radar" (Probert-Jones, 2014). His device was based on the research described in Figure 1.

2. The Pioneers and the development of analog radars

Research on meteorological radars between 1936–1970 was conducted mainly in the United Kingdom, United States, India, China, and Japan, which not only acknowledged their potential to investigate meteorological phenomena, but also had the technological capability to implement applications.

The military usage boosted the progress. One of the research purposes concerning the signals received from atmospheric phenomena was represented by obstacles in locating aircraft or bombers. The period is limited to the analogue era and to the implementation of the Doppler frequency in radar equipment.

During the Second World War, the military radar systems that were used were classified information (secret), which limited their use for meteorological purposes. Starting with the 1950, the manufacture of radar became easier due to the emergence of solid-state electronics. In the 1970s, the digital revolution began, which allowed the implementation of new functions within the weather radar operation (e.g. the Doppler Effect). The end of the 1970s represented the beginning of a new generation of radar, called the NEXRAD (Next-Generation Radar).

Advances in the field of electronics during WWII and Post-war period allowed the radar technology to develop. For example, after developing the cavity magnetron, radars were able to use higher frequencies for research purposes, such as 4 GHz or 10 GHz (Raghavan, 2003; Dummer, 1983). The following sections outline the development in different countries.

2.1 Great Britain

In the UK, research in the field of meteorological radar has begun with Wattson Watt, the so-called "the father of radar". Wattson worked at the British Meteorological Office where, in 1936, he managed to build a device that could determine the position of aircrafts (Probert-Jones, 2014). The imminence of the war made radar evolution grow very fast. During WWII, centimetre wavelength radars (10 cm) were mounted at General Electric Company (GEC) in Wembley and at the Swanage Air Ministry, Dorset. Both radars were able to detect the weather from short distances, and the first storm tracking report was reported on July 21, 1941 (Ligda, 1951). This event marks the start of operational meteorological radar research in the UK.

During the war, research was carried out at GEC and Telecommunication Research Establishment (TRE). After the war ended, the investigations continued in several parts. The British Meteorological Office installed a S-band radar station at East Hill near Dunstable, Bedfordshire (Atlas, 1990). Research has also been done at Cambridge University, the Department of Meteorology (London Imperial College) and TRE, which has changed its name to Royal Radar Establishment (1957).

During the analyzed period, the display of received signals was limited by the use of cathode ray tubes as they only displayed two parameters, and the received signal had four (azimuth, distance, height and intensity). Therefore, three types of display had been studied: Plan Position Indicator (PPI), Range-Height Indicator (RHI), and A-scope. These were implemented in the new radar.

J. W. Ryde and Telecommunications Research Establishment laid the theoretical foundation of the meteorological radar until the end of the war. After the war, J. E. Hooper and A. Kippax began a program to test Ryde's theories.

Using an operational radar on a 3.2 cm wavelength, they investigated the dependency of the received power on the duration of the impulse, the measurement of precipitations, the ratio between echo signal's intensity and wavelenght, the intensity of the echo signal from the snow and the melting band. Following the research, Hooper and Kippax confirmed the wavelength dependence of the echo signal intensity (Probert-Jones, 2014).

From 1948 on, I. C. Browne studied clouds using a radar system operable on a wavelength of 3 cm (Atlas, 1990). Among other things, he also measured polarizing of melting bands and fluctuations of radar echoes in precipitation.

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In 1950, Frank Ludlam began his research by studying the severe storms in southern England, but believed that more violent storms occurred more often in northern Italy, so in 1958 he moved to Italy. Here he gained a vast experience which he used to participate in a observation program in England, 1958. They had 5 radar stations on 3, 4, 7 and 10 cm wavelengths. They managed to investigate atmospheric circulation classes from severe storms through mesoscale phenomena at fronts and cyclones (Atlas, 1990; Probert-Jones, 2014).

In 1967, the British Meteorological Office set up a cooperative association with Plessey Radar Ltd. to investigate the use of radar in determining and quantifying the amount of precipitation. Thus, an operable radar on the 10 cm wavelength was installed in northern Wales.

As it has happened in other countries, problems with equipment instability, lateral lobes, and equipment limitations have slowed progress down, but it has been an impressive research that has led to the development of a meteorological radar.

2.2 U.S.A.

In 1944, the US Air Force Corps initiated a program for training officers in meteorology at Army Electronics Training Center (AETC) in Cambridge, Massachusetts. Here, students had the opportunity to use S-band (8÷10 cm) radars (SCR-717A and SCR-720) for studying the atmospheric phenomena. For the first time they were able to detect and track precipitations, such as rain or storms. After the program completion, they were sent to the WEMS Department (Weather Equipment Methods Section) in New Jersey.

During the period of 1944-1946, Herbert B. Brooks, William C. Kellogg (1867 - 1957), Donald H. Rudd and Donald M. Swingle conducted applied research and modified military radars for meteorological observation. Using the radars SCR-58 and SCR-717B, they tackled precipitation studies, storm detection, winds measurement and discrimination of storm echoes caused by abnormal propagation, birds and other factors. As a result of technical reports received from England, Swingle managed to develop the first meteorological radar equation, which was implemented in the new radars (Wexler, 1947).

In 1945, Swingle established the technical documentation and the necessary requirements for achieving the weather radars. Radars were generally designed to detect winds and storms and were intended to be used by trained meteorologists, with additional skills in interpreting the data.

After WWII, the Radar Branch from U.S.A., decided to set up a radar station in C-band (4÷8 cm). The first radar specially designed to perform meteorological observations was CPS-9 (Atlas, 1990). Due to the narrow width of the beam and of the sensitivity control function in time, the radar had greater discovery possibilities (Fig. 2).

Fig. 2: Overview of the radar AN / CPS-9

Source: http://www.radartutorial.eu

From 1947 to 1950, Swingle expanded his research at Signal Corps laboratories. His main work was the use of SCR-584 radar to investigate clouds and precipitations (Atlas, 1990).

Following the recognition of the radar techniques potential to observe various weather events, a new set of radars called the AN/MPS-34 were developed. The radar was designed with greater sensitivity and came with an RF preamplifier, which led to an increase in the minimum detectable signal.

2.3 India

The first research in India was conducted within the India Meteorological Department (IMD) since 1940, using modified war equipment, which was very useful for the initial research. Among the radars used for meteorological applications one can mention Baby Maggie no. 3, MK III AN / TPS-2, AN / APQ-13 and SCR-717C. The equipment was modified to detect the wind, and to study the nature of reflections from the atmosphere, precipitations and storms.

At the beginning of the 1950s, IMD initiated a program in order to install a radar network on the Indian Territory for detecting severe phenomena. The Indian Meteorological Department chose two wavelengths for the radar network, one in the X-band (2,5÷4 cm) for detecting storms and one in S-band for the detection of cyclons around the coast. Figure 3 shows the distribution of radars in the S-band of IMD.

In 1954, India purchased its first meteorological radar which was installed at the airport of Calcutta. The first detection radar of the storms in the X-band was installed in 1970 at New Delhi, and the first S-band radar became operational only in 1970 on the East coast of India at Visakhapatnam (Atlas, 1990). It is northworty to mention that the meteorological radar program of India was enterly developed by its own resources. The principal meteorological researches were focused on interpretations and classifications of the signal coming from the storms, precipitations, cyclonic storms, monsoon, and land and sea clutter.

Fig. 3: The network of radars in the S-band of India Meteorological Department (Atlas, 1990)

2.4 Canada

The history of meteorological radar in Canada began in 1953 in Ottawa, when the project Stormy Weather was established. The project belonged to the Canadian Army and was led by Stewart Marshall (1911-1992). At first, Stormy Weather were equipped with a height detection unit using microwave and early warning radars, and the first meteorological observations focused on continuous rainfall events. By 1947, Marshal and his team determined the relationship between the ratio of rain, the water content and reflection, by introducing the Z symbol.

The intensity of estimated radar precipitation (R) is based on radar reflections (Z). Estimation of precipitation is based on identifying the best relationships between these two parameters (Atlas et al., 1997). Marshal and Palmer (1948) showed that between Z and R there is the following relationship: Z = aRb, where Z is the reflection, R the precipitation intensity, and a and b are empirical parameters. and that drop size distribution is approximately exponential with a parameter of the R function, resulting in the following values of a = 200 and b = 1.6. Subsequent studies have been led to different values for parameters (see, for example, Battan 1973). The radar used at that time was a TPS-10 positioned in several locations. (Marshall, 1953).

The CPS-9 radar replaced the TPS-10 in 1954, improving the airspace scanning mode, by the use of Fast Azimuth Slow Elevation (FASE) to get the most out of FASE technique, Canada developed a new indicator named Constant Altitude Plan Position Indicator (CAPPI) (Legg, 1960).

In the summer of 1956, the Group Stormy Weather began its research in Alberta area with Decca radar type 41 (produced by the British Company Decca), as a result of the disasters caused by the extreme weather that had taken place (Atlas, 1990). Despite the severe attenuation in larger nuclei of storms, the radar succeeded to measure the echoes height and to determine the link between the height and the hail probability (Hitschfeld, 1986).

In 1967, the FPS-502 radar was deployed in Alberta. An important feature of the radar was its capacity to use different polarizations in sending and receiving electromagnetic waves. The research carried out by this radar showed that the use of polarimetry can identify particles of hail, rain or snow. Meteorological Radar Conference held in 1968 was opened by installing the FPS-18 (10 cm) radar.

2.5 Japan

In Japan, the research using meteorological radar started in 1954 by building radar in X-band, which was installed in Tokyo by the Meteorological Reaserch Institute (MRI) and conducted by Dr. H. Hatakeyama (Galati, 2016). Shortly after the installation of the first radar, a research program was initiated to investigate the statistical relationship between the storm occurrence and the signal reflection from the upper part of the atmosphere.

In 1964, a Doppler radar was constructed that ran on the wavelength of 3 cm. By means of this Doppler radar, the vertical structure of precipitations was investigated. The research was enhanced also by the typhoon disaster of 26 September 1959, when about 5000 people lost their lives. Therefore, the first operational radar functional on X-band for observing the typhoons was built in Osaka. The X-band radar was shortly replaced by a C-band radar due to signal attenuation through the rain. The first two C-band radars were installed at Fukuoka and Tokyo in 1955.

By 1970, the Japanese meteorologists published hundreds of articles in the field of radar meteorology which meant that they made a huge research effort. After 1970, most Japanese radar started a new stage of modernization by converting analogue to digital signals.

Tabel 1: Main technical characteristics of the first weather radar used by the USA, Canada, China, India and Japan

Parameters	S.U.A.							CHINA			JAPAN			CANADA		INDIA
	CPS-9	WSR -74C	FPS -77	TPS-68	WSR-1	WSR-57M	WSR-88D	711	713	714	MRI -X	MRI -C	MRI -K	Decca -41	FPS-103	APQ-13
Frequency (MHz)	9368	5656	5551	5353	2855	2855	2855	9993	5995	2997	8000÷ 12000	4000÷ 8000	18000÷ 27000	9368	9368	9368
Wavelength (cm)	3.2	5.3	5.4	5.6	10.5	10.5	10.5	3	5	10	3.75÷ 2.5	7.5÷ 3.75	1.67÷ 1.11	3.2	3.2	3.2
Pulse duration (μs)	Sh pulse: 0.5 Ln pulse: 5	3	2	2	Sh pulse: 1 Ln pulse: 2	Sh pulse: 0.5 Ln pulse: 4	Sh pulse: 1.57 Ln pulse: 4.7	1	2	1.3	1	2	0,5	Sh pulse: 0.2 Ln pulse: 2	2.25	MD-12: 0.5, 1.12, 2.25 MD-38: 0.5, 0.75, 2.25
Peak transmitter power (kW)	250	250	250	165	50	500	750	-	-	-	250	300	32	30	45	40
Effective antenna system gain (dB)	41.5	40	36.5	38	-	38.1	45	38	38	36	45	42	55	-	30	33
Antenna reflector diam. (m)	3.6	2.4	2.4	1.9	1.8	3.6	8.5	1.5	3.7	4.0	2	3	2,6	90	0.76	0.76
Pulse repetition frequency (s^{-1})	Sh pulse: 931 Ln pulse: 186	259	324	375	Sh pulse: 650 Ln pulse: 325	Sh pulse: 650 Ln pulse: 164	Sh pulse: 318-1304 Ln pulse: 318-452	-	-	-	-	-	-	250	400	1350, 675, 270
Receiver sensitivity (dBm)	-103	-104	-104	-104	-	-108	-113	-	-	-	-	-	-	-	-106	-83
Beamwidth azimuth (°)	1	1.6	1.6	2	4	2	1	1.5	1.2	2	1	1,39	0,25	0.6	3.6	3
Beamwidth elevation (°)	1	1.6	1.6	2	4	2	1	1.5	1.2	2	1	1,39	0,25	2.8	3.6	3
Antenna mobility (°)	360	360	360	360	360	360	360	360	360	360	360	360	360	-	360	360

3. Meteorological radars in the digital age

The digital revolution began around the year 1970 and it was due to the evolution of technology in electronics, which made that the meteorological radar be developed in an accelerated pace. The conversion from analogue to digital signal allowed the data storage in binary format, a considerable reduction in errors and implementation of new functions such as Doppler frequency.

The main difference between the two generations of radars, analogue and digital, is that the prior technology transmitted the information under the form of electrical pulses with variable-amplitude, while the new one did this in a binary format of 0 and 1. Within this development, it was introduced the radial velocity of the weather phenomena, due to the Doppler Effect. Most of the radars with Doppler capabilities were developed in the 1970s. For example, in the USA, at NSSL (National Severe Storms Laboratory) in Oklahoma a radar in S-band with Doppler capabilities was installed.

The end of 1979 marked the beginning of a new radar generation, namely NEXRAD. After nearly 10 years, the first radar of NEXRAD generation, WSR-88D was inaugurated, and the last one was installed in 1997. The project led to the construction of a US radar network, consisting of 159 radars that covered the whole territory (Galati, 2016).

Meanwhile, staring with 1970, the meteorologists were able to process also radar images from different angles of height, due to the development of antenna systems, RHI indicators (Range Height Indicator) and CAPP (Constant Altitude PPI).

By the end of 2000, several countries, such as Canada, Australia, USA and China, developed radar networks with doppler capabilities. For example, the Canadian network was fully completed in 1998. A similar situation occured in Europe, where different countries implemented this type of radar. For example, in 2010, the ARAMIS network in France had 22 Doppler weather radars, out of which 10 were able to use dual polarization (Galati, 2016). Since 2010, European countries have provided the national territory with radar networks, and the data were made available to the public, via internet, such us the European Operational Program for Exchange of Weather Radar Information (OPERA) (Huuskonen et al., 2014; Sireci et al., 210).

In India, Japan and U.S.A. the situation is different due to the extreme weather phenomena that occurred. The first network was developed in 1975 with MULTIME radars, and in 1980, India succeeded to build its first equipment, which met the meteorologist's requirements, before many radar developers countries (Atlas, 1990). In 2011, India had a network composed of 40 radars in X and S-bands, out of which five radars with Doppler capabilities (they became between 2002-2006).

Another significant step in the radar performance, after the introduction of the Doppler Effect, is the polarimetry. The polarimetry has been studied since 1980, but at the operational level it was implemented in 2000. Using this technique, more information can be obtained from the reflection of the precipitation signals.

During the period 2000-2003, USA scientists analyzed the operational advantages and the performance of using the polarimetry within the Joint Polarization Experiment (JPOLE), which resulted in the implementation of technology in all weather radars in the US meteorological service, and the first NEXRAD radar transformed in polarimetrical radar, took place on March 3, 2011.

4. The evolution of weather radar in Romania

The first radar meteorological research in Romania began in 1967, when the first Plessey 42 X radar was installed in Bucharest (Apostu et al., 2005). Two other radars of the same type were installed in Cluj-Napoca (1969) and Mihail Kogalniceanu (1970). The activities were carried out within the Central Meteorological Institute within the structure of the Ministry of Air and Marine (Official Gazette No. 266 of November 14, 1936; Burcea, 2011).

Being aware of the importance of the meteorological radar, the authorities decided to expand the radar research area by acquiring new radars. Thus, since 1973 and until 1990, Russian MRL-2 and MRL-5 production radars have been purchased. Radar stations were installed in Bucharest, Oradea, Iaşi, Timişoara, Craiova and Tuzla (Apostu et al., 2005; Perez et al., 1999).

MRL-5 was specifically designed for hail detection. The radar was designed on two frequency channels (x and s band) and had the advantage of measuring rainfall using two methods. The first method was based on the measurement of the reflection factor on a single wavelength, while the second one measured the attenuation of the signals on both wavelengths. Both methods required different corrections to obtain reliable data (Collier and Chapuis, 1990; Dinevich et al., 2004). The disadvantages of the MRL-5 station included: too much time needed for data processing, manual operation, and technology exceeded by the current needs. Radar data determined by MRL-5 were not available in real time, and this was done only every 3 hours because the operator had to manually draw radar echoes on the map (Burcea, 2011; Apostu et al., 2005; Collier and Chapuis, 1990).

In 2000, two DWSR 2500 C-band Doppler radars were implemented in the meteorological radar network. Radars were manufactured by the American company Enterprise Electronics Corporation and were installed in Bucharest and Craiova. Acquisition of these radars marks the beginning of the digital era and Doppler technology in Romania.

The DWSR 2500 was built in solid state technology (without electronic tubes) and includes digital receivers, Doppler processors, Windows-based operating systems. The radar has the ability to analyze the evolution of storm winds for detecting and tracking severe phenomena, and also allows rainfall to be measured, hail conditions and floods to be detected.

In November 2000, the National Meteorological Administration started the modernization of the meteorological phenomenon monitoring and forecasting network, by implementing the National Integrated Meteorological System (SIMIN) project. Thus, in 2001 and 2004, two METEOR 500C radar systems were installed in Oradea and Baia Mare. Radar stations were produced by the German company Selex ES-Gematronik and provide reliable high resolution data to support meteorological analysis in a very short time. To generate high-frequency pulses, the radar uses a magnetron-based transmitter.

The SIMIN system also involved the installation of WSR-98D type radars supplied by the American company Lockheed Martin. The WSR-98D radars has the ability to research the airspace with a high accuracy over a maximum distance of 300 km. In Figure 4, the current SIMIN architecture in Romania is presented.

In 2003, the SIMIN program ended. Thus, five S-band WSR-98D Doppler radar radars have been installed on the Romanian territory. Existing radar stations in the 1960s were replaced by Doppler radar, 5 WSR-98D in the S band and 4 C-band radars to form a 9-radar network.

WSR-98D radars are valuable tools for detecting heavy convective precipitation, heavy rainfall and typhoons, and are based on meteorological algorithms developed in the US for more than 30 years (Ioana et al., 2004). Today, Romania has the most modern and unique meteorological networks in Europe, which incorporates 3 types of radar stations, the DWSR-2500C, the METEOR 500C and the WSR-98D.

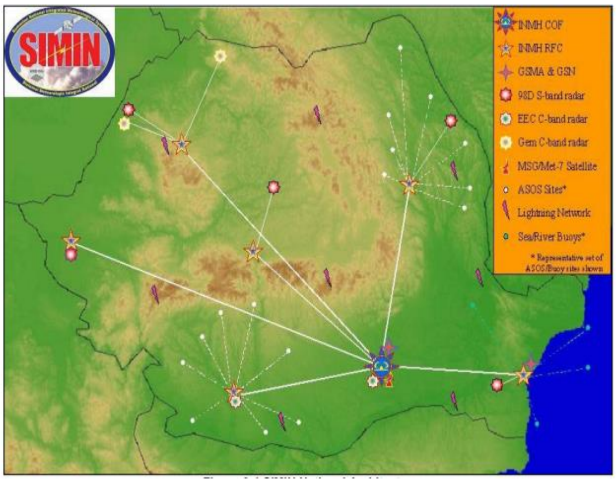

Fig. 4: Architecture of Romania INMS (Ioana et al., 2004)

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Each system generates data every 6 minutes, and the national mosaic is generated every 10 minutes. Through telecommunication systems, the data from radar stations is available anywhere in the NMA system, almost in real time.

In Romania, research in the field of meteorological radar is being done continuously. Research includes both methods and algorithms for estimating atmospheric precipitation, as well as research for the analysis of severe phenomena based on radar data. Among those who studied precipitation estimation are Burcea (2011), Bell, Seed and Bunn (2013), Poalelungi (2011), Burcea et al. (2012), Maier (2011) and Breza (2008).

The increasing occurrence of severe meteorological phenomena has led to increased interest in their research. For example, Paraschivescu (2010) studied the cases of severe weather, Bell, Sed and Bunn (2013) studied the radar characteristics of severe tropical storms and methods of estimating echo radar movement, Apostol and Machidon (2009) investigated hailstones in the Bârlad basin in which he used radar data, and Carbunaru et. al., (2014) analyzed hail detection.

A current concern is also finding new methods for estimating quantitative precipitation (QPE) based on radar observations. These estimates actually help meteorologists make predictions and alert the population in real-time when severe phenomena are going to happen. Crăciun and Catrina (2016) proposed a method of improving QPE compared to rainwater measurements and average polarization adjustment.

Studies have also been done to better understand precipitation data, for example, Burcea et al. (2012) analyzed several measurements in Romania. Also, Georgakakos and Spenser (2009) analyzed real-time rainfall in Romania using radar data.

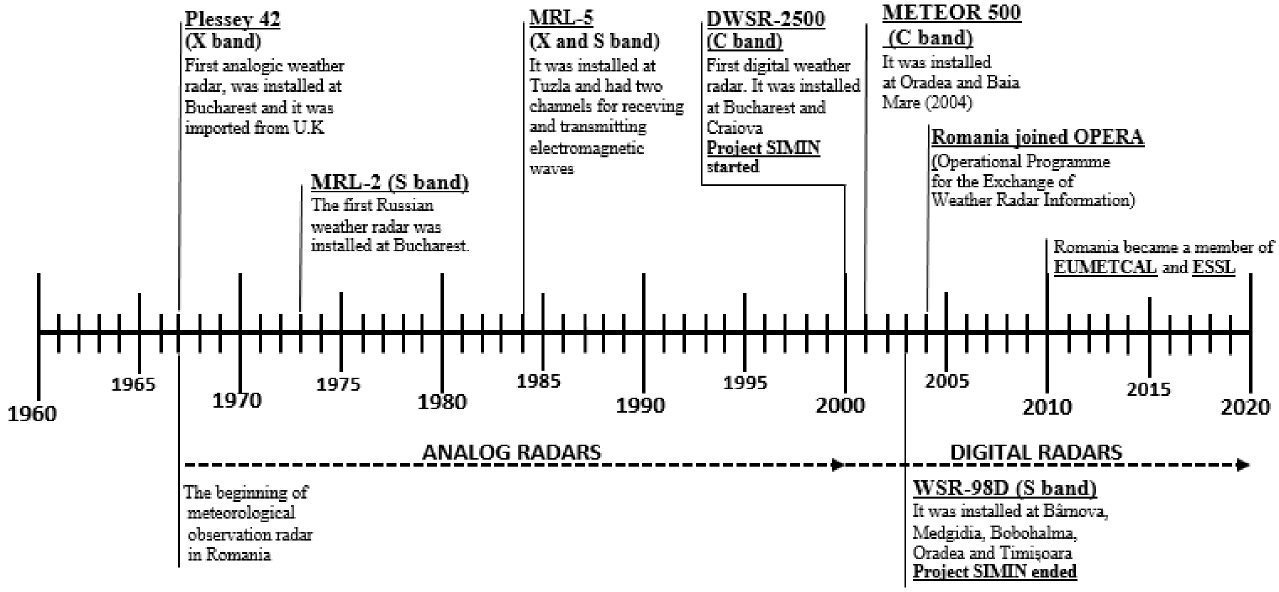

Fig. 5: Evolution of weather radar in Romania, 1967-2010 (Burcea, 2011; Ioana et al., 2004; Apostu et al., 2005; Perez et al., 1999)

5. Recent developments of weather radars

To improve the detection of meteorological phenomena, especially extreme weather conditions, continuous research is being done in the field of weather radar. The first discovery that has made substantial contributions to the analysis of weather phenomena is the Doppler effect. This technique describes the change in the frequency of the signal emitted by the reflective surface of a moving object. With this new capability, new radars can determine the direction and speed of movement of atmospheric precipitation.

Christian Johann Doppler (1803-1853) discovered this method in 1842 (White, 1982). The limitations of the analogue equipment delayed the implementation of the Doppler principle in weather radar, and it was only in the early 1970s that it was applied with the advent of digital techniques (Sundaram et al., 2004; Doviak and Zrnic, 1993).

A first step in improving data provided by radar is faster scanning of the atmosphere. Traditional radars are limited by the mechanical scanning of the antenna, so phased array antennas (PAR) have developed. The Phase Antenna directivity characteristic is electronically controlled and is displaced almost instantaneously in azimuth and angles of elevation, see Figure 5 (Zrnić, 2007; Isom et al., 2013). PAR technology is used for both meteorological phenomena research and aircraft tracking (multipurpose radar) (Newman, LaDue and Heinselman,2008; Cheong et al., 2013).

Most of the current meteorological radar (MRL-5, METEOR 500C, WSR-88D, etc.) are monostatic or bistatic, meaning the receiver and the transmitter are co-located. The performance of these types of radar has been improved by using the new methods of digital signal processing.

When space objects are irradiated by electromagnetic waves, the reflection of waves occurs in all directions. Therefore, several receivers are needed to capture all the energy of the electromagnetic waves. To overcome this limitation, multi-static radars with antenna networks are used, where each antenna has its own transmitter and receiver (Papoutsis, Baer and Griffiths, 2004; Yeary, et al., 2010).

The distribution of hidrometeors at meteorological radars made that the compression of the impulses to be used only for military surveillance radars. This technique, along with other signal processing techniques, has begun to be studied and applied to new meteorological radars.

IEE 686-2008 defines pulse compression as "… a method for obtaining the resolution of a short pulse with the energy of a long pulse of width T by internally modulating the phase or frequency of a long pulse so as to increase its bandwidth B >> 1/T, and using a matched filter (also called a pulse compression filter) on reception to compress the pulse of width T to a width of approximately 1/B" (IEEE, 2018, p.31).

The new weather radar must provide a great temporal and spatial resolution. By using a high frequency band, higher resolutions are possible than with NEXRAD radars. Temporal resolution for severe phenomena is a critical aspect because severe weather changes in a matter of seconds rather than minutes (NEXRAD provides a 4-minute temporal resolution and 6-minute WSR-88D).

Greater resolution is needed, and this can be improved by using the PAR technique.

Polarimetry is another technique present in new weather radars. Unlike the conventional radars, where emission and reception are realised by single polarization, the new radars allow using two types of polarisation (vertical and horizontal) (Figure 6) (Kumjian, 2013).

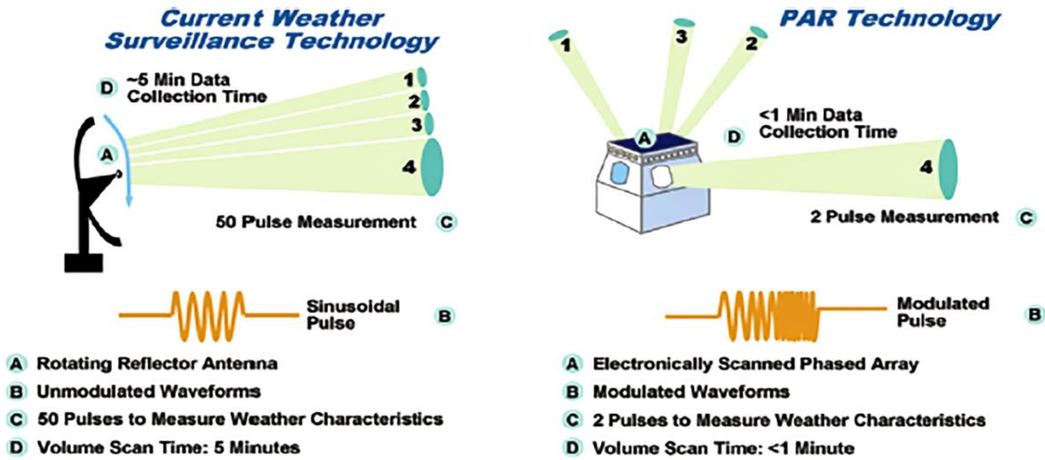

Fig. 6: The differences between traditional radar, and phased array antenna radar (PAR) (Zrnic, 2007)

This has led to a differentiation of radar reflection power Z, which ultimately helps, among other things, to distinguish hail from rain drops. An example of a radar incorporating phased array antenna technology, polarimetry and pulse compression is the CPPAR radar (Cylindrical Polarized Phased Array Radar), developed at the Oklahoma Radar Research Center (Zhang et al., 2011).

Figure 7 shows a photograph of this radar. The CPPAR system provides fast 360° coverage by flexibly adjusting the azimuth beam and height angle. The radar operates in the S band and provides a peak impulse output of only 1.5 kW.

Fig. 7: Cylindrical Polarized Phased Array Radar (Mark, 2014)

The progress made in technology through the development of integrated circuits, the digital processing of Doppler signals and the development of display systems have led to the improvement of radar technology. But the study of radar data has also played an important role in research into atmospheric studies, particularly in terms of cloud physics, the evolution of severe storms, precipitation estimation and hurricane tracking. Such knowledge has led to the development of new algorithms for data processing.

Conclusions

There is a huge effort made by many countries to investigate the atmospheric phenomena using the radar technique. In most countries, the efforts were put in parallel and involved diverse techniques with different approaches. Almost all researches were performed in order to understand the severe weather phenomena and to warn the population about them, but also because they represented obstacles to identify certain space objects. For example, during WWII, the precipitation, storms, tornadoes, etc., represented real problems in identifying own aircrafts or the enemy's aircraft. Early experiments had a huge impact on the new equipment built today, which are found in many countries. From the accidental detection and observation of precipitation on the circular observation gauges until today, technology has evolved continuously.

The history of the meteorological radar has also given rise to new concepts. For example, in 1952 M.G.H. Ligda invented the term of "Mesoscale" to describe the phenomena observed by the meteorological radar.

The meteorological radar was and still is highly used in meteorology due to its ability to operate in all weather conditions and airspace research. Several technological developments have succeeded in producing Doppler radars, radars in impulse, mono-impulse, networks phased array antenna, solid state transmitters, radar components digitizing as well as complex techniques of modulation of signal transmitted. All these techniques can be found in almost all modern radars, which, most of the times, are implemented in meteorology national and global networks. The data provided by each radar sensor provides real-time observation of meteorological phenomena and have an important role in warning.

Researches on meteorological radar technology are widespread and are motivated by the needs of society to improve the prediction of severe weather phenomena and to warn the population on short-term events. Today, researchers are focusing more on engineering in order to develop new tools. In the future, the trend of technology advancement will lead to the construction of passive radars, multi-mission radars, to share the electromagnetic spectrum and to digitize any radar equipment. An example of multi-mission radar can be considered the TPS-79 (R). This radar is mainly used for the air space surveillance and the air traffic control, but it also has the ability to determine up to 6 levels of atmospheric precipitations.

Generally, the information concerning the types of radars used at the international level are rare, but some trends can be deduced. Most radars operate in C-band and S, but most recent, those used the X-band are also used. For example, in October of 2013, the European weather radar network included 202 operational radars, out of which 184 had Doppler capabilities. The network included 169 radars that operated in the C-band and 33 radars in the S-band (Huuskonen et al., 2014).

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In search of the last remaining giants. Modelling the conservation potential of century old trees within the Continental and Steppic Biogeographical Regions of Romania.

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Abstract

The present paper aims to model the potential for conservation of some very large specimens of either indigenous or human introduced tree species located within the Continental and Steppic Biogeographical Regions of Romania, areas characterized by considerable natural diversity. Centuries of human intervention have resulted in the major replacement of the natural vegetation with semi natural forests in the highlands, pastures and permanent crops at the hills and arable land in the lower areas. The once pristine landscapes present numerous remains in the form of old trees, while other exotic introduced species are common. In order to assess their conservation potential, we applied an encyclopedically approach centered on numerous field observations, measurements, scientific literature research, historical maps analyses and discussions with locals. The results certify the existence of different species characterized by a medium and high potential for conservation. Some of them are the subject of numerous researches and possess favorable conservation status while many are poorly or virtually unstudied and not protected. Such findings are usable in complex domains, mainly biodiversity conservation, durable ecosystem management and ecotourism.

Keywords: *remarkable trees, conservation potential, conservation status, Continental Bioregion, Steppic Bioregion*

Rezumat. În căutarea ultimilor giganți. Modelarea potențialului de conservare al arborilor seculari din Regiunile Biogeografice Continentale și Stepice ale României.

Articolul de față urmărește modelarea potențialului de conservare al câtorva specimene foarte mari de arbori aparținând unor specii atât autohtone cât și exotice din Regiunile Biogeografice Continentale și Stepice ale României, areale caracterizate de o mare diversitate a mediului natural. Secole de intervenție antropică au generat înlocuirea majoră a vegetației inițiale cu păduri seminaturale în zone de munte, pășuni și culturi permanente la deal sau terenuri arabile la câmpie. Peisajele inițial virgine prezintă numeroase rămășițe prin prisma arborilor bătrâni, în timp ce alte speciile exotice sunt comune. În vederea identificării potențialului de conservare a acestora, a fost aplicată o abordare enciclopedică axată pe numeroase deplasări în teren, măsurători, cercetări în literatura de specialitate, analiză de hărți istorice și discuții cu localnicii. Rezultatele certifică existența a diferite specii caracterizate de un potențial de conservare mediu și ridicat. Câteva dintre aceste specimene sunt subiectul a numeroase cercetări și posedă un statut de conservare favorabil, în timp ce numeroase altele sunt practic necunoscute și neprotejate. Rezultatele sunt utile în domenii complexe precum conservarea biodiversității, managementul durabil al ecosistemelor și ecoturism.

Cuvinte-cheie: *arbori remarcabili, potential de conservare, statut de protecție, Bioregiunea Continentală, Bioregiunea Stepică*

Introduction

Remarkable trees represent some of the largest, rarest and most spectacular life forms. A remarkable tree is defined as a specimen characterized by: a) a quantitative aspect represented by an unusual size or age, which exceeds the species' normal thresholds and b) a qualitative one, centered on the specimen's ability of offering complex ecosystem services for both humans and animal communities (Hartel & Tamas 2015). Other common approaches concerning the subject include secular, several centuries old, exceptional or even veteran tree (Vasile et al. 2013). Due to their ability of growing for such long periods of times and consequently reaching considerable sizes, large trees possess complex ecological, physical, scientific, economic, historical or cultural values, usable for both wildlife and humans (Radu & Coandă 2005). Large and old specimens offer important economic resources for rural populations, maintain suitable habitats for a wide range of animal or plant species and could expose valuable scientific information concerning primeval landscapes or archaic cultures, traditions and beliefs (Hartel & Moga 2010). Some specimens enhance the cultural and historical identity of traditional communities or celebrate notable historical events or actions (Hartel et al. 2015). Others possess a powerful sacral identity, being perceived by locals as holy elements. Based on their remarkable physical particularities and mythological aura, some specimens portrait mystical images regarding frightening creatures and demonical characters or by opposite, heroes or guardians of significant places and legendary objects (Kingsbury 2015). The sum of all these values composes the trees' conservation potential, which differs considerably between specimens based on the selected criteria for analysis.

The trees' conservation potential usually represents the main trigger regarding their conservation status. Therefore, a tree conservation or protection status is composed of: a) the specimens' conservation potential discussed above and b) the economic, administrative and legislative will regarding the local actors legally capable of deciding and assessing that status (Bolea et al. 2011). Old trees are conserved and therefore protected as both individual elements stated as natural monuments or as integrated elements of larger and more complex landscapes, such as primeval forests, secular ones or medieval wooden pastures, which benefit by a favorable status due to Natura 2000 sites, national or natural parks or scientific reserves.

Remarkable trees are characterized by a complex geographical distribution, spreading from the tropics to temperate regions. Within the tropical areas, the African baobabs, oriental planes of the Mediterranean regions, kauri trees of New Zeeland or camphor trees of Easter Asia reach some of the largest ages and girts (Kingsbury 2015). Some exemplars, as the famous sequoias of North America, are the largest living life forms in the history of the natural world, reaching heights of almost 100 meters and ages exceeding 2000 years. Europe stands out by conserving the largest and oldest oaks, poplars or benches within the world. Therefore, the oak with the largest girth measured in modern times is located in Norra Kvill, Sweden and named Kvilleken. It was registered as having 14.75 meters girth at a height of 130 cm above ground level (Pătruț 2011). Also, the great oak located within the zoological garden of Ivenack, Germany, possesses a volume of 180 m3, a total height of 35.5 m and a girth of 11.35 m, therefore being the largest oak by volume ever estimated (Pătruț 2011). In Romania, at the outskirts of Răfăilă village stood intact until 1997 the world's thickest grey poplar, associated with Stefan the Great and having a girth of 14.1 m at its peak while at Mocod, Bistrița-Năsăud, a black poplar possessed at its prime a girth of 12 meters (Pătruț et al. 2012). Nevertheless, according to Pătruț, some of the oldest oaks ever analyzed are located within Romania, namely the oaks of Cajvana and Țebea, both exceeding 800 years (Patrut et al. 2010, Pătruț et al. 2011).

All of these exceptional trees of Romania, some of them being the oldest and largest of Europe, are located within the vast Continental Biogeographical Region (BCR) or in the Steppic Biogeographicall Region (BSR) and represent a solid statement concerning the regions potential respect to this subject. Romania encompasses five Bioregions, more than any European country besides Russia. These are the Continental, Alpine, Pannonic, Steppic and Pontic Bioregions (EEA 2016) (Figure 1). The BCR occupies the largest part of the country, entirely enclosing as a giant arch the Alpine Bioregion. It neighbors in the east the Steppic Bioregion and the west the Pannonic one. It spreads mainly over plains, plateaus, hill areas and low mountains, being by far the most diverse and biogeographically complex within the five bioregions. The BCR extends over two latitudinal vegetation belts, namely the southern sylvosteppes and the nemoral deciduous xerothermal forests of the higher plains (Călinescu 1969). It also encompasses two vegetation altitudinal levels, such as the durmast mixed oak forests, disposed within the humid central plains of Muntenia and the hill oak and bench mixed forest spread in the higher hills and lower mountains. Finally, there is the azonal floodplain vegetation composed by poplar and willow forests growing within the occasionally flooded internal river meadows (Geacu et al. 2018). The BSR was occupied by immense swamps and flooded forest especially in the Danube meadows, while the higher plateaus of Dobrudja were the domain of vast sylvosteppes and steppes (Geacu et al. 2018). Despite its complex natural potential, the BCR is characterized by an aggressive human impact, dating back over hundreds of years. Consequently, the once huge lowland durmast and dry oak forests were massively cut off and replaced with arable crops starting with the 1829 Treaty of Adrianople while the hill forests were converted into vineyards, plantations or pastures (Iojă 2000, Muică & Dumitrașcu 2001, Dumitrașcu 2007, Grigorescu 2010, Niculae 2012, Vijulie 2010). The only potential virgin areas are represented by the isolated bench forest protected in the Carașului Key National Park in the Banatului Mountains (Khorn et al. 2012). Nevertheless, the BCR suffered undergone the human introduction of numerous exotic phytogeographical elements, such as the oriental plane and chestnut tree from the Mediterranean regions or the mulberry tree and Japanese acacia of Easthern Asia (Dumitrașcu & Ines 2016). Concerning the BSR, starting with 1950 all of the regions primeval natural habitats were converted into arable land, present day remains of pure wilderness being extremely scarce (Pașcovscki & Doniță 1967).

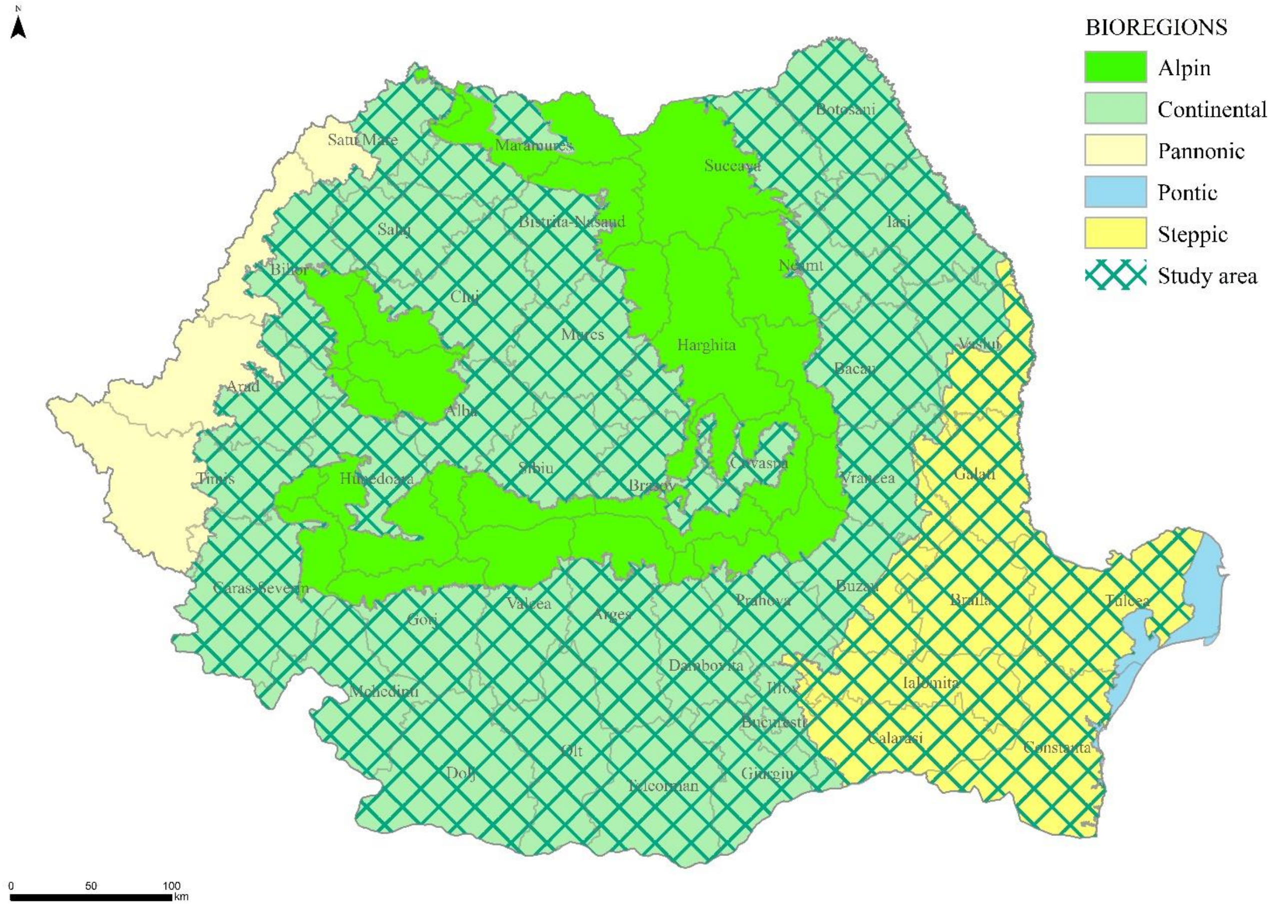

Fig. 1: The location of the study area (Source: EEA 2016)

The importance of protecting remarkable trees is crucial in order to favor the access of both people and animals to numerous ecosystem services and resources. Nevertheless, their conservation is beneficial in different modern research domains, namely conservation biogeography, biodiversity protection, landscape ecology, sustainable landscape planning, agro-forestry, agriculture, modelling species distributions, ecotourism, social and cultural studies, historical geography and toponimy, research regarding human impact over natural ecosystems, analyses concerning land cover and land use dynamics or phyto and zoological elements response to climate change (Radu & Coandă 2005, Bolea et al. 2011, Vasile & Scărlătescu 2013, Vasile et al. 2013, Bolea 2013, Hartel et al. 2015).

Other studies related to our research theme comprise assessments centered on carbon dating very old oaks, poplars or ashes (Pătruț et al. 2010, Pătruț 2011, Pătruț et al. 2011, Pătruț et al. 2012, Patrut et al. 2018), encyclopedically approaches concerning information regarding exceptional specimens (Bolea & Vasile 2011, Vasile & Peter 2011, Bolea & Ienășoiu 2011, Constandache et al. 2012, Bolea et al. 2012, Bolea et al. 2013) and even theoretical papers seeking to highlight the importance of protecting remarkable trees (Radu & Coandă 2005). Furthermore, numerous investigations are developed over the goal to document the human influence over natural environment elements, especially lowland forests within urbanized and agricultural areas (Grigorescu & Geacu 2017). Finally, several evaluations which highlight the biological characteristics of very old virgin or quasi-virgin forest (Giurgiu et al. 2001, Veen et al. 2010, Khorn et al. 2013).

Based on the stated aspects, we have formulated the next research topics: the BCR and BSR are characterized by the presence of diverse high conservation potential remarkable trees that are poorly studied and by consequence possess an unfavorable conservation status. The research question supporting the study is: are there remarkable trees within the BCR and BSR encompassing both a high conservation potential and complementary an unfavorable protection status? The aim of the study is represented by the conceiving of a diagnosis in order to highlight the existence of high conservation potential remarkable trees within the BCR, which are not valued. The two objectives of the research are: O1) to identify the spatial distribution of various representative

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remarkable trees within the BCR or BSR and O2) to analyze their conservation potential and protection status in respect to establish major vulnerabilities and potential hotspots.

Method

In order to conduct O1, we have performed analyses of scientific literature and oral information, conducted field observations and validations and developed a map consisting in the distribution of remarkable trees number per TAU, representing Result 1. Also, for assessing O2 we have conceived a selection of criteria usable for identifying various potential types of values proper to be attributed to remarkable trees. The trees were filtered according to the selected set of criteria. Consequently, Result 2 is represented by a table encompassing the conservation potential and protection status for every specific individual.

The first step consists of the investigation of a rich pallet of sources, both written and oral, in order to select our potential candidates as remarkable trees. Within oral sources, discussions with locals proved the most productive due to their own complex field experiences. Nevertheless, the information contained by old toponyms scattered on historical maps (Specht 1790-1791, Szatmary 1864, Crăciunescu et al. 2011) were consistent. Various web sites engorge a large volume of precious data, particularly the ones dedicated to promote remarkable trees (Hartel & Tamas 2015). The last groups of sources accessed is represented by specialty books and articles, characterized by a high level of credibility due to their scientific background. Major examples include touristic atlases and guides, specialty books regarding the fields of ecology, forestry, nature protection, history and tourism or scientific articles written in order to analyze different monumental trees exceptional age or capability of offering complex services (Giurescu 1976). Furthermore, the trees' location within virgin or quasi-virgin forests, cultural landscapes or protected areas are subjects commonly studied (Giurgiu 2001, Veen et al. 2010). Despite the fact that they lack a scientific background and consequently possess low credibility, the personal descriptions of amatory travelers engorge precious information concerning different monumental trees (Vârzaru 1974).

The second step consists of filed validations that extended over a five years period (2015, 2016, 2017, 2018 and 2019). Field trips were conducted using different methods of travel in every season, each site being analyzed only once. A total of 26 TAUs along with Bucharest Municipality were filtered, located within twelve counties, displayed especially in the central and southern part of Romania. Due to our personal material and temporal limitations we were unable to develop a uniformly displayed sampling over the entire BCR and BSR, regions as Moldavia being currently outside our reach.

The third step in centered on conducting a cartographical approach in order to express the number of remarkable trees identified per TAU. Prior to this purpose we have accessed spatial vector data consisting in Bioregions, TAU and County limits of Romania (EEA 2016, A.N.C.P.I. 2006). The projection system used is Stereo 70.

We have identified tree major dimensions encompassing a set of six potential values proper to be attributed to remarkable trees which highlight their utility for human and wildlife communities. These are the Phytogeographical, Zoogeographical and Human dimensions and include Taxonomic-ecologic, Physical, Habitat for animals, Historical-cultural-mythical, Scientific and Economic-touristic values (Radu & Coandă 2005, Hartel et al. 2015, Moga et al. 2016). Nevertheless, in order to determine if the sampled trees possess the respective values, we have established several criteria both quantitative and qualitative according to which the specimens were evaluated.

The Phytogeographical dimension reflects the trees utility for plant communities. It encompasses two values, the Taxonomic-Ecologic and the Physical-Aesthetical. The first value is identifiable by several criteria, such as the presence of valuable species (namely rare, endemic, indicative taxa, relict or under protection) (Geacu et al. 2018) and location within or in the proximity of a site characterized by an advanced natural value (such as SCI, SPA, National or Natural parks, Scientific reserves, Potential Virgin or Quasi-virgin forests, forests characterized by a High Conservation Potential, wetlands or monuments of nature) (Pătru-Stupariu et al. 2013). The second corresponds to cases were the following elements occur: presence of remarkable physical characteristics such as an exceptional girth, caves, hillocks, very large branches, advanced level of preservation or intactness, positive anthropic interventions as protective fence, informative panels or plates (Popa 2016).

The Zoogeographic dimension represents the remarkable trees possibility to offer services for various animal species, namely habitats, resources or shelter. It encompasses only one value, the Habitat for animals function, determinable by the next criteria: presence of common animal borrows and nests indicating habitats for a wide range of generalist species and location within or in the proximity of a site characterized by the presence of large carnivores, examples being bears, wolves or lynx (Roelling et al. 2014, Cristescu et al. 2019), raptor or water birds, reptiles and valuable cinegetic species as wild boar or reindeer (Geacu 2011).

The Human dimension highlights the trees importance for people. It is decomposed into tree values, each of them possessing various identification criteria. The first is the Historical-Cultural-Mythical value, recognizable by the trees significance based on an exceptional age, toponyms, association with historical events, characters, places or other elements, location within or in the proximity of a valuable historical site due to notable concentration of historical monuments or sites included under UNESCO, inclusion in a cultural landscape characterized by the presence of traditional activities, religious significance due to a holy or sacral identity and mythical aura based on popular believes, rituals and legends (Hartel & Moga 2010, Hartel & Tamaș 2015, Hartel et al. 2015, Moga et al. 2016). The second is the Scientific value and it is expressed by the presence of studies and researches materialized through scientific articles, books, research projects, encyclopedias or documentaries. We also included the Economic-Touristic value, which includes several criteria: attractiveness and notoriety based on the presence of infrastructures, thematic trails or popularity within web sites or other online sources, accessibility based on road distance to the nearest village, road altitude variation to nearest village, nearest village distance to rail station, presence of mobile phone signal, location accessibility based on land cover characteristics and propriety regime and location within or in the proximity of a site characterized by the potential to offer natural resources for human activities such as wood or timber.

The proposed aspects are selected based on cross-referencing the available geographical, biological, historical and scientific literature (Geacu et al. 2018). We consider relevant in order to achieve our goal the selected set of dimensions, types of values and complementary criteria due to the fact that they encompass the majority of possible utilities offered by very old and large trees. Based on investigating the specimens correspondence to the selected criteria we could determine the type of value and consequently dimension proper to be assigned to the respective individual. Consequently, if the specimen possesses only one dimension it shall be assessed with a low conservation potential, reflecting usually a unidirectional usable specimen valuable only from one perspective, which can be natural (either by plant or animal communities) or social-economic (by humans). The presence of two dimensions is specific to individuals characterized by a medium potential due to their utility in providing much more complex services while the exemplars assessed as having three dimensions are the ones characterized by a high or advanced conservation potential, being able to offer numerous benefits for a wide variety of natural and anthropic entities.

Finally, the trees' conservation potential was correlated with their protection status, in order to identify both favorable situations and possible dysfunctions. The protection status was established by intending discussions with local forest men and investigating the information retailed by protected areas management plans, touristic guides, forestry books and scientific articles (Pașcovschi & Doniță 1976, Giurescu 1976, Brânzan 2013).

Result and discussion

The first result, corresponding to O1 is represented by a map encompassing the number of remarkable trees identified at TAU level (Figure 2). The 68 specimens are disposed within 26 TAU and one municipality as it follows: only one specimen in thirteen TAUs, specifically Bănești, Bărcănești, Bogdana, Botoroaga, Breaza de Jos, Buftea, Cocorăști-Misli, Fundeni, Mangalia, Răsuceni, Remetea, Sibiu, and Tătărani, two specimens in eight TAUs, namely Ciolpani, Conțești, Drăgănești-Olt, Drăgănești-Vlașca, Frumușani, Gruiu, Obârșia, and Ștefăneștii de Jos, three individuals in Toporu, four exemplars in Homorod, Iormenești, and Sighișoara, eight trees in Bordușani and sixteen remarkable trees in Bucharest Municipality, by far the largest number recorded. Except Bordușani and Mangalia, which are located in the BSR, all of the other TAUs are disposed in the BCR.

The second result representing the materialization of O2 consists in a table (Table 1) encompassing the 68 specimens analyzed, their conservation potential and their protection status. All the remarkable trees have been coded with numbers from 1 to 68. The order of the trees from the table does not follow a specific criterion. From the total number of specimens, only four have both a high conservation potential and are not protected, being located in TAU Mercheașa (No. 6, 7, 8) and TAU Iormănești (No. 9). By opposite, the five oaks of Sighișoara (No. 1, 2, 3, 4) and Mercheașa (No. 5), despite expressing a similar potential, possess a negative status. Fourteen tress were assessed as having a medium conservation value and an unfavorable status. These are the ones situated in Iormănești (No. 10, 11, 12), Ciolpani (No. 23, 24), Gruiu (No. 25, 26), Fundeni (No. 45), Frumușani (No. 46, 47), Bujoreni (No. 48), Drăgănești – Vlașca (No. 50, 51), and Obârșia (No. 57). Nevertheless, twenty-one specimens respect the same potential and are protected, namely the ones of Sibiu (No. 13), Remetea (No. 14), Cococrăști-Misli (No. 15), Tătărani (No. 16), Breaza de Jos (No. 17), Bucharest

(No. 27, 33, 34, 37), Bogdana (No. 55), Obârșia (No. 56), Drăgănești – Olt (No. 58, 59), and Bordușani (No. 61, 62, 63, 64, 65, 66, 67, 68). A low conservation potential was modelled for ten trees that are not protected. These are the specimens from Bănești (No. 18), Bărcănești (No. 21), Buftea (No. 22), Bucharest (No. 38), Ștefănești de Jos (No. 43, 44), Botoroaga (No. 49), and Toporu (No. 52, 53, 54). Finally, fourteen specimens from Conțești (No. 19, 20), Bucharest (No. 28, 29, 30, 31, 32, 35, 36, 39, 40, 41, 42) and Mangalia (No. 60) are protected and assigned with a low conservation value.

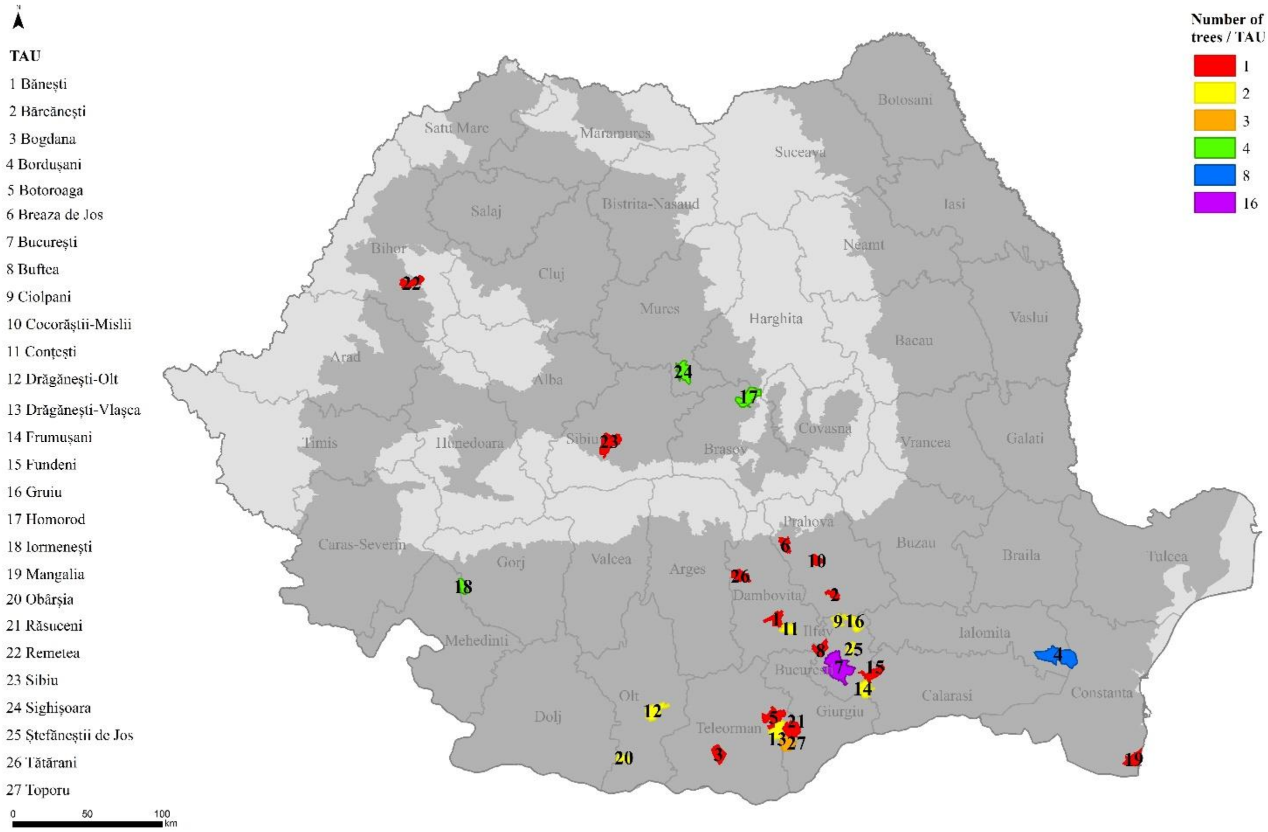


Fig. 2: The location of the remarkable trees identified within the Continental and Steppic Biogeographical Regions of Romania at TAU level (Source: A.N.C.P.I. 2006)

In order to facilitate the discussion session, the 68 specimens analyzed were grouped according to six major forested landscapes based on their spatial distribution: the wooden pastures of Transylvania, the Subcarpathian forests of Muntenia and Oltenia, the forests within the plains of Vlăsia and Vlașca, the southern dry oak forests of Muntenia and Oltenia, the flooded forest within the Danube meadows and the silvosteppes of Dobrudja. The wooden pastures of Transylvania encompass four TAUs (Mercheașa, Sighișoara, Sibiu and Remetea), a total number of ten remarkable trees, all of them being common oaks (Quercus robur). Despite the fact that all the oaks within the pastures of Mercheșa stand out as having a high conservation potential, only one specimen (No. 5) is declared monument of nature, having both protective fence and informative panel. The individual possesses the largest girth within all the measured trees (930 cm) being consistently larger that the next two trees, No. 6 (760 cm) and No. 7 (660 cm) (Bolea & Vasile 2011). No. 8 reveals as a distinctive feature a very large cave. The oaks are scattered in the proximity of the Homorod Hills SPA which protects numerous bird species, especially night raptors, certifying the areas zoogeographical value (Brânzan 2013). Furthermore, they and many other specimens form one of the largest concentration of several-century old trees within Romania, a solid prove concerning the pastures phytogeographical potential (Hartel et al. 2015, Hartel & Tamaș 2015). The services regarding human communities consists in the presence of a valuable cultural landscape, were buffalo grazing dates back hundreds of years and numerous fortified churches guard medieval villages. The ancient wooded pastures were the subject of numerous researches concerning their cultural value (Hartel & Moga 2010, Moga et al. 2016). The oaks are integrated in various touristic trails, which connect both geomorphological attractions (such as the Racoș Volcano, the Emerald Lake and Basalt Columns within the Racoș Geopark) and historical ones, namely the fortress of Rupea. Yet, the access is quite precarious due to the lack of touristic infrastructure and mobile signal, the pastures being disposed at a distance of over two kilometers from the isolated village of Mercheașa at the base of the Perșani Mountains.

The oaks of Sighișoara are protected within the Breite plateau secular oaks reserve as part of the SCI Târnava Mare – Sighișoara and form the largest concentration of secular trees of Romania and probably south-central Europe (Bolea & Vasile 2011, Patrut 2011, Brânzan 2013). All of the specimens are assessed as having a high conservation value. The largest specimen has a girth of over 700 cm (No. 1). The plateau stiff rock slopes covered partially by bench forests conserve large carnivore habitats such as bears and wolves (Roelling et al. 2014, Cristescu et al. 2019) while the upper swampy areas protect medieval grasslands. The plateau represents a representative cultural landscape, several trees being carbon dated and estimated as having between 300 and 400 years (Patrut 2011). The presence of Sighișoara fortress, a UNESCO medieval site fulfills the areas historical value while the reserve is accessible through a one kilometer hike starting from the city.

The several centuries old oak within the zoological garden of Sibiu (No. 13) it is assigned as having a medium conservation value. It represents the largest living remain of the relict meadow forest protected in the Dumbrava Sibiului Natural Park and it is stated as a monument of nature (Bolea & Vasile 2011). The forest guards mainly generalist animal species. The presence of the Sibiu historical center and the garden itself which is the oldest in Romania favor the areas historical value.

The largest tree within the county of Bihor is represented by the oak of Remetea (No. 14, 660 cm girth) also protected as a monument of nature. The oak guards the road connecting the historical village of Remetea with the famous Meziad cave, the areas major touristic attraction, located within the Crișul Repede Gorge – Piatra Craiului Mountains SCI (Brânzan 2013). Similarly, the lack of valuable zoological elements in the surrounding forests justifies us to model the tree as having just a medium conservation value.

Four TAUs are located in the Subcarpatian forests of Muntenia and Oltenia, the main species being oaks, sessile oaks, benches (Cococrăști-Misli, Tătărani and Breaza de jos) and exotic oriental planes (Iormănești), totaling seven specimens. The giant oak of Tătărani (No. 16, 750 cm girth) is protected as monument of nature and characterized by a medium conservation potential, being located in a large forest at the end of three kilometer forest road (Bolea & Vasile 2011). The area is difficult to access and lacks mobile signal. The oak is the largest within the hill forests of Muntenia and it is associated with the historical character of Matei Basarab. A similar status and potential is assessed to the sessile oak of Cococrăști-Misli (No. 15) and to the giant bench of Breaza de Jos (No. 17), both located in Prahova County. The first possesses a 700 cm girth, being sheltered by virgin or quasi-virgin forest areas that favor the presence of common animal species, especially wild boar (Giurgiu 2001). The second presents an 800 cm girth and it is the largest hill forest tree of Romania. It is hidden in the Lazului Hill forest, which also neighbors potential virgin sectors (Giurgiu 2001) and lies in the proximity of a valuable local geomorphological attraction, the Târsa river gorge (Muzeul Județean de Științele Naturii Prahova 2013). Record sizes also characterize the largest oriental plane of Iormânești (No. 9), which reaches over 700 cm girth. The specimen is not protected and possess a high conservation value. The rest of the planes encompassed by the Glogova domain, which also shelters an impressive fortified mansion, form the largest concentration of exotic remarkable tress analyzed. There are located near the Motru River SCI, a proper habitat for numerous amphibians and large mammals (Brânzan 2013).

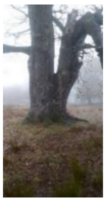
The mixed oak forests within the Vlăsia and Vlașca plains include seven TAUs (Bănești, Conțești, Ghighiu, Buftea, Gruiu, Ciolpani and Bucharest Municiplality) and total thirty-five specimens consisting in both autochthonous species (common oak, ash, poplar and lime tree) and introduced ones (mulberry tree and oriental plane) (Călinescu 1969, Iojă 2001, Grigorescu 2010). The poplars of Bânești and Conțești possess just a low conservation potential because their only distinctive feature is the exceptional size, specifically 920 cm girth (No. 18) and 850 cm girth (No. 19, 20), aspect which certifies only their physical value. Only the specimens of Conțești are protected. Two trees that encompas the same potential are the oaks of Ghighiu (No. 21) and Buftea (No. 22), neither being protected. A medium potential was assigned to the oaks of Ciolpani (No. 23, 24) and Gruiu (No. 25, 26) due to the fact that there are located in the proximity of valuable historical monuments, namely the monasteries of Țigănești and Snagov. They are also included in protected areas, such as Scroviștea SCI and Snagov forest reserve, which preserve rare bird species, representative being the lowland eagle (Bolea & Vasile 2011, Brânzan 2013). Particularly, neither of the specimens are stated as monuments of nature.

Bucharest possesses numerous protected trees assigned with a medium (No. 27, 33, 34, 37) or low (No. 28, 29, 30, 31, 32, 35, 36, 39, 40, 41, 42) conservation value. They are some of the largest ashes (No. 27, 640 cm girth), mulberry trees (No. 37, 550 cm girth), lime trees (No. 28) or exotic American oaks (No. 29) within the BCR (ANPM 2009).

The dry oak forests of southern Muntenia and Oltenia shall be separated into four distinct sub regions, each encompassing diferent TAUs: Vlăsia (Ștefăneștii de Jos, Fundeni, Frumușani), Vlașca (Drăgănești-Vlașca, Toporu, Botoroaga, Bujoreni), Deliorman (Bogdana), and Oltenia (Drăgănești-Olt, Obârșia). They total twenty remarkable trees, all of them being dry oaks (Quaercus pedunculiflora), except one specimen, which is an exotic Japanesse accacia. Neither specimen within the Vlăsia sub region is protected, despite the fact that the giant oak of Frumușani (No. 46) is the largest within the area (650 cm girth) while the Japanese acacia of Fundeni is the largest of its species measured (370 cm girth). The first is located in the proximity of the Pitar Bridge forest (Quercus cerris) which shelter a densely population of wild boar and reindeer (Geacu 2011). The second is disposed near the abandoned historical church of the Gherassy family. Both possess a medium conservation value. The oaks of Ștefănești de Jos (No. 43, 44) are the largest located in mixed forests within the plain (over 4 m girth) (Iojă 2010). They are modelled as having a low conservation potential because they do not offer other values and they are not protected. The Vlașca dry oak sub region consists in specimens which do not benefit by a favorable preservation status, yet some reveal a medium potential, namely the ones of Drăgănești-Vlașca (No. 50, 51) which are difficult to access due to the Dandara-Corneanca forest, a SCI destined to protect an old relict Quercus cerris forest and consistent population of wild boar and other cinegetic species (Brânzan 2013). The largest figures on old maps as the oak of Toni, a mysterious significance (Crăciunescu et al. 2011). The 550 cm girth specific to the oak of Toporu (No. 52) assigns it the title as the largest within the Vlașca plain, while the specimen of Bujoreni (No. 43), historically known as the oak of Pietriș (Crăciunescu et al. 2011) lies in occasionally flooded forest proper to preserve water birds in the Călniștea Valley SPA (Brânzan 2013). Reindeer are common in the forest of Comoara, where the oak of Botoroaga (No. 49) is located (Mustățea 2017). The trees of Deliorman and Oltenia are modelled with a medium potential. The largest forest specimen within Teleorman County is the oak of Bogdana (No. 55, 550 cm girth) associated with Mihai de Brave. It is considered a monument of nature. Similarly, based on our field observations, the gigantic 660 girth Quercus peduncunliflora from the Braniștea Catârilor forest is the largest of its specie from Romania (No. 56). Yet, it is very isolated, the forest is one of the best preserved remains of primeval dry oak forest of our country, being protected within the homonymous SCI (Brânzan 2013, Geacu et al. 2018). Drăgănești-Olt protects two secular trees, one being known as the oak of Tudor Vladimirescu (No. 58, 650 cm girth) (Consiliul Local Drăgănești-Olt 2015).

The flooded forest within the Danube meadows reveal a very isolated relict, the Hățis forest of Bordușani, which is the largest concentration of several century old trees of the countries swampy lowlands. There are protected giant oaks (No. 64 with almost 800 cm girth or No. 61 with over 600 cm girth), poplars (No. 68, 850 cm girth) and willows (No. 67, over 600 cm girth) The region is occasionally flooded being impossible to access and lacks touristic infrastructure. It shelters wild boars, jackals and diurnal raptor birds such as hawks due to the Bordușani SPA (Brânzan 2013). Another concentration of old dry oaks it is protected near the forest of Comorova, Mangalia (No. 60) (Bolea & Vasile 2011). The specimens are not remains of the initial silvosteppes, being planted over one hundred years.

Table 1: The trees location, year of investigation, conservation potential and protection status

			
No.: 1 TAU: Sighișoara Year: 2018 Protected: yes Potential: high	No.: 2 TAU: Sighișoara Year: 2018 Protected: yes Potential: high	No.: 3 TAU: Sighișoara Year: 2018 Protected: yes Potential: high	No.: 4 TAU: Sighișoara Year: 2018 Protected: yes Potential: high


No.: 5
TAU: Mercheașa
Year: 2016
Protected: yes
Potential: high


No.: 6
TAU: Mercheașa
Year: 2016
Protected: no
Potential: high


No.: 7
TAU: Mercheașa
Year: 2016
Protected: no
Potential: high


No.: 8
TAU: Mercheașa
Year: 2016
Protected: no
Potential: high


No.: 9
TAU: Iormănești
Year: 2015
Protected: no
Potential: high


No.: 10
TAU: Iormănești
Year: 2015
Protected: no
Potential: medium


No.: 11
TAU: Iormănești
Year: 2015
Protected: no
Potential: medium


No.: 12
TAU: Iormănești
Year: 2015
Protected: no
Potential: medium


No.: 13
TAU: Sibiu
Year: 2017
Protected: yes
Potential: medium


No.: 14
TAU: Remetea
Year: 2017
Protected: yes
Potential: medium


No.: 15
TAU: Cocorăști-Misli
Year: 2015
Protected: yes
Potential: medium


No.: 16
TAU: Tătărani
Year: 2015
Protected: yes
Potential: medium


No.: 17
TAU: Breaza de Jos
Year: 2017
Protected: yes
Potential: medium


No.: 18
TAU: Bănești
Year: 2015
Protected: not
Potential: low


No.: 19
TAU: Conțești
Year: 2015
Protected: yes
Potential: low


No.: 20
TAU: Conțești
Year: 2015
Protected: yes
Potential: low


No.: 21
TAU: Bărcănești
Year: 2015
Protected: no
Potential: low


No.: 22
TAU: Buftea
Year: 2017
Protected: no
Potential: low


No.: 23
TAU: Ciolpani
Year: 2017
Protected: no
Potential: medium


No.: 24
TAU: Ciolpani
Year: 2017
Protected: no
Potential: medium

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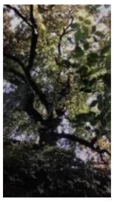
No.: 25
TAU: Gruiu
Year: 2017
Protected: no
Potential: medium

No.: 26
TAU: Gruiu
Year: 2017
Protected: no
Potential: medium

No.: 27
TAU: Bucharest
Year : 2015
Protected: yes
Potential: medium

No.: 28
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low



No.: 29
TAU: Bucharest
Year : 2018
Protected: yes
Potential: low

No.: 30
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 31
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 32
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 33
TAU: Bucharest
Year : 2015
Protected: yes
Potential: medium

No.: 34
TAU: Bucharest
Year : 2015
Protected: yes
Potential: medium

No.: 35
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 36
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 37
TAU: Bucharest
Year : 2015
Protected: yes
Potential: medium

No.: 38
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 39
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 40
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 41
TAU: Bucharest
Year : 2015
Protected: yes
Potential: low

No.: 42
TAU: Bucharest
Year: 2015
Protected: yes
Potential: low

No.: 43
TAU: Ștefănești de Jos
Year: 2017
Protected: no
Potential: low

No.: 44
TAU: Ștefănești de Jos
Year: 2017
Protected: no
Potential: low


No.: 45
TAU: Fundeni
Year: 2018
Protected: no
Potential: medium


No.: 46
TAU: Frumușani
Year: 2018
Protected: no
Potential: medium


No.: 47
TAU: Frumușani
Year: 2018
Protected: no
Potential: medium


No.: 48
TAU: Bujoreni
Year: 2018
Protected: no
Potential: medium


No.: 49
TAU: Botoroaga
Year: 2015
Protected: no
Potential: low


No.: 50
TAU: Drăgănești-Vlașca
Year: 2017
Protected: no
Potential: medium


No.: 51
TAU: Drăgănești-Vlașca
Year: 2017
Protected: no
Potential: medium


No.: 52
TAU: Toporu,
Year: 2018
Protected: No
Potential: low


No.: 53
TAU: Toporu,
Year: 2018
Protected: No
Potential: low


No.: 54
TAU: Toporu
Year: 2018
Protected: No
Potential: low


No.: 55
TAU: Bogdana
Year: 2018
Protected: Yes
Potential: medium


No.: 56
TAU: Obârșia
Year: 2018
Protected: Yes
Potential: medium


No.: 57
TAU: Obârșia
Year: 2018
Protected: No
Potential: low


No.: 58
TAU: Drăgănești-Olt
Year: 2015
Protected: Yes
Potential: medium


No.: 59
TAU: Drăgănești-Olt
Year: 2015
Protected: Yes
Potential: medium


No.: 60
TAU: Mangalia
Year: 2016
Protected: Yes
Potential: low


No.: 61
TAU: Bordușani
Year: 2019
Protected: yes Potential: medium


No.: 62
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium


No.: 63
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium


No.: 64
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium

No.: 65
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium

No.: 66
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium

No.: 67
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium

No.: 68
TAU: Bordușani
Year: 2019
Protected: yes
Potential: medium

Source: Mustățea Mihai 2015, 2016, 2017, 2018, 2019

Conclusion

Applying an overall perspective, Transylvania stands out as the region encompassing by far the most valuable tree specimens due to the presence of cultural landscapes unique in Romania. Furthermore, the pastures massive concentration of medieval oaks certifies the researcher's interest in terms of both history, ecology and dendrochronology. Conversely, the isolation and poverty that affects these rural regions favors the unfavorable protection status of numerous remarkable trees which are virtually unknown and, consequently, they are not preserved. Therefore, these wooden pastures cluster a major hotspot in terms of suitable candidates for future protection. By comparison, the remarkable trees within Subcarpathian forests do not integrate major cultural landscapes. Despite this fact, they possess complex historical value based on the presence of numerous legends concerning rulers and historical characters. They represent the largest hill forest life forms of the BCR and consist of individual elements without forming notable concentrations. The specimens present a positive preservation status and consequently do not reveal potential vulnerabilities, except the imposing concentration of giant oriental planes of Iormănești, which are not protected. The exemplars scattered in the Vlăsia plain are valuable especially due to their association with old historical monasteries, densely sprawled in the forested areas north of Bucharest. All of these trees are accessible based on the proximity to Bucharest. Also, due to the presence of the largest concentration of lowland oak forests of Romania, the trees maintain a notable ecological value. The lack of favorable individual protection arguments the existence of a second major hotspot concerning vulnerable old trees after Transylvania. A similar situation characterizes the southern BCR dry oak forests species, which represent a third potential vulnerable hotspot. Despite the fact that they do not possess the historical significance specific to the oaks of Vlăsia, the southern ones stand out especially due to their impressive size, isolation and consequent natural potential. Yet, many specimens are usually difficult to access due to the rural regions lack of touristic infrastructure. Rural regions within poor Counties, particularly Teleorman, Giurgiu, Olt or Călărași reveal major economic and demographic problems, situation that slows their touristic development and scientific progress. By consequence, the century old trees of these regions will probably remain outside scientific and touristic interest, the chances of them to benefit in the future by a favorable conservation status being extremely low.

Our assessment reveals the presence of one major hotspot concerning areas sheltering high conservation value unprotected century old tree specimens within the BCR, namely the wooden pastures of Transylvania and two less extended but still notable ones, materialized by the vast mixed oak forests within the Vlăsia plain and the rare and scarce dry oak forests of Vlașca. Here the specimens are poorly studied and despite their remarkable features, denote an eager need for an enhancement regarding their conservation status.

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Peri-urban livelihood dynamics: a case study from Eastern India

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Abstract

An important development of the urban settlements during the last few decades has been the rapid expansion of the population and the built-up area into the administratively different suburbs and areas surrounding the large towns and cities. These areas suffer from the negative consequences of unplanned urban growth, associated land use changes, rapid social change and degradation of natural resources. Burdwan city is situated along the greater Kolkata metropolitan area and Asansol industrial area corridor. As a result, this city has experienced problems such as socio-spatial segregation, socio-economic and cultural gaps as well as uncontrolled land markets and the spread of informal development.

The present study examines the empirical findings of socio-economic transformation as a part of peripheral urbanization. For a better analysis, the livelihood asset index (LAI) and household quality of life index (HQLI) were determined. Livelihood asset index is analysed by considering four capitals i.e. physical, human, financial and social with 12 index components. Villages located nearby city have high index whereas far distance villages have a low index. Finally, it is concluded that as livelihood asset increases, the quality of life also increases in the peri-urban villages of Burdwan area.

Keywords: *livelihood asset index, quality of life, Burdwan, households, peri-urban, socio-economic transformation*

Rezumat. Dinamica periurbanului rezidențial: Estul Indiei ca studiu de caz

O dezvoltare importantă a așezărilor urbane în ultimele decenii a constat în extinderea rapidă a populației și a zonei construite în suburbiile și zonele diferite din punct de vedere administrativ din jurul orașelor mari. Aceste zone sunt afectate de consecințele negative ale creșterii urbane neplanificate, modificărilor asociate utilizării terenului, schimbărilor sociale rapide și degradării resurselor naturale. Orașul Burdwan este situat în zona metropolitană extinsă Calcutta și în coridorul zonei industriale Asansol. Drept urmare, acest oraș a întâmpinat probleme precum segregarea socio-spațială, decalaje socio-economice și culturale, precum și creșteri necontrolate ale prețurilor terenurilor și dezvoltare rezidențială neconformă.

Prezentul studiu prezintă rezultatele cercetării empirice privind transformarea socio-economică ca parte a urbanizării periferice. Pentru o analiză mai bună, s-au determinat indicele mijloacelor de trai (LAI) și indicele calității vieții în gospodărie (HQLI). Indicele mijloacelor de trai este analizat luând în considerare patru coordonate majore: fizice, umane, financiare și sociale, cu 12 componente ale indicatorului. Satele situate în apropierea orașului au un indice ridicat, în timp ce satele de la distanță au un indice redus. În cele din urmă, se concluzionează că pe măsură ce mijloacele de trai cresc, crește și calitatea vieții în satele din zona periurbană Burdwan.

Cuvinte-cheie: *indicele mijloacelor de trai, calitatea vieții, Burdwan, gospodării, periurban, transformare socio-economică*

Introduction

Peri-urban area development is a cumulative result of the process of urbanization and economic development. The traditional discrete relationship between the city and contiguous villages is now being substituted by a new era of mutual existence that not only rely on each other but also intertwines into a new whole (Torres, Alves, & Aparecida De Oliveira, 2007). A peri-urban area is a place where urban and rural activities meet, and a mosaic of rural and urban systems prosper, which is economically and socially heterogeneous and subject to rapid change. The peri-urban area is at the center stage of urbanization process as the rapid transition process is highly conspicuous here. The transformation process in the peri-urban area has become increasingly complex with the intermixing of rural and urban characters (Mycoo, 2006). Presence of a city in the peripheral villages not merely changes the land use of the peri-urban but also shapes the socio-economic life of the people living there. The socio-economic transformation of the people is the result of many factors that are influenced by the city in its proximity.

The formation and development of a peri-urban area is the result of an interaction between rural areas and the city. Peri-urbanization, irrespective of context, is characterized by a transformation of economic activities from agriculture-based livelihoods into non-farming occupations. Based on a study of in-situ urbanization in China, (Dong, 2017) finds that rural areas are no longer associated with agrarian livelihoods. There are several significant factors fostering the transformation of rural to an urban economy that includes:

(1) The relocation of manufacturing and service industries to the peripheral areas of the city because of a low land rent that in turn incentivizes people to leave the city and reside in suburban areas.

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(2) A decline in employment, particularly for those who live in relatively remote regions, has forced the young population to migrate out and engage in non-farm work in the peripheries.

(3) The desire of the urban middle-class to seek a better quality of life by residing in a healthy, salubrious, and verdant milieu in the peripheral zones.

The development of the peri-urban area is not only influenced by the city but also by the surrounding rural areas. Therefore, there are two landscape elements, which initiate the socio-economic transformation in the peri-urban area (Adesina, 2007). These elements are further classified into two categories. The rural landscape elements include the water bodies, farmlands, and vernacular architecture. This landscape is the carrier of the primary resource based on farming culture. On the other hand, urban landscape refers to buildings, industries, streets, shopping center, parks, public amenities and recreational facilities.

Socio-economic stratification in terms of inequality of wealth, power and access to resources is an inherent characteristic of all the societies. As such, some households are always at a higher status than others (Agergaard et al., 2009). Peri-urban areas are mosaics of fleeting and new residents mingled with longstanding land uses, including farms, villages, quarries and forest patches. The city of Burdwan is no exception to this phenomenon of accelerated population growth. It is growing rapidly and services are not able to keep pace with the pressure of population. Therefore, the city has literally expanded into the surrounding areas leading to a change in social and economic lives. In time, Burdwan city is expanding towards the peri-urban villages and in that process strongly influence the peripheral rural settlements in the dimensions of both natural and social resources.

This paper aims to explain the empirical findings with respect to socio-economic transformations taking place as a consequence of development processes in the peri-urban areas. The study examines the process of economic change in which specific circumstances and new opportunities lead the resident people to involve in the non-farming sector. This section will also discuss the transformations taking place in a social environment of the peri-urban area.

Literature review

Peri-urban areas are environments where livelihoods are diversified and urban production processes are rapidly outflowing (Simon, 2008). According to Ramachandran (1992) the outskirt in Delhi extends well beyond the city limits. This area is mosaic of rural area and urban area. It is a region beyond the municipal limits and is a significant region for new residential, industrial and commercial growth that reflects the city's outward expansion. Allen (2003) stated that there is no consensus on the conceptual definition of the peri-urban interface. He also argued that rural and urban features continue to coexist increasingly within and outside cities, and that the conventional urban-rural dichotomy is deeply rooted in our planning system, which is insufficient to cope with the process of change in the peri-urban interface in the environment and development. Samanta (2001) in her research on Burdwan town examined that the socio-economic characteristics of settlements that are located midway along the continuum. However she also analyzed role of rural market centres for integrating rural and urban economics of the region and the pattern of the level of development of the rural areas of the Burdwan town. Another issue she stated that the informal sector especially migrant rickshaw pullers have significant role in Burdwan's economy. This research concentrates on the livelihood of the villagers in peri-urban area of Burdwan city.

The word livelihood refers to the different means of survival, i.e. methods to acquire food, income and hereditary wealth. Consequently, the concept of living conditions often involves change over time and adaptation to changing circumstances (Fazal, 2014). Lerner and Eakin (2010) spoke about changing livelihoods and their links with urban settlement using the term hybrid landscape for peri urban area. They addressed social changes such as lifestyle changes, land use and livelihood. They want to demonstrate the ability of peri-urban areas to tackle food security, environmental integrity and economic growth challenges. In his research for developing nations, Adedayo Adesina (2007) found that the urban outskirts of housing bequests and industrial facilities infringe into formerly rural landscapes and these households in developing countries had turned out to be occupationally diversified, integrating job patterns and networks linked to the metropolitan economy. In the sense of rapid urbanization in poorer countries, Simon (2008) discusses the dynamics of increasing peri-urban growth and living systems.

Livelihoods are the ways people meet their needs and earn a living (Chambers and Conway, 1992). A livelihood is a collection of income streams that comes from a variety of sources and practices. Livelihood requires property and resources, actions and access to them through institutions and social relationships that together decide the person or household's living (Ellis, 2000). Development analysts have advocated increasing use of capital in developing countries to balance income and consumer-based welfare and wealth initiatives (Carter and May 2001; Filmer and Pritchett, 2001). Income has long been the standard measure for welfare analysis because it is a cardinal parameter that is directly comparable between observations, making it easy for quantitative analysis to be understood and used (Ravallion, 1992). The study and redistribution of assets are meant to supplement these steps by broadening our perception of the multidimensional essence of poverty and the scope of the poverty reduction processes (Adato et al., 2006). Moser and Felton (2007) contributed to the debate on asset assessment and asset indices growth.

This explains the basic approach built to construct an asset index based on observational data panel collection in Guayaquil, Ecuador. To order to create a single wealth factor, Filmer and Pritchett (2001) use 21 asset categories from Demographic and Health Surveys, representing both consumer durables and housing stock. They prove that the resulting parameter has empirically probable implications and forecast higher than spending school enrolment. Sahn and Stifel (2003) were similar to a multidimensional approach being applied. They categorize their index components into three asset categories (household durables, household attributes, and human capital), but then merge them into a single index. Dokov and Stamenkov (2017) used the "Development and Prosperity Index" (DPI) calculated using the latest available data for 8 key indicators to measure the current socio-economic spatial development of the Danube regions on a complex basis. Prakongsai (2006) was to investigate the connection between outcomes using alternative methods for categorizing households into various socio-economic classes, ranked by income and property list. To determine the weight or factor score of each asset, the asset index was developed using Principal Component Analysis (PCA).

Kibwage et. al. (2009) analyzed tobacco-growing household wealth and subsistence approaches compared to non-tobacco-growing households in southern Nyanza, Kenya. It was also noticed that the majority of non-tobacco farming households have a better quality of housing and education and a greater diversity of businesses than their counterparts.

Hagerty et. al (2001) established quality of life indexes, numerical indices aimed at defining a national or regional quality of life metric. To determine the validity and utility of such indexes for public policy purposes, we used 14 parameters and also analyzed 22 of the most commonly employed indices in the most diverse countries. At long last, they have reasoned that huge numbers of these records are successful; on the off chance that they are done genuinely, on the off chance that they depend on time arrangement and in the event that they can be disaggregated at subpopulation level. Dunn and Holtz-Eakin (2000) measured the effect of individual wealth and human capital and parental resources and self-employment on the rate of employee transits from income to self-employment. Several objections, however, levelled against the use of the asset index to determine socio-economic positions of households. It is important to be conscious that the index includes a quantitative benefit evaluation but does not mention anything about actual wealth or poverty levels. The index can therefore be used over time to track changes in deprivation and wealth of homes, but cannot be converted into a decrease in cash word or resource poverty.

Study area

The study area is located within the peri-urban area of Burdwan city. This city is located on the bank of the Damodar river in West Bengal state of Eastern India (Fig. 1). Rural areas surrounding the Burdwan city lack the amenities and facilities like employment in secondary and tertiary sectors which are available in city. These availabilities are the pull factor to attract migrants from the surrounding villages. The inflow of migration into the city expanded physically to accommodate these people. The net result has been encroachment of urban land uses within the rural areas surrounding the fast growing Burdwan city.

Peri-urban area of Burdwan city extends over 170 sq km with a geographical extent between latitudes 23°10' to 23°20' North and between longitudes 87°46' to 87°58' East. The total area lies within 10 kilometers from the center of the Burdwan city. The area includes 57 villages in 7 gram panchayats (village council) in two community development blocks (C.D. Block), i.e. Burdwan I and Burdwan II. Within Burdwan I C.D. Block, there are 34 villages for 126 sq. km and 23 villages within an area of 44 sq. km in Burdwan II C.D. Block. It has extended over 170 sq. km, accommodating about 158,504 persons (Table 1).

The Damodar and Banka are the major rivers. The whole area is well connected by roads (National Highway-2, Katwa road, Kalna road, Guskara road and Arambagh road) and railway network towards Howrah and Asansol division. This zone also circumvents the district headquarters related to administration, transportation and education. All administrative offices, medical college and hospital, university and engineering college are located in Burdwan city.

Table 1. Administrative framework of study area

Demographic characteristics	West Bengal State	Barddhaman District	Study Area	Share in the district
Total Population	91,276,115	7,717,563	158,504	2.05%
Urban Population	29,093,002	3,078,299	73,540	2.38%
Rural Population	62,183,113	4,639,264	84,964	1.83%
No. of Households	20,309,872	1,725,511	38,089	2.2%
Area (in sq. km.)	88,752	7,024	170	2.42%

(Data Source: Census of India, 2011)

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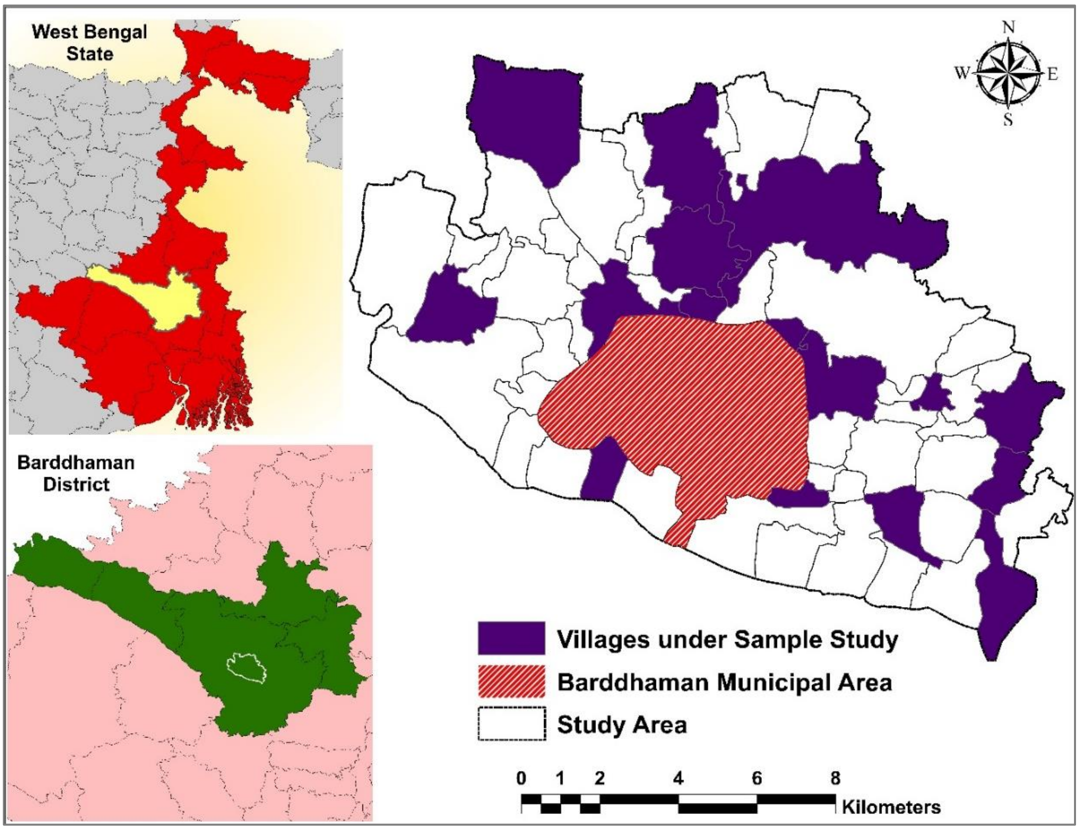

Fig. 1: Location map of the peri-urban area in Burdwan city

Methodological framework

A study gains meaning only with the availability of appropriate information. The present study requires a detail information regarding socio-economic transformation in the peri-urban area of Burdwan city. To meet this end, a wide range of data were collected from different sources especially for getting a reconnaissance idea of the study area and the land use changes over time. Besides, a large array of primary information was also procured from the field survey of the sample areas.

Primary information was collected by field survey through use of questionnaire schedules, and interviewing a sample population and local actors. The sample survey has given a first-hand account of the questions encircling socio-economic transformation of a peri-urban area of Burdwan city. It included data on infrastructure, amenities and public utility services available in the village. In order to understand the socio-economic transformation in the periurban area of Burdwan city at household level, 250 households were surveyed. The households are selected by stratified random sampling, in order to get representative data from villagers of the study area. It includes 72 households belonging to farming class, 117 households belonging to non-farming class (native residents) and 61 migrant households (out of which 31 households reside in own house and 30 households are tenants). Data at the household level include demographic pattern, occupational structure, level of expenditure, the daily usable assets, housing, household amenities and environment. 12 real estate agents and speculators were also interviewed. Secondary data includes statistical information on the city & the various settlement norms & their expansion in the regions & field areas concerned. The data thus collected from various primary and secondary areas to assess the socioeconomic transformations were represented using several cartographic techniques and statistical methods. The spatial analysis was done on ArcGIS (ESRI, 2017) and statistical analysis on R software (R, 2013). The base map was prepared from the topographical sheet map from Survey of India (1974 and 1975) at the scale of 1:50000 (Survey of India, 1974 and 1975).

About 16 villages are surveyed out of 57 villages on the basis of three categories of population density and distance from city center. As it is considered that density gradually decreases as we move out from the city centre. Hence to get the variety, we have set a logic to survey of villages considering both the distance from the city centre and density of population. So we have three categories of villages. These are as follows:

- High density and shortest distance from the city center
- Medium density and average distance from the city center

- Low density and longest distance from the city center

After creating the centres, 30% villages were selected randomly from each category and nearly 20% households were randomly selected from each village representing people in peri urban area of Burdwan city. The present analysis is largely based on an analysis made on the footsteps of DFID[1]'s Sustainable Livelihood Framework (SLF). It is modified to fit into the present study. To evaluate the livelihood asset index (LAI), some capital assets are used for broad analysis. Capital assets are critical markers of livelihood conditions available in the peri-urban households of Burdwan city. Four main types of livelihood assets are considered here - physical, human, financial and social assets - each of which is administered using context-specific indicators. The analysis consists of 12 quantitative indicators at village-level that were used for measuring the status of four livelihood capital assets. Household quality of life index (HQLI) consist of housing condition index and household asset index. About 11 indicators were used for compiling HQLI index. The LAI and HQLI index is constructed with the help of range equalization and normalization technique. Here, all unidirectional variables are normalized by dividing the difference between maximum and minimum to the difference between observed value and the minimum value. Scale-free scores of each observation vary between 0 and 1. For livelihood Asset Index and household quality of life index, higher score means better prosperity in life.

Results and discussion

Livelihood Asset Index (LAI) analysis

Livelihood Asset Index (LAI) is characterized by multidimensional, integrated and rational approach targeted to understand the livelihood of households that ranges from rich with greater access to resources to poor with lesser access to resources (Ashley and Carney, 1999; Moser and Felton, 2007). A household (HH) is a clearly distinguishable social unit under the management of a household head (HHH) (Morse et al., 2001). The HH shares a commonality in being answerable to an HHH and shares a common kitchen. The four capital assets in the framework are major elements to analyse dynamic processes of socio-economic transformation in peri urban area. Assets are not only resources that people use; they are also what give people the capability to act (Banu and Fazal, 2017). Physical capital refers to the basic material infrastructures needed for any household to have a decent life (Hulme and McKay, 2013). However, in the present study, the physical capital assets focus on the village-level infrastructural facilities like the type of housing material, access to blacktop road, availability of market, and drinking facility. Human capital includes the level of literacy, type of household fuels used for cooking, the percentage of the non-agricultural population and family size of the HH. It can be measured both quantitatively and qualitatively. Financial capital refers to monetary resources that are available to the households in peri-urban villages. It includes per capita income and type of employment. An examination of HH assets as a means of assessing wealth information is often used in some cases. Social capital assets are important aspects of any society. Money borrowing and assistance from relatives is considered as an indicator for measuring social capital. It can be assumed how much affluent household in peri urban area with this indicator. The measurement of livelihood assets is based on a balanced weighted average approach where each index components contributes equally to the overall index. So this way asset index is summarized as:

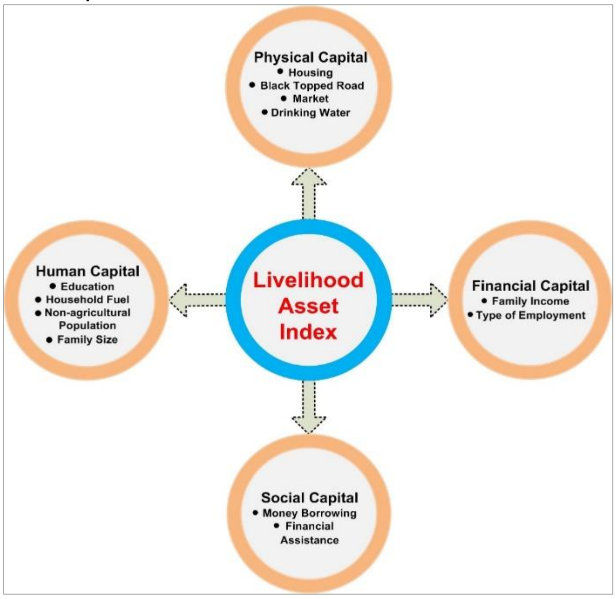

Fig. 2: Flow chart of Livelihood asset index

After analyzing all the capitals, it is found that Gopalnagar village has the highest livelihood asset index followed by Nari village. Villages which are located near the city have high LAI (Fig. 3, Table 2, 3, 4). Most of the high income people are staying in these villages. On the other side, some villages have poor livelihood index like Belkash, Amirpur and Pampra. These villages are located far from the city and also less wage people are staying in these places.

[1] Department for International Development (DFID) is a United Kingdom government department

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Table 2. Major capitals, assets and index value comprising Livelihood Asset Index (LAI)

Capital Type	Asset Index Categories	Index Components	Component Value
Physical Capital	Housing	Mud Bricked Thatched	0.33
		Brick cement with Non-RCC	0.66
		Brick cement with RCC	1
	Access to black Topped Road	0-1 km distance from village	1
		1-5 km distance from village	0.66
		>5 km distance from village	0.33
	Availability of market	0-1 km distance from village	1
		1-5 km distance from village	0.75
		5-10 km distance from village	0.50
		>10 km distance from village	0.25
	Drinking Water	Tube well	0.25
		Hand pump	0.5
		Tap water	0.75
		Submersible	1
Human Capital	Levels of Education	Illiterate	0.2
		Primary	0.4
		Secondary (up to 10th standard)	0.6
		Higher Secondary (up to 12th standard)	0.8
		Graduation & above	1
	Household Fuel	Wood-cow dung	0.33
		Kerosene	0.66
		LPG	1
	Non-Agricultural Population	0-25%	0.25
		25-50%	0.5
		50-75%	0.75
		>75%	1
	Family Size (Persons)	0-4	0.33
		5-8	0.66
		>8	1
Financial Capital	Family Income (In Indian Currency)	0-8000[2]	0.2
		8000-16000	0.4
		16000-24000	0.6
		24000-32000	0.8
		>32000	1
	Type of Employment	Daily Wager	0.25
		Self Employed	0.5
		Private Job	0.75
		Govt. Job	1
Social Capital	Money Borrowing	Yes or No	1 or 0
	Financial Assistance From Relatives	Yes or No	1 or 0

(Data Source: Census of India, 2011; Primary household survey 2018)

Furthermore, these villages have been classified into three categories, i.e. low, medium and high LAI (Table 4). Among these villages Amirpur, Pamra and Belkash have low LAI as they have poor infrastructure and are also located farther from city. On the other hand, Mirzapur, Krishnapur, Sadhanpur and Nari have very good LAI. These villages have good infrastructure as well as high income level. The rest of the villages have medium level of LAI. However, villages ranked in medium category are also located near the city.

[2] 1 dollar = 64 rupees on January 2018

Table 3. Value of Asset Index

VILLAGE NAME	ASSET INDEX CATEGORIES												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
KRISHNAPUR	0.6	0.78	1	0.95	0.51	0.58	0.59	0.33	0.13	0.66	1	1	**8.13**
BELKASH	0.46	0.71	0.74	0.58	0.58	0.41	0.47	0.37	0.25	0.33	0.25	0.25	**5.4**
SARAI TIKAR	0.47	0.8	0.93	0.83	0.71	0.46	0.52	0.6	0.4	1	0.5	0.25	**7.47**
GODA	0.53	0.7	0.86	0.68	0.562	0.5	0.52	0.35	0.1	1	1	0.5	**7.302**
FAKIRPUR	0.38	0.764	0.731	0.6	0.662	0.45	0.66	0.6	0.2	1	0.25	0.75	**7.047**
MIRZAPUR	0.7	0.83	0.99	0.944	0.625	0.583	0.588	0.555	0.166	1	0.75	0.25	**7.981**
PALITPUR	0.483	0.635	1.02	0.771	0.61	0.437	0.483	0.583	0.25	1	0.25	0.5	**7.022**
SADHANPUR	0.576	0.8	0.802	0.926	0.603	0.544	0.482	0.647	0.235	0.66	0.75	1	**8.025**
NANDARA	0.483	0.635	0.72	1	0.468	0.458	0.483	0.33	0.166	1	0.25	0.25	**6.243**
PAMRA	0.433	0.718	1.164	0.562	0.58	0.416	0.416	0.5	0.166	0.66	0.25	0.25	**6.115**
AMIRPUR	0.44	0.597	0.829	0.475	0.595	0.4	0.46	0.7	0.2	0.66	0.25	0.25	**5.856**
GOPALNAGAR	0.84	0.932	1	1.22	0.562	0.65	0.68	0.7	0.3	1	0.75	0.5	**9.134**
TALIT	0.49	0.61	1.01	0.625	0.562	0.41	0.49	0.75	0.35	1	0.75	0.5	**7.547**
BAIKUNTHAPUR	0.56	0.63	0.68	0.86	0.63	0.387	0.44	0.6	0.4	1	0.5	0.25	**6.937**
JOTRAM	0.58	0.66	0.93	1.075	0.595	0.525	0.45	0.7	0.3	1	0.75	0.25	**7.815**
NARI	0.539	0.81	0.911	1.12	0.503	0.51	0.565	0.434	0.26	1	0.75	0.5	**7.902**

1 – Education; **2** - Type of house; **3** - Type of fuel; **4** - Drinking water; **5** - Family size; **6** - Type of employment; **7** - Total family income; **8** - Whether borrowed money; **9** – Borrowed money from relatives; **10** - Access to black topped road; **11** - Availability of market; **12** – Non-agricultural population; **13** - Livelihood Asset Index (Summation of all index categories).

(Data Source: Sample Sourvey, 2018)

Table 4. LAI categorization

LAI index category	LAI index range	Name of villages	Percentage among sampled villages
Low	**5.4 – 6.6**	Belkash, Pamra, Amirpur, Nandara	25
Medium	**6.61 – 7.9**	Talit, Saraitikar, Palitpur, Goda, Fakirpur, Baikunthapur, Jotram	44
High	**7.91 – 9.1**	Mirzapur, Krishnapur, Sadhanpur, Nari, Gopalnagar	31

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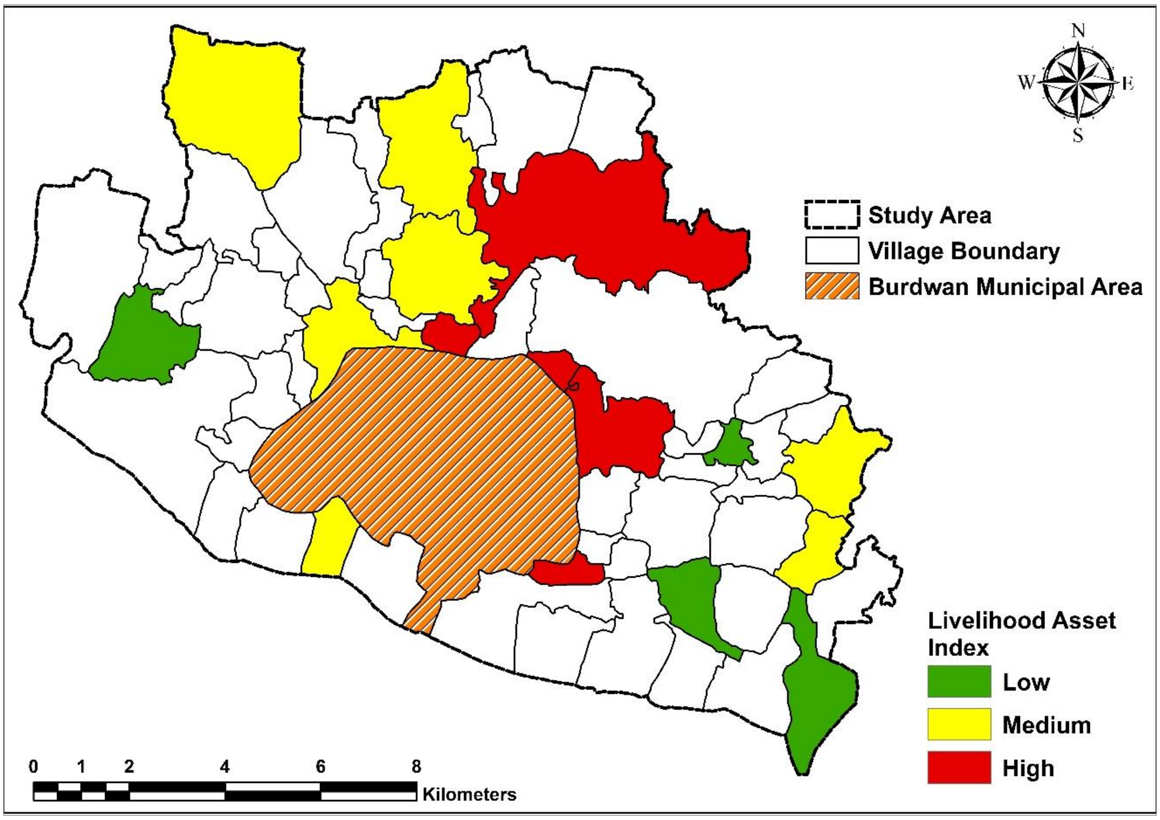

Fig. 3: Livelihood asset index of sampled villages

(Source: Authors' computations from Field Survey (2018)

Household quality of life index (HQLI) analysis

The term quality of life describes both an objective and subjective state of living condition and charts a change in them over time. Individual and collective preferences and priorities differ, causing differences in the way it is perceived, either as being good or bad, static or dynamic. Data regarding housing condition and asset possession were collected from the household-level primary survey. In order to analyze the spatial plurality of household quality of life index in the peri-urban area of Burdwan city, different variables are selected within the two category indices. These two indices are housing condition index and household asset index. The housing condition index is compiled based on material used for house, portable dinging water availability within the premises, electricity, sanitation status and Liquid Petroleum Gas (LPG) using as fuel for cooking. Another household asset index calculated by the personal belongings like television, bicycle, motorcycle, car/ tractor, refrigerator and air conditioner. These two index clearly indicated that economic prosperity of peri-urban area respondents. The eleven selected variables under these two indices are given below (Fig. 4).

The higher the index value is, higher the quality of life of that household ranks. The analysis finds that there was a marked influence in the quality of life among the peri-urban households. There was a significant improvement in the peri-urban households that have become more urbanized and the quality of life have improved consequently. Peri-urban villages located nearby Burdwan city boundary have good household quality of life. People have better possession in housing condition as well as household assets.

After analyzing LAI and HQLI in the sampled villages, a correlation coefficient is estimated between these two index values. The correlation coefficient (r) is 0.678. Therefore, the livelihood asset index has a close relationship with the quality of life index. As livelihood asset increases, the quality of life also increases in the peri-urban villages of Burdwan area. There are improvements in housing condition as well as in the possession of modern household assets. However, these improvements increase with city accessibility.

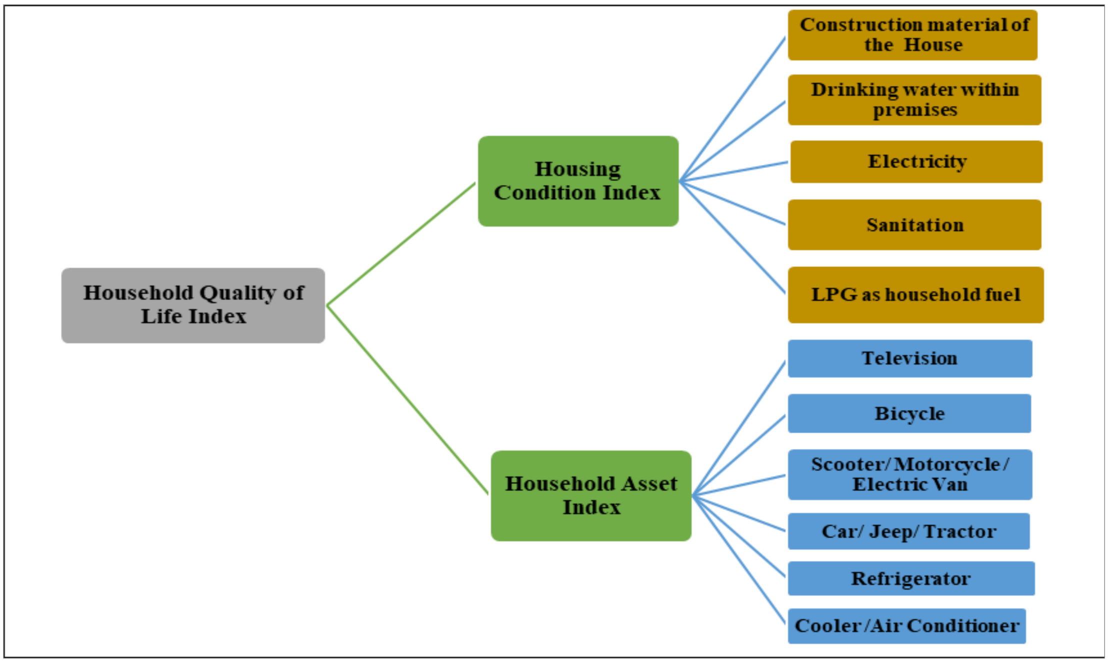

Fig. 4: Variables used for household quality of life index

Table 5. Value of different indices of HQLI

Village name	Housing Condition Index (a)	Household Assets Index (b)	Household Quality of Life Index(HQLI) (Sum of a + b)
Krishnapur	0.77	0.65	**1.42**
Belkash	0.75	0.45	**1.2**
Saraitikar	0.86	0.51	**1.37**
Goda	0.7	0.49	**1.19**
Fakirpur	0.68	0.531	**1.211**
Mirzapur	0.866	0.571	**1.437**
Palitpur	0.766	0.442	**1.208**
Sadhanpur	0.823	0.43	**1.253**
Nandara	0.566	0.442	**1.008**
Pamra	0.833	0.442	**1.275**
Amirpur	0.58	0.398	**0.978**
Gopalnagar	0.98	0.547	**1.527**
Talit	0.73	0.44	**1.17**
Baikuntha-pur	0.78	0.43	**1.21**
Jotram	0.8	0.448	**1.248**
Nari	0.774	0.469	**1.243**

(Data Source: Authors' computations from Field Survey, 2018)

Micro-analysis

Analysis has been done on the basis of 250 sample households from 16 villages in peri urban area of Burdwan city.

Results of the Pearson correlation coefficient showed a significant large, and positive association between LAI and HQLI [where r (248) = 0.58, $p < .001$***].

Table 6. Summary statistics of LAI and HQLI

	LAI	HQLI
Minimum Value	2.97	0.366
1st Quartile	6.24	0.932
Median	7.45	1.332
Mean	7.377	1.244
3rd Quartile	8.518	1.498
Max	11.94	3.098

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Table 7. Tracking the Association between LAI and HQLI using Pearson Correlation Coefficient

Test statistic	Degree of freedom (df)	P value	Alternative hypothesis	Correlation
11.32	248	3.293e-24 * * *	two-sided	0.5835

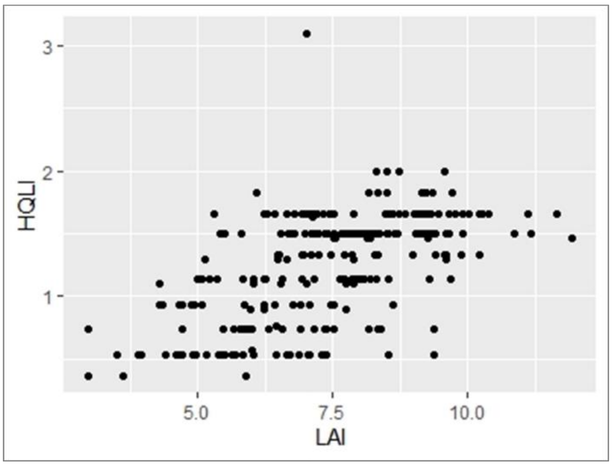

Fig. 5: Scatter plot between LAI and HQLI

Above analysis clearly stated that the correlation between HQLI and LAI are positively correlated. We want to build a model that predicts the HQLI has given the LAI for the sampled respondents. The model considered here is simple linear regression. Thus we propose that:

HQLI = α + β (LAI) + ∈

Where α and β are the regression coefficients to be estimated. ∈ is the error term, such that

$\in \sim N(\mu, \sigma)$

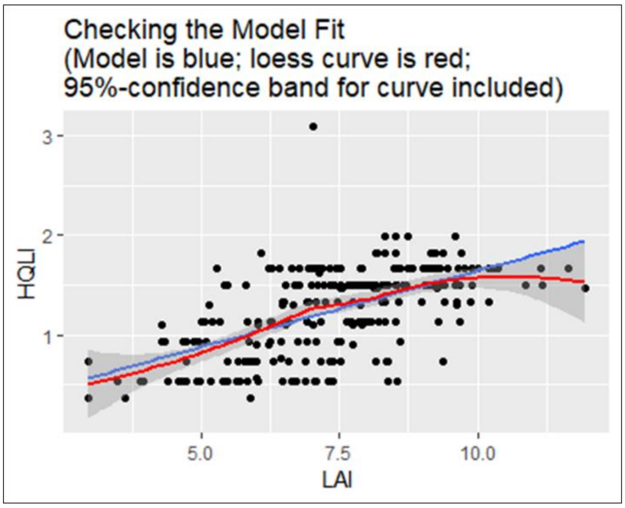

Fig. 6: Fitting linear regression of LAI and HQLI of all 250 respondents

Using Ordinary Least Square (OLS) regression method, α and β are estimated from the sample data. Results of the regression analysis are presented in Table 6 and 7.

The overall model predicting HQLI (formula = HQLI ~ LAI) explains 34.05% of the variance of the endogen (adj. R2 = 33.78). The model's intercept is at 0.11 [SE = 0.10, 95% CI (-0.087, 0.32)]. Within this model: The effect of LAI is significant (beta = 0.15, SE = 0.014, 95% CI [0.13, 0.18], t = 11.32, p < .001) and can be considered as medium (std. beta = 0.58, std. SE = 0.052).

Testing the assumption of regression

Table 8. Linear Regression of HQLI on LAI

	Dependent variable
	HQLI
LAI	0.153*** (0.014)
Constant	0.114 (0.102)
Observations	250
R2	0.340
Adjusted R2	0.338
Residual Std. Error	0.356 (df = 248)
F Statistic	128.042*** (df = 1; 248)

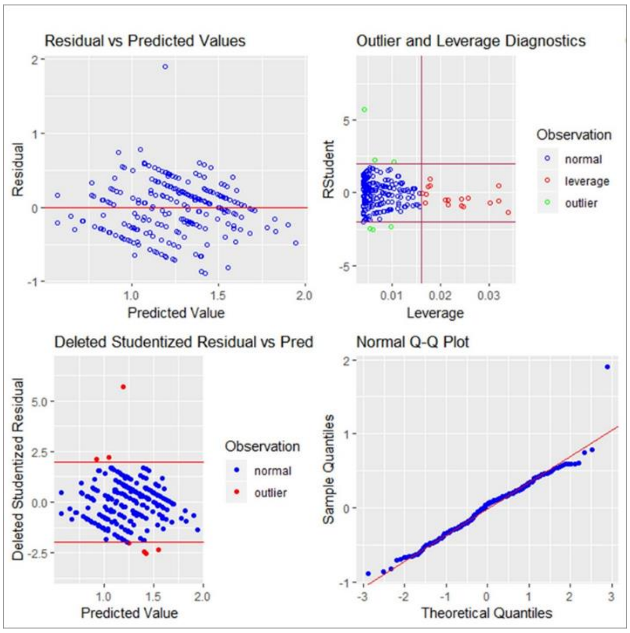

Fig. 7: OLS assumptions check

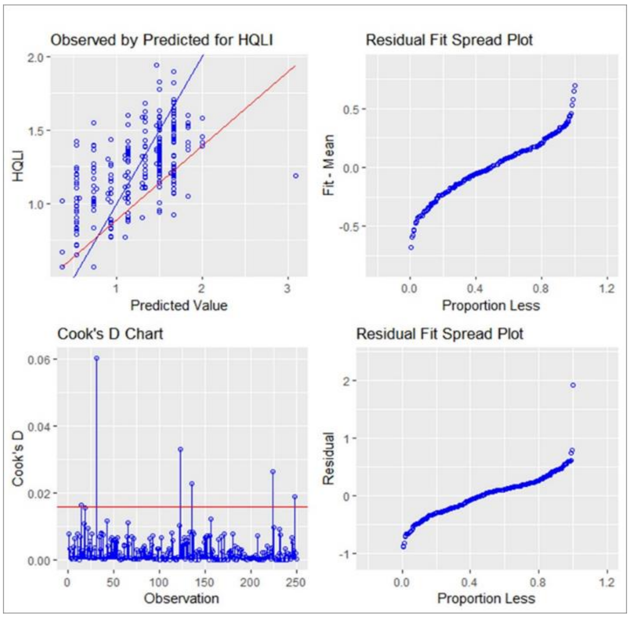

Fig. 8: Plotting of observed vs predicted value

From table 7, it is evident that LAI is a statistically significant prediction of HQLI as the β coefficient value is 0.153 and is significant at 1% level. The overall model is also statistically significant with an R^2 value of 0.34. Thus the model says that 34% of the variation in HQLI is accounted for by LAI. The β coefficient indicates that a unit change in LAI leads to (0.15) units change in HQLI in a positive direction. The assumptions of the OLS regression are verified, graphically using loess curve, residual plot, Q-Q plot and outliers plot as shown in figures 6, 7 and 8.

Conclusion

Peri-urban is such an area where few people have to change their occupation suddenly on the face of either voluntary sale of land in the open market or land acquisition by the government for development projects (Chambers & Conway, 1992). Such changes do not occur uniformly over time and space. It depends on the geography; on the location.

Distribution of occupation type is not uniform all over the peri-urban villages (Fellmann et.al. 2007). The zone near the Burdwan city has higher urban influence and prototypical urban land use than the areas farther away from the city, which influences the occupation structure. The study finds that informal work, petty trading, and low-level services have diverse nature in the sampled villages. Sample survey examined that income diversification with different sectors is very much common with the combination of farming and non-farming activity. The main occupation in the primary sector is cultivation. Villages located in the most distant and low-density areas have a higher percentage of medium and large holdings. In addition, the availability of other activities is low; hence, a large number of people are still cultivators. Besides, many people have also engaged in livestock ranching, and milk-producing in these villages. In the secondary sector, the occupation group of skilled workers has the least percentage of workers.

This study has examined the spatial and socio-economic transformation of the peri-urban Burdwan. The pull factor of urban infrastructure and good employment opportunities attract migrants from the surrounding villages. The study finds that there are clear signs of socio-economic transformation in the peri-urban area of Burdwan city. This zone is characterized by the coexistence of both primary, secondary, and tertiary activities. The easy access to market and the monetized urban economy is of great advantage for these peri-urban producers and providers. Thus better economy, larger market, greater advantage and higher wages have led peri-urban households to diversify their livelihood that led to improved living. A large number of people engaged in agriculture have sold off their land at a better price and invested a part of it in petty businesses. Thus, occupational change has happened significantly in the peri-urban area. The study also found that city impact has significantly transformed the social environment too. This area has witnessed the transformation in family structure. The families that have undergone a change in the occupational structure are increasingly getting nuclear. To access the living standard in the peri-urban area, livelihood asset index (LAI) and household quality of life index (HQLI) were devised. The sample survey finds that within the peri-urban villages, there is a marked influence of city life on their living style and quality of life. This improvement is also evident from their housing condition and household assets. There have been improvements also in sanitation, water supply, electric supply, use of household fuel, means of transport to the city, and level of education. Urban amenities are gradually gearing up in the sample villages. Almost all the sample villages are provided with metalled and semi-metalled roads, health facilities and potable water supply. LPG fuel is used in 64% of the households in the peri-urban interface. However, only 42% of the households are living in brick cement RCC house. The study also finds that a peri-urban area is a place of new social class, who are more inclined towards ultra-urbanity. Overall, the transformation and access to infrastructural facilities and public amenities in the peri-urban have greatly improved, as also evident from inferential statistics performed for gauging socio-economic transformation.

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A Belief-Desire-Intention Agent-based procedure for urban land growth simulation. A case study of Tehran Metropolitan Region, Iran

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Abstract

Urbanization, growth of urban areas, is a process that has been growing rapidly during the last two decades. This phenomenon affects aerobiological, economical, industrial, ecological processes, social control, and the family. Hence, the prediction of the urban area extent has an important role in the future decision of the municipality. Multi-Agent System (MAS) is a proper tool for simulation and modeling process, which has been used for solving different types of spatial and non-spatial problems. In this article, we use MAS for urban simulation in the rural area around Tehran, which is the most populated and the fastest-growing city of Iran. In this paper, the behavior of three groups of agents: environmentalist, industrialist, and resident are simulated. These three groups are the dominant and influential population in the formation of urban texture. In this research, the behavior of these three groups of agents is specified, according to a series of map layers, such as slope, aspect, soil type, distance of urban areas, roads, and so on. The Belief-Desire-Intention (BDI) architecture of agents is used for the simulation, which is defined based on some variables, functions, and coefficients. The simulation is carried out based on two different interaction scenarios: Rational and Nash-Equilibria. The future urban area is predicted by a combination of MAS and spatial urban area. To evaluate the proposed model, the comparison of the predicted area is made at different times and scenarios. The results of implementation in different scenarios show that the residents of the study area follow the Nash-Equilibria interaction with Kappa Coefficient accuracy of 0.8104.

Keywords: *multi-agent systems, interaction, landscape metrics, Tehran metropolitan area*

Rezumat. Asupra unei proceduri de simulare a extinderii terenurilor urbane pe baza credinței – dorinței – intenției. Studiu de caz: Regiunea Metropolitană Teheran, Iran

Urbanizarea, extinderea ariilor urbane, a avut o dinamică rapidă în ultimele două decenii. Fenomenul afectează procesele aerobiologice, economice, industriale, ecologice, controlul social și familia. Astfel, anticiparea extinderii zonei urbane are rol semnificativ în deciziile municipalității. Sistemul Multi-Agent (MAS) este un instrument bun pentru simularea și modelarea procesului, fiind folosit pentru rezolvarea unor problem spațiale și non-spațiale diverse. În acest articol, MAS este utilizat pentru simularea dinamicii urbane în aria rurală din jurul Teheranului – cel mai mare și dinamic oraș al Iranului. În lucrare se simulează comportamentul a trei grupuri de agenți (ecologist, industrial și rezidențial), aceste grupuri influențând dominnt populația în formarea texturii urbane. Cercetarea urmărește comportamentul acestor grupuri de agenți prin straturi tematice precum panta, aspectul, tipul de sol, distanța la zonele urbane, drumurile etc. Arhitectura agenților credință-dorință-intenție (BDI) este utilizată pentru simulare, aceasta fiind definită pe baza unor variabile, funcții și coeficienți. Simularea se desfășoară pe baza a două scenarii de interacțiune diferite. Viitoarea suprafață urbană este prevăzută prin combinația între MAS și spațiul deținut de oraș. Pentru a evalua modelul propus, compararea zonei previzionate se face pentru momente și prin scenarii diverse. Rezultatele implementării în diferite scenarii arată că rezidenții urmează interacțiunea Nash-Equilibria, coeficientul Kappa fiind de 0,8104.

Cuvinte-cheie: *sisteme multi-agent, interacțiune, parametrii ai peiasajului, aria metropolitană Teheran*

Introduction

Land is the main resource for nearly all people. Land use change is the main theme of global environmental change research (Liu et al., 2014). Land use change is done naturally or man-made. The latter is done for different purposes. The impacts of human activities on the natural environment are becoming more and more pronounced (Szu-Hua Wang, Shu-Li Huang, & William W. Budd, 2012). Land use changes have dramatic effects on aerobiological (García-Mozo, Oteros, & Galán, 2016), economical (Wang, Chen, Shao, Zhang, & Cao, 2012), industrial (Tonini, Hamelin, & Astrup, 2016), ecological processes (Kovács-Hostyánszki et al., 2017), and social control (Wang, He, & Lin, 2018; Weathers et al., 2016).

Urbanization represents a type of land use changes happening in urban land and its surrounding. Worldwide, countries are becoming increasingly urbanized and within a few years, more than 50% of the world population will reside in urban areas (Gül, Gezer, & Kane, 2006).

Urbanization has significant effects on climate, soil, water resources, and grasslands (Valbuena, Bregt, McAlpine, Verburg, & Seabrook, 2010). As the urbanization has noticeable effects on a variety of factors, it represents an important phenomenon. That is why a large area of studies pays attention to this problem, and a great number of researches were done in the field of urbanization (Taleai, 2007). As a result, different models were proposed for urbanization.

Cellular Automata (CA) is a common model used for land use planning, particularly in urbanization (Gong, Yuan, Fan, & Stott, 2015; Rimal, Zhang, Keshtkar, Wang, & Lin, 2017; Wu 2010). In these models, the process of urbanization is defined based on some rules for cells. For example, Berling-Wolff and Wu developed CA to simulate the urban growth of Phoenix, which is in four different types of urban growth - spontaneous, diffusive, organic and road-influenced distinguished (Berling-Wolff & Wu, 2004).

Urbanization is a complex issue and cannot be analyzed with some preliminary rules. On the other side, the urban area's texture is not similar and uniform, so the regular structure of CA cannot be the right tool for solving urbanization problems. For solving the first problem, they often combine CA models with artificial algorithms such as Fuzzy Logic, neural network, Makov chain and so on. (Qiang & Lam, 2015). For instance, in Maria and Gleriani's research, CA simulation was introduced on urban land use change, in which Neural Network has been used to modify the simulation model. Then the model was tested in a medium-sized town (Maria & Gleriani, 2005). The second problem is one of the CA model's weaknesses. Using cells with different dimensions, cells with smaller dimensions and topology relations are recommended as a solution for this issue (Behzadi & Alesheikh, 2014), but, occasionally, the complexity and irregularity of the urban areas are very high and require researchers to look for other methods of simulation (Aburas, Ho, Ramli, & Ash'aari, 2016; Chopard, 2018). Consequently, these shortages made CA ineffective for urban simulation.

MAS is more flexible than CA models (Behzadi & Alesheikh, 2013b). These models do not have any restrictions on the physical structure. The study area is definable for MAS models with any shape and texture. On the other side, this model supports learning capabilities, logical rules, optimization, autonomous, etc. in addition to its common reactive rules. These specifications have recommended the appropriate use of these models for complicated problems (Abar, Theodoropoulos, Lemarinier, & O'Hare, 2017; Michel, Ferber, & Drogoul, 2018; Ringler, Keles, & Fichtner, 2016). In MAS, agents are used to present a group of people and organizations with the same behavior. This means that they act as specific groups in urbanization (A. Ligtenberg, Wachowicz, M., Bregt, AK., Beulens, A., Kettenis, DL, 2004; Guangjin Tian et al., 2016). As a result, the combination of all organizations (agents) decides for the present and future of the urban land. Ligtenberg's research (A. Ligtenberg, Wachowicz, M., Bregt, AK., Beulens, A., Kettenis, DL, 2004) and Tian's study (G. Tian, Ouyang, Quan & Wu, 2011) are samples of using MAS in land use modeling and simulation. In Ligtenberg's study, multi-agent systems are used to simulate land use changes. For the simulation, some multi-decision makers are used in spatial planning to generate spatial scenarios. Tian and his colleagues developed an agent-based model of urban growth for the Phoenix metropolitan region of the United States. In this paper, they simulated the behavior of different groups, such as regional authorities, real estate developers, residents, and environmentalists in the urbanization. The main difference between the current research and previous studies refers to the fact that in this paper special architecture of agent-based models (Belief-Desire-Intention architecture) has been used, which is high in proportion to human behaviors. For this reason, the predicted behaviors by agents are far closer to reality.

In the present paper, a BDI agent-based model is proposed for urban simulation. The simulation of the urban area is done based on different scenarios, among different groups of agents with distinctive behaviors. The following section approaches the study area. In the next section, the conceptual framework of the model is introduced. Then, the model is implemented for simulation. Next, the evaluation of the model is made in the 6th section. Finally, the conclusion is discussed in the last section.

Study area and data

Tehran metropolitan area is the most populated and the fastest-growing city in Iran. It is located in the center of Iran, being characterized by a temperate climate.

During the last decade, Tehran exemplifies urbanization with an underground and overland network from the center and industrial area to the surrounding in west open space. During recent years, Tehran has been changing as the fastest-growing city in Iran, with a population growth rate of 1.84% between 2000 and 2010. More than 90% of the population growth was due to immigration from other cities. Because of physical and geographical barriers in north, east, and south of the city, Tehran is prone to development from the west area. That is the reason for using the west part of Tehran in this Research. The geographical location of the study area is 35° 41′ to 35° 46′ N latitude and 51° 05′ to 51° 18′ E longitude (Fig. 1).

Table 1: Statistical data for the study area

	Year 2000	Year 2010
Number of urban parcels	2442	2618
Urban area	50.98 km²	65.86 km²
Population	> 17000	> 33000

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Required data such as slope, aspect, soil type, urban land, agricultural land, water resource, major road, railway, service area are collected from Tehran's official website (www.tehran.ir). The statistical data for the study area are shown in Table 1.

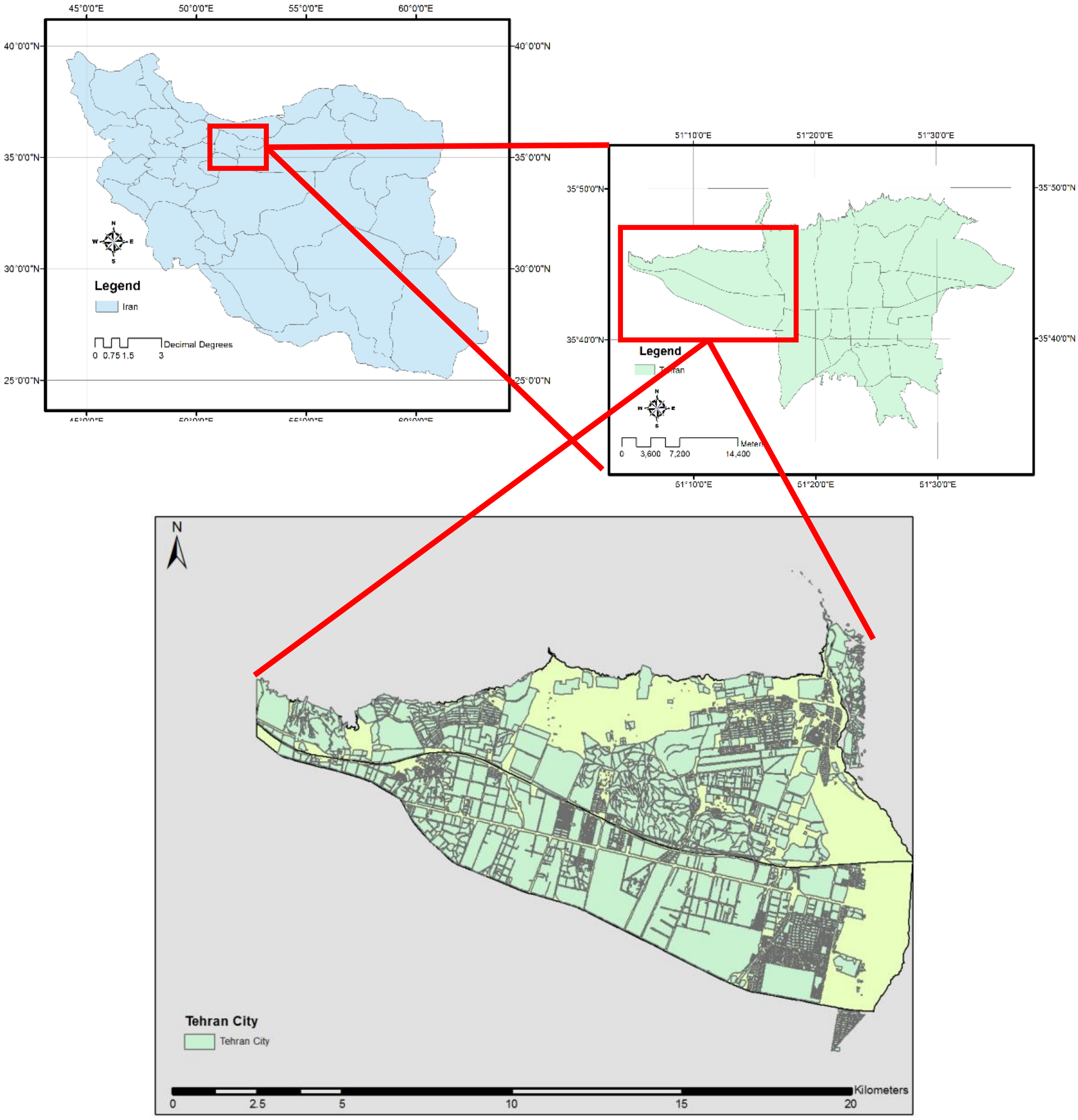

Fig. 1: Case study area (West of Tehran City)

Methodology

A multi-agent system (MAS) is a system composed of multiple interacting agents to solve problems that are difficult or impossible for a monolithic system to solve (Behzadi & Alesheikh, 2013a). In such a framework, an agent is a computer system that is situated in some environment and that is capable of autonomous action in the environment to meet its design objectives (Tweedale et al., 2007; Weiss, 1999; M. a. J. Wooldridge, N. R., 1995; M. J. Wooldridge, 2002). Based on this definition of agents, four classes of architectures were introduced, namely logic-based, reactive, hybrid, and belief-desire-intention (BDI) architectures. The latter has received more attention from scientists than the other ones, due to the implementation of intentional stance, which has been built after the philosophical work of Bratman (Bratman, 1987) and Dennet (Dennett, 1988; Brison, 1989). In BDI architecture, each agent believes the environment, desires what it wants to be true in the environment, and intends to do an action based on its belief and desire (A. Ligtenberg, Beulens, A., Kettenis, D., Bregt, A. K., & Wachowicz, M. , 2009; A. Ligtenberg, Wachowicz, M., Bregt, AK., Beulens, A., Kettenis, DL, 2004). Belief refers to the current state of the environment. Hence, belief is considered by perceiving the spatial and attributive information of the land use map. For example, the type of the land, area, and distance to roads are considered as elements of belief. The objectives of the agent are considered as the desire. For example, environmental protection and industrial development are considered as the desire of the model. Intentions are considered as changes in the environment. The agents make their belief by observing the environment; they make their intentions by adjusting specific weights to their belief. The result displays their desire obtained by implementing the intention on the belief (Relation 1) (Hall, Guo, Davis, & Cegielski, 2005).

$$F(des) = F(bel) \times F(int) \qquad (1)$$

In this article, the agents are considered as a group of individuals with the same behavior. Our model presents three groups of agents with different behavior: environmentalists, industrialists, and residents. Environment, water resources, and soil type for farming are the main factors for the agents from the environmentalist group. So, these parameters are with the highest priorities in the agent's behavior. The economic issues completely affect the behavior of the agents in the industrialist group. Being in the adjacency of the urban area and of the main roads are two fundamental characteristics of the behavior of the industrialist group. The behavior of resident agents is determined by their location and mobility. Adjacency to urban areas and communication networks (railroad and main road) are the highest priorities for resident agents.

The interaction among agents is done based on the payoff table. If we have two agents and T_1, T_2 are two tasks that agents can do, the payoff table is shown as:

		Agent$_1$ T_1	Agent$_1$ T_2
Agent$_2$	T_1	P^1_{T1T1} / P^2_{T1T1}	P^1_{T1T2} / P^2_{T1T2}
	T_2	P^1_{T2T1} / P^2_{T2T1}	P^1_{T2T2} / P^2_{T2T2}

The upper-right value shows the desire values obtain by Agent$_1$, and the lower-left value shows the desire values obtain by Agent$_2$. The interaction is done based on one of the two strategies: *Rational* and *Nash-Equilibria* (Uhrmacher & Weyns, 2009). In the Rational interaction, each agent computes the minimum profit of each intention based on the other agent's intentions, and then it selects the intention of which profit has maximum value among these minimum values. In the Nash-Equilibria interaction, two strategies were followed by agents: 1) under the assumption that agent *i* selects the intention *1*, agent *j* can do no better than the selection of intention *2*, and 2) under the assumption that agent *j* selects the intention *2*, agent *i* can do no better than the selection of intention *1*.

Then, four common landscape metrics (Seto, Fragkias, & Schneider, 2007) are used to evaluate implementation results (McGarigal & Marks, 1995): 1) NP: the total number of urban patches in the area. 2) ED: the total length of all urban patch edge segments per square kilometers. 3) MPS: mean urban patch size. 4) AWMPFD: averages of the fractal dimensions of all patches by weighting larger land cover patches (Equation 2) (G. Tian et al., 2011).

$$AWMPFD = \sum_{i=1}^{n} \frac{2\ln 0.25P_i}{\ln(a_i)} \left(\frac{a_i}{A}\right) \qquad (2),$$

where P_i is the perimeter of patch *i*, a_i is the area of patch *i*, *n* is the number of land patches, and *A* is the total landscape area.

Figure 2 shows the conceptual model of the MAS for the urban development issue. As in this figure, three groups of agents (environmentalist, industrialist, and resident) are inside the model. These agents build their beliefs based on observations of the environment. Then, a set of actions is determined based on their desires. Finally, each agent does its best action on the environment based on its interactions.

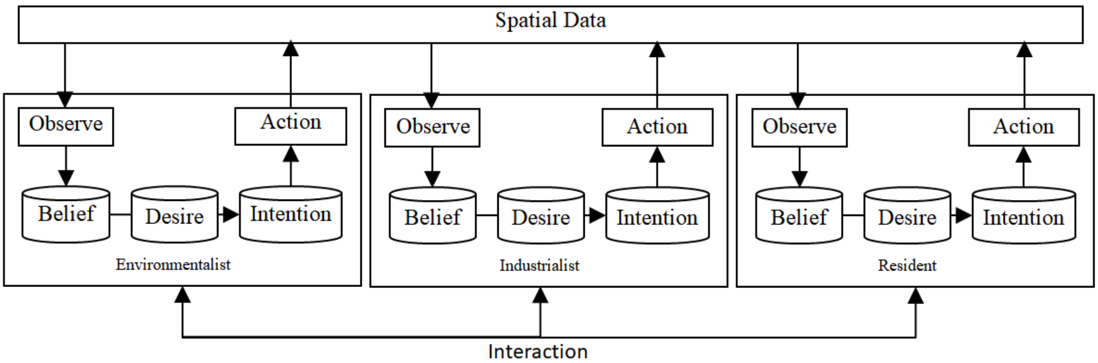

Fig. 2: The conceptual MAS framework for land use processes

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Model implementation

Each parcel represents a small patch of the land with some attributes, such as soil type, topology. The proposed model takes some variables into account, which can affect the land use: neighborhood of urban land, neighborhood of agricultural land, distance to urban land, distance to agricultural land, distance to water resource, distance to major roads, distance to railways, distance to open space, distance to service area. All these variables are considered as the belief of the agent.

In this study, the land use conversion function is defined as:

$$LUC = \sum_{i=1}^{12} \alpha_i Y_i \qquad (3),$$

where Y_i represents the deriving factors, and α_i are corresponding coefficients. The α_i values were obtained by agents through land-use data. Table 2 presents the description of each variable.

Table 2. Description of the variables

Main Variables	Sub Variables	Description
Y_1	$0.5X_1^2 + 4X_1$	slope
Y_2	$0.2\ln(X_2)$	aspect
Y_3	$4X_3^3 + 3X_3^2 + X_3$	soil type
Y_4	X_4	neighborhood of urban land
Y_5	X_5	neighborhood of agricultural land
Y_6	X_6	distance to urban land
Y_7	X_7	distance to agricultural land
Y_8	X_8	distance to water resource
Y_9	X_9	distance to major road
Y_{10}	X_{10}	distance to railway
Y_{11}	X_{11}	distance to open space
Y_{12}	X_{12}	distance to service area

The behavior of agents significantly affects the land-use conversion value, which is represented in the model by changing the coefficients of these factors. The coefficient domains of the variable are represented in Table 3 for each group of agents.

These values are obtained by expertise, based on the importance of each main variable for the specific group. For example, "neighborhood of agricultural land" is the same for the three agent groups (industrialist, environmentalist and resident). Therefore, the range of coefficients of variation associated with the "neighborhood of agricultural land" is assumed to be uniform for these three groups of agents. For environmentalists, "distance to agricultural land" is twice as important as to the other two agents, so its average range of coefficients is more than the other two agents.

Table 3. The coefficient domains of the variable (for each group of agents)

Coefficient domains	Environmentalist	Industrialist	Resident
α_1	[0.10 - 0.15]	[0.0 – 0.10]	[0.0 - 0.5]
α_2	[0.05 - 0.10]	[0.0 - 0.10]	[0.0 - 0.5]
α_3	[0.15 - 0.20]	[0.0 - 0.10]	[0.0 - 0.5]
α_4	[0.0 - 0.5]	[0.10 - 0.15]	[0.5 - 0.10]
α_5	[0.0 - 0.5]	[0.0 - 0.5]	[0.0 - 0.5]
α_6	[0.0 - 0.5]	[0.15 - 0.20]	[0.15 - 0.20]
α_7	[0.5 - 0.10]	[0.0 - 0.5]	[0.0 - 0.5]
α_8	[0.15 - 0.20]	[0.5 - 0.10]	[0.10 - 0.15]
α_9	[0.10 - 0.15]	[0.20 - 0.25]	[0.15 - 0.20]
α_{10}	[0.0 - 0.5]	[0.0 - 0.5]	[0.15 - 0.20]
α_{11}	[0.5 - 0.10]	[0.5 - 0.10]	[0.0 - 0.5]
α_{12}	[0.5 - 0.10]	[0.5 - 0.10]	[0.15 - 0.20]

The coefficient domains directly depend on the behavior of each agent. The land-use type of each patch is considered based on the land-use conversion function's value. The land-use type of each patch is obtained as:

$$\begin{cases} \text{If } 0 \leq \text{land use conversion} < \text{T} & \text{'Urban'} \\ \text{If } \text{T} < \text{land use conversion} \leq 1 & \text{'Agriculture'} \end{cases} \qquad (4)$$

The threshold T is obtained based on the land use data and the interaction among agents. The desire function of each group of agents is obtained as:

$$Desire = \min\left(\sum_{i=1}^{patch\ Number} (LUC_i - LUC^T)^2\right) \qquad (5),$$

where LUC_i is the land-use conversion proposed by the agent for parcel i, and LUC^T is the land-use conversion obtained from the interaction.

Equation 5 shows that the desire of the agent depends on the coefficient value, as well as threshold T. These two sets are the main unknown variables of this problem. The main goal is to find the appropriate values for these two categories of unknown elements, so that the predicted value by agents in 2010 should be the most similar to the actual one.

For each value of the threshold, each agent proposes a set of values for α_i to minimize the desire function. The T value is selected as the best threshold to minimize all agents' desires. As a result, the interaction among agents can obtain the best coefficients for each agent.

Model simulation

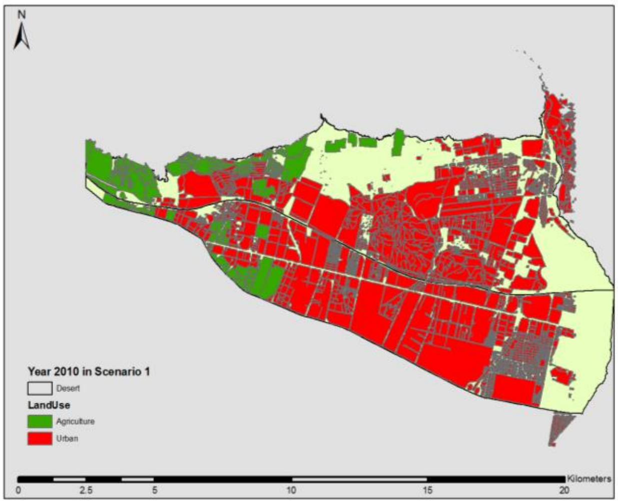
In this paper, two scenarios are designed for simulation analysis. In both scenarios, three agents handle the problem. They compute different values of coefficients for different threshold values to obtain an acceptable desire.

The interaction among agents adjusts the threshold value for obtaining acceptable coefficient values. Once the values are obtained, each agent uses the Equation 3 to find the land use of each patch. The final land use of each patch is obtained based on the combination of three agents' suggestions.

In Scenario 1, the rationality is the interaction strategy. Three defined agents interact based on this strategy. Figure 3 shows the result of the agents' action on the land use map in the years 2010 and 2020 in Scenario 1. Table 4 shows the coefficient of variables suggested by three groups of agents.

Table 4 The coefficient of variables suggested by three groups of agents (Scenario 1)

Coefficient domains	Environmentalist	Industrialist	Resident
α_1	0.10	0.06	0.04
α_2	0.07	0.06	0.04
α_3	0.19	0.06	0.01
α_4	0.02	0.11	0.10
α_5	0.04	0.03	0.02
α_6	0.04	0.16	0.15
α_7	0.07	0.04	0.01
α_8	0.20	0.08	0.12
α_9	0.15	0.21	0.15
α_{10}	0.01	0.03	0.17
α_{11}	0.06	0.08	0.01
α_{12}	0.05	0.08	0.18



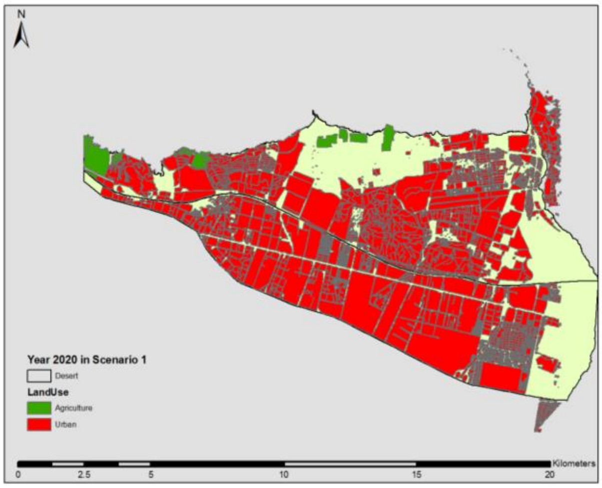
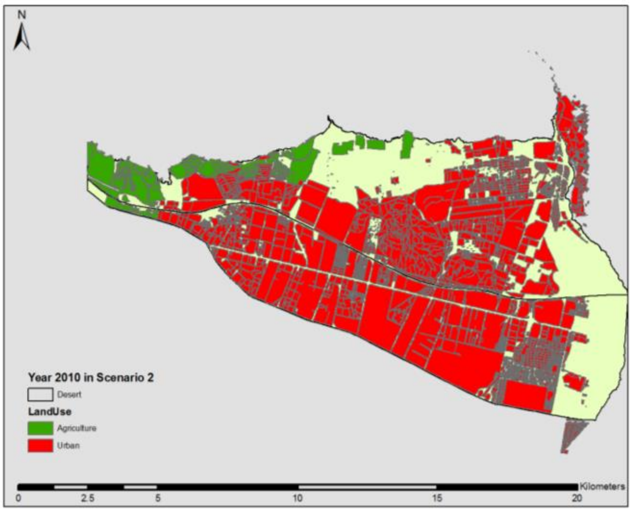


Fig. 3: The result of the agents' action on the land use map in the years 2010 and 2020 in Scenario 1

In Scenario 2, the Nash-Equilibria strategy is used for interaction. Figure 4 shows the result of the agents' action on the land use map in the years 2010 and 2020 in Scenario 2. Table 5 shows the coefficient of variables suggested by three groups of agents.

Table 5 The coefficient of variables suggested by three groups of agents (Scenario 2)

Coefficient domains	Environmentalist	Industrialist	Resident
α_1	0.12	0.03	0.02
α_2	0.10	0.04	0.03
α_3	0.17	0.02	0.01
α_4	0.02	0.15	0.04
α_5	0.03	0.03	0.01
α_6	0.03	0.19	0.20
α_7	0.05	0.03	0.01
α_8	0.18	0.08	0.15
α_9	0.14	0.22	0.18
α_{10}	0.01	0.05	0.18
α_{11}	0.09	0.06	0.01
α_{12}	0.06	0.10	0.15



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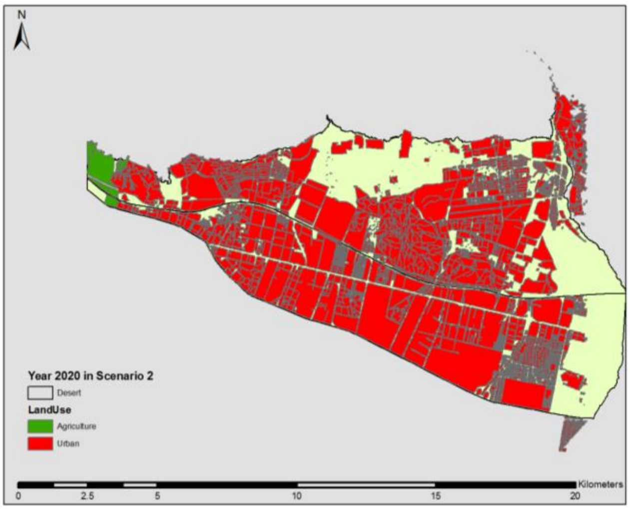


Fig. 4: The result of the agents' action on the land use map in the years 2010 and 2020 in Scenario 2

Model evaluation

Before simulating the two scenarios, the projected result is evaluated with the empirical land use map for 2010, using the Kappa coefficient (Congalton & Green, 1999):

$$Kappa = \frac{P_0 - P_C}{1 - P_C} \quad (6),$$

where P_0 represents the correct percent for the model output, and Pc is the expected percent correct just due to chance.

The Kappa coefficient is computed based on the settings of Scenario 1 (*Rational interaction*), and Scenario 2 (*Nash-Equilibria interaction*). The values of Kappa were 0.7881 and 0.8104 respectively. The model is then simulated to project the land use maps for 2010 and 2020, following the two scenarios.

In 2000, the urban land accounted for 69% of the total area.

Scenario 1 projected that the urban land would reach 86% in 2010, and 96% in 2020 (Fig. 3).

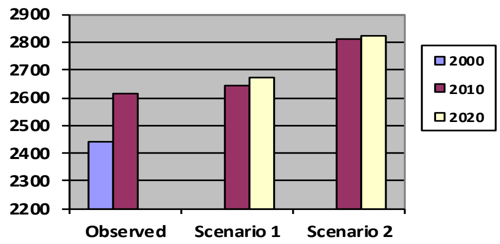
In Scenario 2, urban land would reach 90% in 2010, and 98% in 2020 of the total area (Fig. 4). The urban growth in Scenario 2 is faster than the other one because the industrialist and resident agents have more flexibility with the environmentalist agent in interaction.

To compare the simulated results in detail, four criteria of landscape metrics are used. These factors are used to quantify the urbanization in the west of the city.

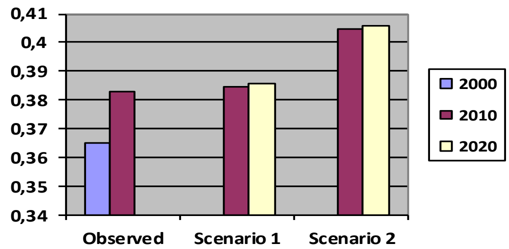
From the simulation results (Fig. 5), the values of NP, ED, and MPS for the two scenarios improve dramatically from 2000 to 2010.

The increase of NP value shows the urban growth. The increase of MPS value shows the emergence of the new small urban areas that we have expected in 2020. The increase of ED value shows the dispersion of the urban patches.

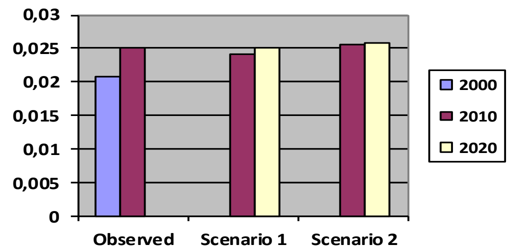
Firstly, from 2000 to 2010, the value of AWMPFD goes down and then (from 2010 to 2020) it goes up in both Scenario 1 and Scenario 2. In both scenarios, the AWMPFD values go down at first. This fact shows the regularity of patch shapes from 2000 to 2010. However, the values of AWMPFD for both scenarios decline dramatically from 2010 to 2020. This second dynamics shows that the shapes of patches are made irregularly.



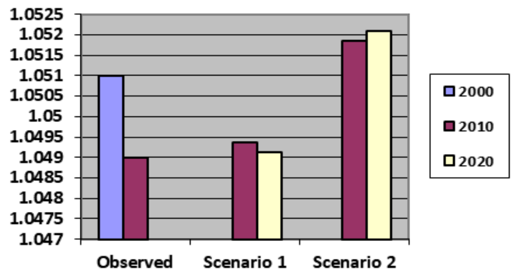
a) number of urban patches (NP)



b) urban edge density (ED)



c) mean urban patch size (MPS)



d) area weighted mean patch fractal dimension (AWMPFD)

Fig. 5: Results of prediction among the two different scenarios for 2000, 2010, and 2020

Conclusion

Nowadays, the use of simulation has made it easier for decision-makers to predict the behavior of the environment. As a result, they make better decisions. In this study, one of the main issues of Tehran city management was investigated. Since MAS represents a model that can simulate human behavior better, it was used for identifying people's behavior in the city. The flexibility of this model and its adaptation to the complexity of the urban context were other reasons for using it instead of previous models, such as CA. In this study, three types of agents (environmentalist, industrialist, and resident) were identified as the main decision-makers. The behavior of these agents was modeled as a series of formulas. These agents were simulated based on two scenarios of *Rational* and *Nash-Equilibria* interactions. The implementation results show that residents have Nash-Equilibria interaction behavior, and this has 81% similarity to Nash-Equilibria behavior interaction. This result has been reached from comparing the obtained maps of Nash-Equilibria interaction and the reality in 2010. The paper evaluates four criteria of landscape metrics to assess the quality of the results. The results show that the surface of urban land in the study area has grown significantly in 2020. This reflects urban growth in the region.

The values in the MPS diagram show that the probability of creating settlements in this area is very low and somehow impossible and the city of Tehran will have only the urban development in the mentioned area. The values in the ED diagram indicate that there is a possibility of urban land use scattering in the area, which reflects the behavior of urban development in the area. The results obtained from the AWMPFD diagram show that the growth behavior of the western area of Tehran is completely irregular.

In summing up the results of this section, it can be said that urban development behavior in this area is carried out without the supervision of the relevant organizations, and this development is carried out by the residents of the city sporadically. The lack of a definite structure in this development is one of the prominent characteristics that can be mentioned. The present study was based on data available in 2000 and 2010. The large time difference between the data can be one of the weaknesses of this study, which is inevitable due to the ten years of data updating from the municipality. The existence of more data certainly had a significant impact on improving the results, but in the present study, ground observations at present can confirm the model's accuracy, as the Kappa Coefficient indicates this.

In this article, the urban simulation is done by MAS. However, the main groups of decision-makers (environmentalists, industrialists, and residents) are introduced here. To simulate the urbanization completely, the other miner groups of agents are needed to be defined in the model. The behavior of the new groups must be defined based on the coefficients domain. Moreover, twelve essential variables of urbanization are discussed in the present paper. However, considering the other variables will make the model more realistic.

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Romanian born population residing in Hungary, 2011-2017

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Abstract

Foreign citizens began to immigrate to Hungary following its democratic transformation. Ethnicity had a decisive role during this period: mostly people with Hungarian nationality arrived. Later, following Hungary's accession to the European Union, global trends had an impact on the Hungarian migration networks: Hungary's migratory source extended, and it was able to attract foreign citizens from greater distances.
Thus, two levels of international migration to Hungary are markedly separated: the impact of global migration and the movements from the countries of the Carpathian Basin to Hungary. Within Europe, the primary weight of neighbouring countries is linked to cross-border linguistic and culture relations. International migration to Hungary is characterised by short distances, and the majority of the immigrant population has Hungarian nationality or is native speaker of Hungarian.
Most immigrants to Hungary are arriving from Romania, so the aim of the article is to analyse the social, economic and demographic characteristics of the migrants according to their areas of birth.
Migration flows between the two countries have been territorially concentrated; one quarter of the movements between 2011 and 2017 took place between Central Hungary and the Central Romanian Development Region. In the choice of the new place of residence, in addition to the economic centre areas border regions also play an important role, which can partly be explained by the phenomenon of circular migration, and partly by the easier interaction with those family members who have remained home.

Keywords: *international migration, Romania, spatial statistics*

Rezumat. Cetățenii născuți pe teritoriul României cu domiciliul actual în Ungaria, în perioada 2011-2017

Cetățenii străini au început să imigreze în Ungaria în urma transformării sale democratice. Etnia a avut un rol decisiv în această perioadă: au sosit mai ales oameni cu naționalitate maghiară. Ulterior, în urma aderării Ungariei la Uniunea Europeană, tendințele globale au avut un impact asupra rețelelor de migrație maghiare: sursa migratorie a Ungariei s-a extins și a fost capabilă să atragă cetățeni străini la distanțe mai mari.
Astfel, se disting două niveluri cauzale ale migrației internaționale către Ungaria: impactul migrației globale și deplasările din țările din bazinul carpatic spre Ungaria. În Europa, ponderea principală a țărilor vecine este legată de afinitățile transfrontaliere de natură lingvistică și culturală. Migrația internațională din Ungaria se caracterizează prin predominanța distanțelor scurte, iar majoritatea populației imigrante are naționalitate maghiară sau vorbește nativ limba maghiară.
Cei mai mulți imigranți din Ungaria sosesc din România, astfel încât obiectivul este analizarea caracteristicilor sociale, economice și demografice ale migranților în funcție de zonele lor de naștere. Fluxurile migratorii între cele două țări au fost concentrate spațial; un sfert din mișcările cuprinse între 2011 și 2017 au avut loc între Ungaria Centrală și Regiunea de Dezvoltare Centru din România. În alegerea noului loc de reședință, pe lângă centrele de mare importanță economică, regiunile de frontieră joacă și ele un rol important, fapt care poate fi, în parte, explicat prin fenomenul migrației circulare, dar și prin interacțiunea mai lesnicioasă cu acei membri ai familiei care au rămas acasă.

Cuvinte-cheie: *migrație internațională, România, statistică spațială*

Introduction

On a global scale, Hungary is a country hosting non-typical international migrants. On the one hand, in terms of the volume of migration, its share to the total population is significantly lower than that in the large receiver countries; on the other hand, the global trends of world's migration have only a lesser impact.

Hungary continues to be the target destination for Europeans: international movements of short distance are more typical. Within Europe, the primary weight of neighbouring countries is linked to cross-border linguistic and culture relations. The consequences of World War I and World War II are still determining migration flows within the Carpathian Basin. Most immigrants to Hungary arrive from Romania, so the aim of the article is to present the social, economic and demographic characteristics of the migrants and their impact to the source and destination areas. The analysis will address in detail the regional and local level exploration of outward migration areas of those arriving from Romania and the links between the emigration and current residences.

Data and methodology

In the analysis, the 2011 and 2017 stock data of Hungarian databases were used, which are relevant to the topic: personal data and address records, records on foreigners of the Immigration and Asylum Office, population census data, microcensus. A part of the data basis for the analysis were not directly accessible[1], specific classifications were needed to assess territorial effects. The mapping of source areas of international migrations allows a deeper understanding of the migration flows in the Carpathian Basin.

Both types of data sources (administrative and census type data) contain information that are missing from the other (e.g. data on educational attainment and economic activity are available from the microcensus, but are not part of the register of the Ministry of Interior, while settlements of birth are included in the administrative database). It was therefore necessary to link the two datasets[2]. To do so, a multi-step key system was applied by using gender, year of birth and month, the name of the Hungarian settlement, name of the public place and the house number. Where it was necessary, there was applied the ratio estimation method.

For the 2011 data, the administrative data were linked to the population census data (this is the source of official statistics in the reference year of the population census), while for the year 2017, the information from the register of the Ministry of Interior was used (for the years between population censuses administrative records are used as official statistics).

International migrants in Hungary

Foreign citizens began to immigrate to Hungary after its democratic transformation. During this period, ethnicity had a decisive role, as people with Hungarian nationality arrived predominantly (Tóth, 2005). Later, following Hungary's accession to the European Union, global trends had an impact on the Hungarian migration networks (Rédei, 2009): Hungary's migratory source extended, as it attracted foreign citizens from greater distances. Foreigners residing in Hungary had a total of 175 different nationalities in 2017. The proportion of foreigners arriving from Europe was steadily decreasing: while in 1995, 89% of the foreigners arrived from our continent, this rate reduced to 65% by 2017. At the same time, on global scale, Hungary cannot be considered as a typical receiver country. The volume of migration and its proportion compared to the population is significantly lower than that in large receiver countries, on the other hand the global trends of world migration (Hatton and Williamson, 2005) have only a lesser impact. Hungary (albeit to a diminishing extent) remains a target for Europeans and rather short distance international movements are characteristic (Dövényi, 2011).

Table 1. Foreign-born Hungarian citizens and foreign citizens by country, in 2011 and 2017

Citizenship/ Country of birth	2011			2017		
	Foreign citizens	Foreign-born Hungarians	Foreign-linked population, total	Foreign citizens	Foreign-born Hungarians	Foreign-linked population, total
Romania	38,574	139,093	177,667	24,040	182,387	206,427
Slovakia	8,246	25,195	33,441	9,519	17,376	26,895
Austria	3,936	2,897	6,833	4,021	7,102	11,123
EU28	***85,414***	***183,761***	***269,175***	***76,270***	***248,524***	***324,794***
Ukraine	11,820	23,953	35,773	5,774	59,272	65,046
Serbia	7,752	21,306	29,058	2,312	37,497	39,809
Total Europe	**112,522**	**237,785**	**350,307**	**99,194**	**350,756**	**449,950**
Total Asia	**22,304**	**4,760**	**27,064**	**39,937**	**6,539**	**46,476**
Total America	**4,743**	**3,785**	**8,528**	**5,397**	**9,149**	**14,546**
Total Africa	**2,853**	**1,190**	**4,043**	**5,985**	**2,398**	**8,383**
Total Australia	**775**	**360**	**1,135**	**619**	**1,284**	**1,903**
Total	**143,197**	**247,870**	**391,067**	**151,132**	**370,126**	**521,258**

[1] One example: Székelyhidegkút (Vidăcutu Român in Romanian, Kaltenbrunnen in German) a former village in today's Romania, Harghita County. It was born by the unification of Magyarhidegkút (Vidacutul Unguresc in Romanian) and Oláhhidegkút in 1926. Today it is part of the settlement Hidegkút (Vidăcut in Romanian), a village in Romania, in Harghita County and belongs administratively to Székelyandrásfalva (Săcel in Romanian).

[2] Mr. Marcell Kovács, director of the Population Census and Demographic Statistics Department, Ms. Zita Ináncsi and Mr. János Novák, experts of the aforementioned department have provided essential assistance to this work. I am grateful for their contribution.

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Between 2011 and 2017, the number of foreign citizens in Hungary increased by 5.5%, from 143,197 to 151,132. For example, in 2017 due to the global migration trends, more Chinese than Romanian citizens resided in Budapest. However, while analysing the impact and volume of immigration we cannot neglect the impacts of naturalisation: the foreign-born Hungarian citizens who already live in Hungary. Their number is significantly higher than that of foreign citizens. Within this group, the weight of foreign citizens is steadily decreasing: from 37% in 2011 to 29% in 2017.

In 2017, the proportion of foreign-linked population residing in Hungary was higher than 5% of the total population (Table 1). The majority of the naturalised people arrived from the neighbouring countries. In 2017, the total number of Romanian-linked population (Romanian citizens and Hungarian citizens born in Romania) residing in Hungary was in total 206,427 people.

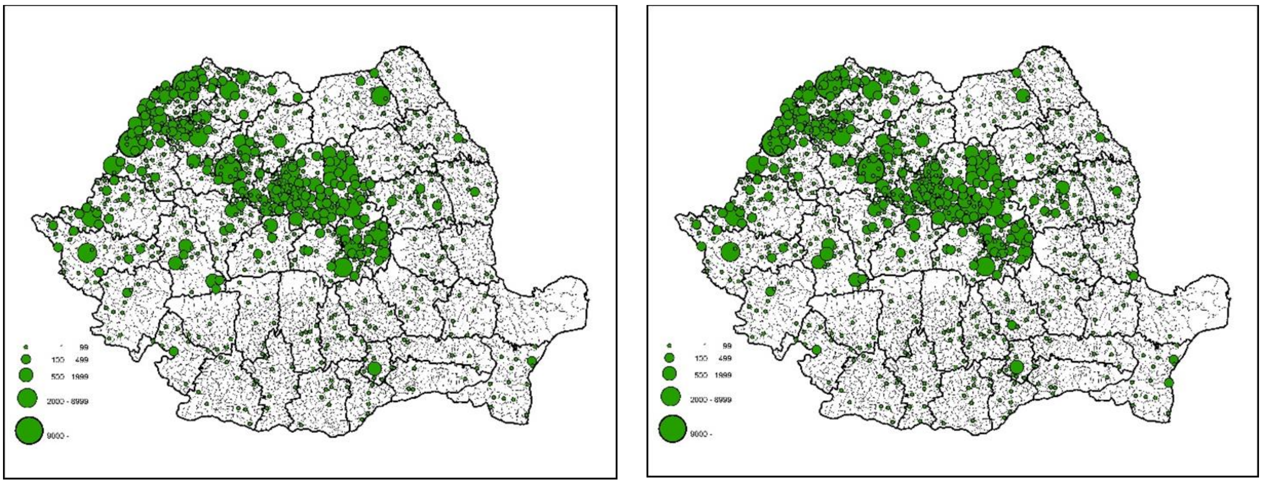
Results and discussions

Romanian source areas of the emigration to Hungary

The largest ethnic Hungarian population outside Hungary lives in Romania. In 1992, 7.1% of Romania's population, in 2002-6.6%, while in 2011-6.5% of Hungarians declared Hungarian nationality. The proportion of Hungarians in Transylvania, Partium and Banat is 19%. More than half of the Hungarian community in Romania lives in Central Development Region. In Romania, outside Transylvania, a significant number of Hungarians live in Bacău and Iași counties and Bucharest (Kapitány, 2015; Kincses, 2015). Nationality has for a long time been an important factor in the characteristics of international migrations between the two countries. The Hungarian peculiarity of international migration is the significant ethnic migration. The strength of cross-border linguistic and cultural relations is primarily the consequence of the peace treaties of World War I and World War II. This determinism is constantly decreasing, but it is still decisive.

The Orthodox-majority Romanian community was under-represented in the migration processes before 1990 (Brubaker, 1998). Based on the findings of the Romanian migration sociology and demography, the Romanian migrant population has at least in 90% comprised Romani ethnics (Sandu, 2000). While for the Hungarian ethnics from Romania Hungary is the main destination, it is more important for Romanians to have employment opportunities in Italy and Spain. That is to say, Romania, a source country of migration as a whole, is characterised by shifting migration towards Western Europe. Ethnicity has a decreasing role in the development of migration networks (Gödri, 2007); migration is organised not only on the basis of nationality, but also on personal relations.

Romanian-Hungarian migration relations are traditionally strong. According to the data of 2017, some 206,000 people from Romania have settled in Hungary, of which 182,000 have already acquired Hungarian citizenship, with a 16% increase since 2011. The process covered 30% of the Romanian and 84% of the Hungarian settlements. Therefore, we can witness strong regional influences.



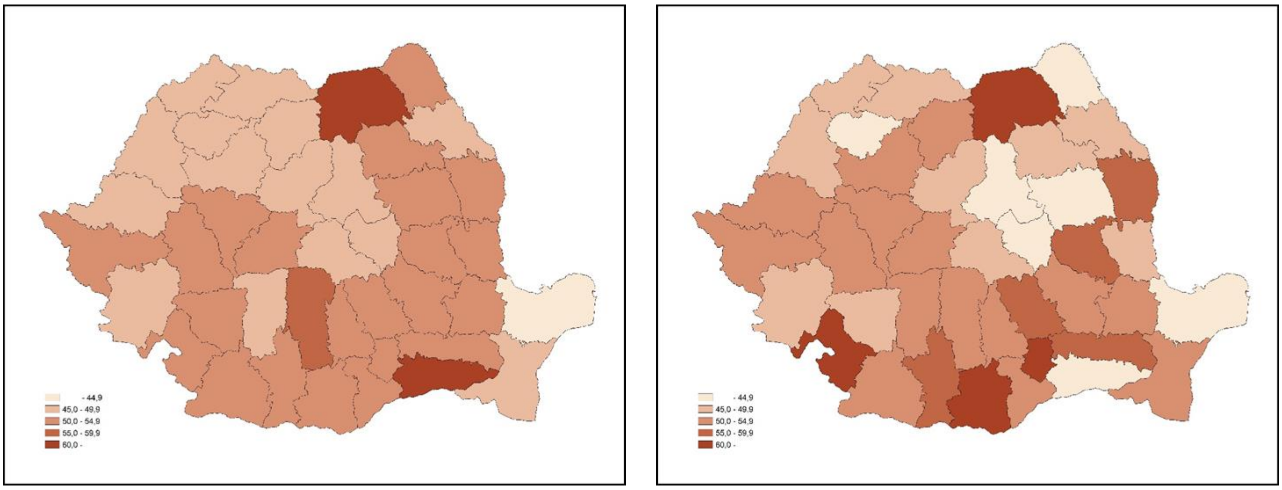
2011 **2017**

Figure 1: Population with Romanian attachment residing in Hungary by the settlement of emigration (2011 and 2017)

Hereinafter authors will study those Romanian citizens who live in Hungary together with the Romanian-born Hungarian citizens. The most affected Romanian settlements by the emigration to Hungary are: Târgu Mureș (in 2017, there were 19,758 citizens living in Hungary who were born in Târgu Mureş, Romania), Oradea (17,760 persons), Cluj-Napoca (14,052 persons), Satu Mare (11,444 persons), Odorheiu Secuiesc (9,509 persons), Miercurea Ciuc (8584 persons), Sfântu Gheorghe (7,376 persons), Gheorgheni (5,551 persons) Târgu Jiu (4,649), and Arad (4,486 persons). The most affected counties are Harghita (35,613 persons), Mures (32,433 persons), Bihor (31,587 persons), Satu Mare (20,075 persons), Cluj (19,540 persons), Covasna (17,021 persons). A significant number of Hungarian minorities live in these areas.

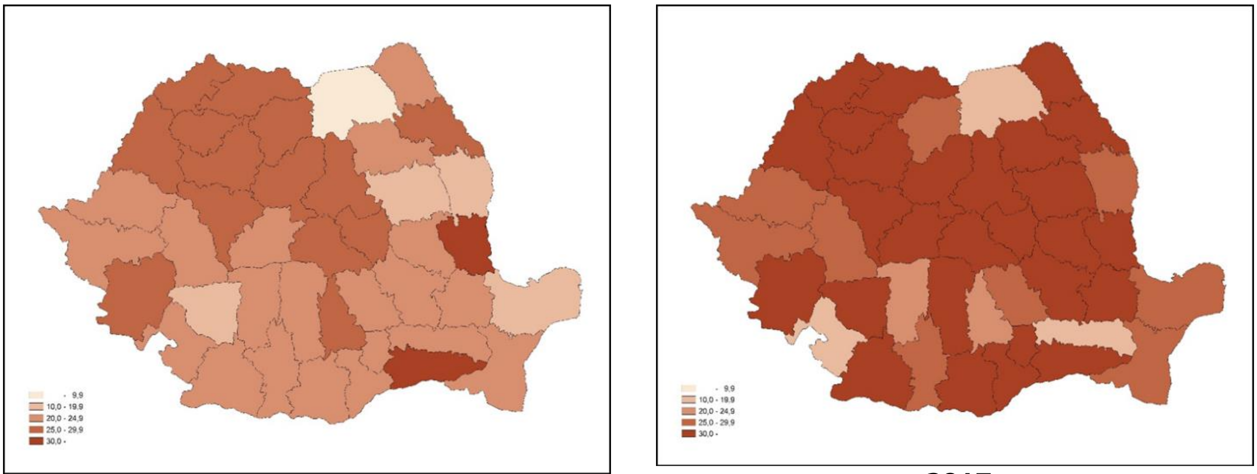
The demographic and labour market characteristics of the Romanian born population

The average age of the Romanian population residing in Hungary decreased from 47.5 years to 46.1 between 2011 and 2017, but is still higher than the relevant value of the resident population (41.2 years in 2011 and 41.6 in 2017). The average age of people originating from outside Transylvania in Romania is the highest, at county level it exceeds 50 years in many cases (Fig. 2). The reason for that, however, is not the old age migration, but the mobility of many people of working age and migration of few young people. Most young people arrive from counties near the border, as well as from Harghita, Mures and Covasna counties. The ratio of the working population, aged 25 to 64, is the highest for those coming from Transylvania. It is also generally true that there are more retired people and young people among those who were born near the border, while working age in more typical for people born in more distant regions.



2011 **2017**

Figure 2: Population with Romanian attachment residing in Hungary by average age and regions of birth (2011 and 2017)



2011 **2017**

Figure 3: Population aged 25 years and over with Romanian attachment residing in Hungary by higher educational attainment and regions of birth (2011 and 2017)

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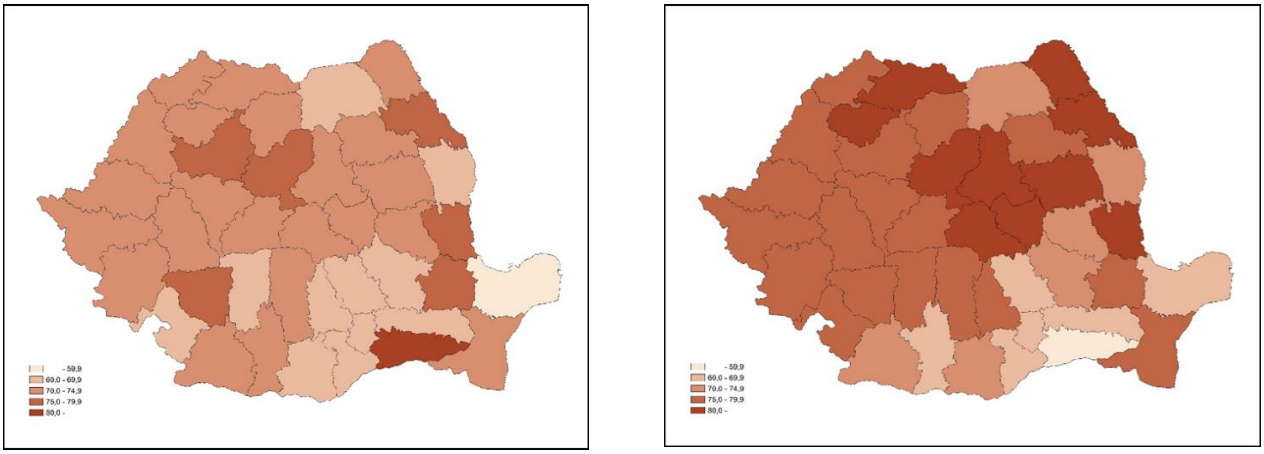
The educational attainment of Romanian-linked citizens residing in Hungary (Fig. 3) is higher than the average of the Hungarian resident population: in 2011, 25.6% of this population had higher education, while in 2017 it augmented to 32% (in 2017 22.8% of the Hungarian resident population had higher education, compared to 38.1% of the total foreign linked population). The educational attainment of Romanian people residing in Hungary is steadily increasing (just as that of the Hungarian resident population), while there are no large territorial differences in the distribution of qualifications according to source regions.

The several decades old rule that the potential impact area of migration is increasing according to the educational attainment seems to fall (Rédei, 2007). In fact, nowadays people with lower educational attainment share a similar proportion in longer distance migration than in shorter distance movements.

Educational attainment has a decisive impact on labour market characteristics, too (Fig. 4). The employment rate of the Romanian-linked population aged between 25-64 years and residing in Hungary was 80.1% in 2017. The similar data of the Hungarian resident population was 75.1%, while it was 80.2% of all foreign citizens of the same age group. The proportion of people coming from close to the border areas remains below that of those arriving from the more internal areas, which can be stemmed from the differences of the age structure. In case of employment, differences among counties are weaker than in case of educational attainment.

According to the regions of birth, employment rates are the highest in Romanian regions away from the border, which can partly be linked to higher values of educational attainment.



2011 **2017**

Figure 4: The employment rate of the population aged 25 years and over with Romanian attachment residing in Hungary by regions of birth

In this section, the relations between the place of birth and current place of residence of the Romanian born population residing in Hungary are analysed at NUTS3 level, based on stock data of 2017. The result is the matrix of migration from the 41 Romanian counties and Bucharest to the 19 Hungarian counties and Budapest, which presents significant concentrations. Highlighting the regions that effect more than 0.5% of the total migration, a much narrower group is realised. This way, in 4.3% of all matrix cells (42*20=840) (36 county pairs) 60.5% of the migrations were concentrated in 2017, meaning that the spatial distribution of migrations showed a strong concentration.

Central Hungary was the most attractive for those arriving from the Central Romanian Development Region, one quarter of the movements taking place between these two regions. Five percent of all migrations from Romania to Hungary has been realized between Harghita County and Budapest, while 4.8% between Mureș County and the Hungarian capital city.

Border areas are also of great importance, partly due to the phenomenon of circular migration (Fercsik, 2008; Illés and Kincses, 2009) and partly due to the easier interaction with family members who remained home (Rédei, 2007). Intense flows can be detected between neighbouring counties (Anderson and O'Down, 1999; Baranyi and Balcsók, 2004; Hansen, 1977; Van Geenhuizen and Ratti, 2001). The movements between Bihor and Hajdú-Bihar (3.4%), Satu-Mare and Szabolcs-Szatmár-Bereg (2.2%), Bihor and Békés (1.2%) and Arad and Békés (0.9%) were the most important.

In the choice of the new place of residence, border areas play also an important role alongside the economic centre areas, but they are rather local destinations offering an attracting place of establishment for those who arrive from the other side of the border.

Table 2. The ratio (%) of major migration flows between Romania and Hungary at county level*, 2017

Region of birth		Region of current place of residence										
In Hungarian	**In Romanian**	**Budapest**	**Pest**	**Fejér**	**Veszprém**	**Győr-M-S**	**Borsod-A-Z**	**Hajdú-B**	**Szabolcs-Sz-B**	**Bács-K**	**Békés**	**Csongrád**
Arad	Arad	0,52	0,53	0,07	0,05	0,07	0,06	0,08	0,02	0,07	0,87	0,37
Hunyad	Hunedoara	0,63	0,36	0,09	0,11	0,07	0,05	0,06	0,05	0,12	0,07	0,06
Bihar	Bihor	3,23	2,53	0,83	0,47	0,49	0,34	3,41	0,29	0,37	1,16	0,42
Kolozs	Cluj	3,45	2,32	0,47	0,43	0,28	0,18	0,35	0,15	0,27	0,17	0,16
Máramaros	Maramureș	0,65	0,48	0,18	0,19	0,08	0,07	0,15	0,21	0,06	0,05	0,04
Szatmár	Satu Mare	1,99	1,90	0,28	0,27	0,29	0,30	1,09	2,20	0,21	0,15	0,14
Szilágy	Salaj	1,18	1,05	0,19	0,08	0,14	0,08	0,35	0,15	0,12	0,12	0,09
Brassó	Brașov	0,58	0,43	0,05	0,04	0,08	0,03	0,07	0,03	0,14	0,05	0,07
Kovászna	Covasna	2,31	2,05	0,43	0,44	0,36	0,08	0,15	0,07	0,86	0,17	0,16
Hargita	Harghita	5,23	4,32	0,63	0,91	0,73	0,55	0,43	0,26	0,95	0,32	0,58
Maros	Mureș	4,76	4,42	0,60	0,35	0,63	0,27	0,37	0,17	0,79	0,30	0,70

* 100% means the total of persons born in Romania, residing in Hungary

Budapest and Pest County, as Hungarian economic centre areas, attract people from a greater distance (Rédei, 2009; Soltész et al., 2014), most non-European foreigners living here. The Hungarian capital city hosts almost half of the foreigners residing in Hungary, while also being attractive for Romanian emigrants.

Thus, the region of Central Hungary (Budapest and Pest county) is the preferred target destination for the more mobile population of working age (Siposné et al., 2017), with higher educational attainment, in a leadership position, as well as for the autochthon population (Szirmai, 2011). In case of shorter geographical distances and movements close to the border area, the educational attainment and occupations of migrants are more diversified, but there are no major differences in their economic activity compared to that of migrants of longer distance.

Table 3. The ratio (%) of major migration flows between Romania and Hungary among those with tertiary educational attainment at county level, 2017**

Region of birth		Region of current place of residence										
In Hungarian	**In Romanian**	**Budapest**	**Pest**	**Fejér**	**Veszprém**	**Győr-M-S**	**Borsod-A-Z**	**Hajdú-B**	**Szabolcs-Sz-B**	**Bács-K**	**Békés**	**Csongrád**
Bákó	Bacău	0,61	0,28	0,31	0,01	0,01	0,00	0,03	0,02	0,20	0,02	0,03
Arad	Arad	0,63	0,49	0,05	0,04	0,05	0,05	0,07	0,02	0,04	0,43	0,33
Hunyad	Hunedoara	0,75	0,34	0,10	0,11	0,05	0,04	0,06	0,02	0,09	0,05	0,04
Temes	Timiș	0,53	0,27	0,02	0,02	0,04	0,02	0,06	0,02	0,04	0,04	0,29
Bihar	Bihor	4,53	2,23	0,73	0,41	0,45	0,28	3,38	0,18	0,27	0,77	0,39
Kolozs	Cluj	4,71	2,21	0,43	0,36	0,19	0,16	0,34	0,10	0,25	0,13	0,15
Máramaros	Maramureș	0,93	0,49	0,14	0,22	0,07	0,06	0,17	0,17	0,06	0,03	0,03
Szatmár	Satu Mare	2,68	1,81	0,19	0,25	0,30	0,31	1,25	1,71	0,13	0,07	0,18
Szilágy	Sălaj	1,59	1,17	0,21	0,05	0,11	0,07	0,38	0,08	0,07	0,08	0,10
Brassó	Brașov	0,77	0,32	0,03	0,03	0,08	0,02	0,05	0,02	0,15	0,04	0,06
Kovászna	Covasna	3,23	2,05	0,38	0,46	0,24	0,06	0,16	0,06	0,81	0,10	0,16
Hargita	Harghita	7,25	4,21	0,46	0,74	0,59	0,54	0,42	0,18	0,63	0,23	0,56
Maros	Mureș	6,63	4,10	0,49	0,28	0,47	0,21	0,38	0,16	0,63	0,19	0,65

** 100% means the total of persons born in Romania, residing in Hungary with higher education

Table 4. The ratio (%) of major migration flows between Romania and Hungary among employed persons at county level*, 2017**

Region of birth		Region of current place of residence										
In Hungarian	**In Romanian**	**Budapest**	**Pest**	**Fejér**	**Veszprém**	**Győr-M-S**	**Borsod-A-Z**	**Hajdú-B**	**Szabolcs-Sz-B**	**Bács-K**	**Békés**	**Csongrád**
Bákó	Bacău	0,53	0,35	0,33	0,01	0,02	0,01	0,02	0,01	0,28	0,04	0,04
Arad	Arad	0,39	0,53	0,05	0,04	0,06	0,05	0,05	0,02	0,06	0,72	0,35
Hunyad	Hunedoara	0,67	0,36	0,09	0,12	0,06	0,03	0,05	0,03	0,15	0,05	0,06
Bihar	Bihor	3,37	2,59	0,94	0,54	0,51	0,31	3,15	0,28	0,35	1,07	0,42
Kolozs	Cluj	3,42	2,29	0,48	0,47	0,27	0,15	0,29	0,12	0,27	0,15	0,13
Máramaros	Maramureș	0,69	0,48	0,19	0,24	0,08	0,06	0,14	0,22	0,06	0,04	0,03
Szatmár	Satu Mare	2,05	1,97	0,26	0,31	0,29	0,26	1,00	2,07	0,18	0,13	0,13
Szilágy	Sălaj	1,31	1,10	0,21	0,08	0,11	0,07	0,38	0,15	0,13	0,11	0,09
Brassó	Brașov	0,61	0,47	0,05	0,04	0,09	0,01	0,07	0,02	0,16	0,05	0,06
Kovászna	Covasna	2,52	2,25	0,50	0,56	0,35	0,07	0,14	0,07	1,04	0,14	0,15
Hargita	Harghita	5,72	4,63	0,62	1,15	0,73	0,64	0,40	0,23	0,88	0,28	0,59
Maros	Mureș	5,28	4,99	0,61	0,36	0,59	0,24	0,34	0,17	0,80	0,26	0,76

*** 100% means the total of employed persons born in Romania, residing in Hungary

Conclusion

Two levels of international migration to Hungary are standed outseparately: the impact of global migration and the movements from the countries of the Carpathian Basin to Hungary. The Hungarian characteristic of international migration is that the majority of the immigrant population has Hungarian nationality or is Hungarian native speaker. Hungary is the target destination mainly for Europeans, international movements of short distance are more typical. Romania has a prominent role, with most people coming to Hungary. In 2017, the total number of Romanian-linked population (Romanian citizens and Hungarian citizens born in Romania) residing in Hungary totalled 206,427 persons.

The number of foreign citizens immigrating to Hungary began to grow after the democratic transformation. During this period mainly ethnicity had a decisive role, an overwhelming majority of people with Hungarian nationality arriving. Later, following Hungary's accession to the European Union, global trends had an impact on the Hungarian migration networks: Hungary's migratory source area extended, it was able to attract foreign citizens from greater distances. In 2017, foreigners residing in Hungary were born in 175 different countries. International migrants account for more than 5% of the resident population. The consequence of the peace treaties of World War I and World War II still play a vital role in the migration flows of Hungary, as it is demonstrated by the fact that the number of people born in Romania is the highest among the foreign-bound population.

Migration flows between the two countries were territorially concentrated, one quarter of the movements taking place between Central Hungary and the Central Romanian Development Region. Some 5% of all migrations from Romania to Hungary has been realized between Harghita County and Budapest, and Mureș County respectively.

The location of destination areas also has a decisive role. In addition to the economic centre areas, border regions also play an important role in the choice of the new place of residence, which can partly be explained by the phenomenon of circular migration, partly by the easier interaction with the family members who have remained home. With respect to the movements between neighbouring counties, the most intense ones were between Bihor and Hajdú-Bihar, Satu-Mare and Szabolcs-Szatmár-Bereg, Bihor and Békés and Arad and Békés.

Budapest is the Hungarian area which is a constant destination for the Romanian born people, even in case of larger geographical distances. Thus, the Central Hungarian region is the target destination for those of working-age, with higher educational attainment and working in a leadership position. In case of shorter geographical distances and movements close to the border area the educational attainment and occupations of migrants are more diversified, but there are no major differences in their economic activity compared to that of migrants of longer distance.

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Estimating the tourist carrying capacity for protected areas. A case study for Natura 2000 sites from North-Western Romania

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Abstract

The estimation of the tourist support capacity for three Natura 2000 sites located in North-Westerm Romania and the appropriate use of a quantitative methodology adapted to the current working techniques are the main objectives of this scientific approach. In this respect, parameters were determined for obtaining the physical carrying capacity, then the resulting value was modified by the coefficients related to the correction factors. They also consider CAV_NDVI, a factor reflecting the abundance of vegetation and the value of the NDVI spectral index at pixel level, used to quantify the state of vegetation health, as a measure of the ecological status of the sites. The obtained results highlight the sensitivity of the algorithms used for the correction factors and the possibilities of converting these results into elements with practical possibilities for the sustainable sites management.

Keywords: *Tourism Carrying Capacity - TCC, Physical Carrying Capacity - PCC, Real Carrying Capacity -RCC, Linear Spectral Unmixing - LSU, Normalized Difference Vegetation Index - NDVI*

Rezumat. Estimarea capacității turistice de suport pentru situri Natura 2000. Studiu de caz din NV României

Estimarea capacității turistice de suport pentru trei situri Natura 2000 din NV României și utilizarea adecvată a unei metodologii cantitative adaptată tehnicilor de lucru actuale reprezintă obiectivele principale ale acestui demers științific. În acest sens, s-au determinat parametri pentru obținerea capacității fizice de suport, după care valoarea rezultată a fost modificată prin coeficienții aferenți factorilor de corecție. În cadrul lor a fost introdus și CAV_NDVI, factor ce reflectă abundența vegetației și valoarea indicelui spectral NDVI la nivel de pixel, prin care cuantificăm starea de sănătate a vegetației, ca măsură a stării ecologice a siturilor. Rezultatele obținute indică senzitivitatea algoritmilor utilizați la coeficienții factorilor de corecție și posibilitățile de conversie ale acestor rezultate în elemente cu valențe practice pentru gestionarea sustenabilă a siturilor.

Cuvinte-cheie: *capacitate turistică de suport - TCC, capacitate de suport fizică - PCC, capacitate de suport reală - RCC; analiză spectrală liniară - LSU, indicele normalizat de diferențiere a vegetației -NDVI*

Introduction

The statements that render in many ways the idea that the global development of tourism with its dual valences of economic activity and social act asserts an even greater strain on the terrestrial or maritime protected natural areas, represent already introductory patterns found in a lot of papers, studies, articles and special reports (Coccossis et al., 2002, Salerno et al., 2013, Weber et al., 2017).

Actually, these statements with postulate value express a reality noticed since the '30s, but especially after WW2, when the first worrying signs related to the rapid growth of outdoor recreation tourism and the degradation of the natural elements of the environment appeared (Butler, 1996, Whittaker et al., 2011).

Naturally, as the dichotomous aspect of this reality exacerbates, in the sense of raising the economic benefits for the stakeholders on the one hand, and declining the quality of the environmental factors in the protected areas on the other hand, we have conceived working techniques and methods to help us evaluate the qualitative and quantitative limits regarding the degree of tourist capacity supported by an area, without being irreversibly affected in a negative way.

Thus, beginning with the '60s, the concept of carrying capacity debated rigorously by Wagar, în 1964 (Lime and Stankey, 1971; Manning, 2002) has been coined and implemented in the management of tourist activities within national parks worldwide.

From land protected natural areas (Cifuentes, 1992, Amador et al., 1996, Cifuentes et al., 1999, Somarriba-Chang et al., 2006, Segrado et al., 2008, Viñals et al., 2014, Queiroz et al., 2014), to coastline areas with seaside tourism (Zacarias et al., 2011, Jurado et al., 2012, Jurado et al., 2013) and up to underwater trails in maritime protected areas (Ríos-Jara et al., 2013, Cupul-Magaña and Rodríguez-Troncoso, 2017), all of them have been the subject of a number of laborious studies targeting the estimation of tourist carrying capacity.

We have made this brief presentation to point out the present scientific framework, clearly dialectic, but extremely fertile in terms of knowledge, of this segment of tourist carrying capacity worldwide. In Romania, where according to governmental data (Romanian Government, 2019) the natural protected areas (including Natura 2000 sites) cover 23% of its total area, the concept of tourist carrying capacity entered quite late in the academic literature with more theoretical approaches (Dumbrăveanu, 2004, Erdeli and Gheorghilaș, 2006), and as regards its effective implementation in projects, even much later, after 2010, these being rather few. For example, between 2012 and 2014, there was the project called Evaluating the carrying capacity for visitor management in protected areas. Case study: Danube Delta Biosphere Reserve, as part of ”DANUBEPARKS STEP 2.0 - Anchoring the Danube River Network of Protected Areas as Platform for Preservation of Danube Natural Heritage” project, and currently an application called ”Monitoring system of the ecological carrying capacity” on the site of the National Institute for Research and Development in Tourism (http://smcse.incdt.ro/index.pl/home_ro) is being implemented as a result of a project run by the aforementioned institute.

The main objectives of this study are:

- estimating the physical and real tourist support capacity for the Natura 2000 Sites: Cefa, Valea Roșie and Ferice Plai;
- adapting a classical quantitative methodology to current working techniques;
- identifying correction factors that also meet the needs of the protected areas to maintain
- them in a dynamic environmental balance;
- modeling these factors so that they can be integrated into the standard methodology;
- their partial validation on the three analyzed areas.

Study Area

This research paper focuses on 3 Natura 2000 sites (Sites of Community Importance - SCI): Cefa, Ferice Plai and Valea Roșie (Fig. 1).

Cefa (code ROSCI0025) is located in the Lower Crişurilor Plain from north-west Romania, in the Bihor County, is by far the largest protected area, with 5224 ha (http://natura2000.eea.europa.eu), while Valea Roșie Natura 2000 site (ROSCI0267) is the smallest, with only 786.7 ha (http://natura2000.eea.europa.eu) within the Western Hills, while the Ferice Plai have (code ROSCI0084) 1993 ha.

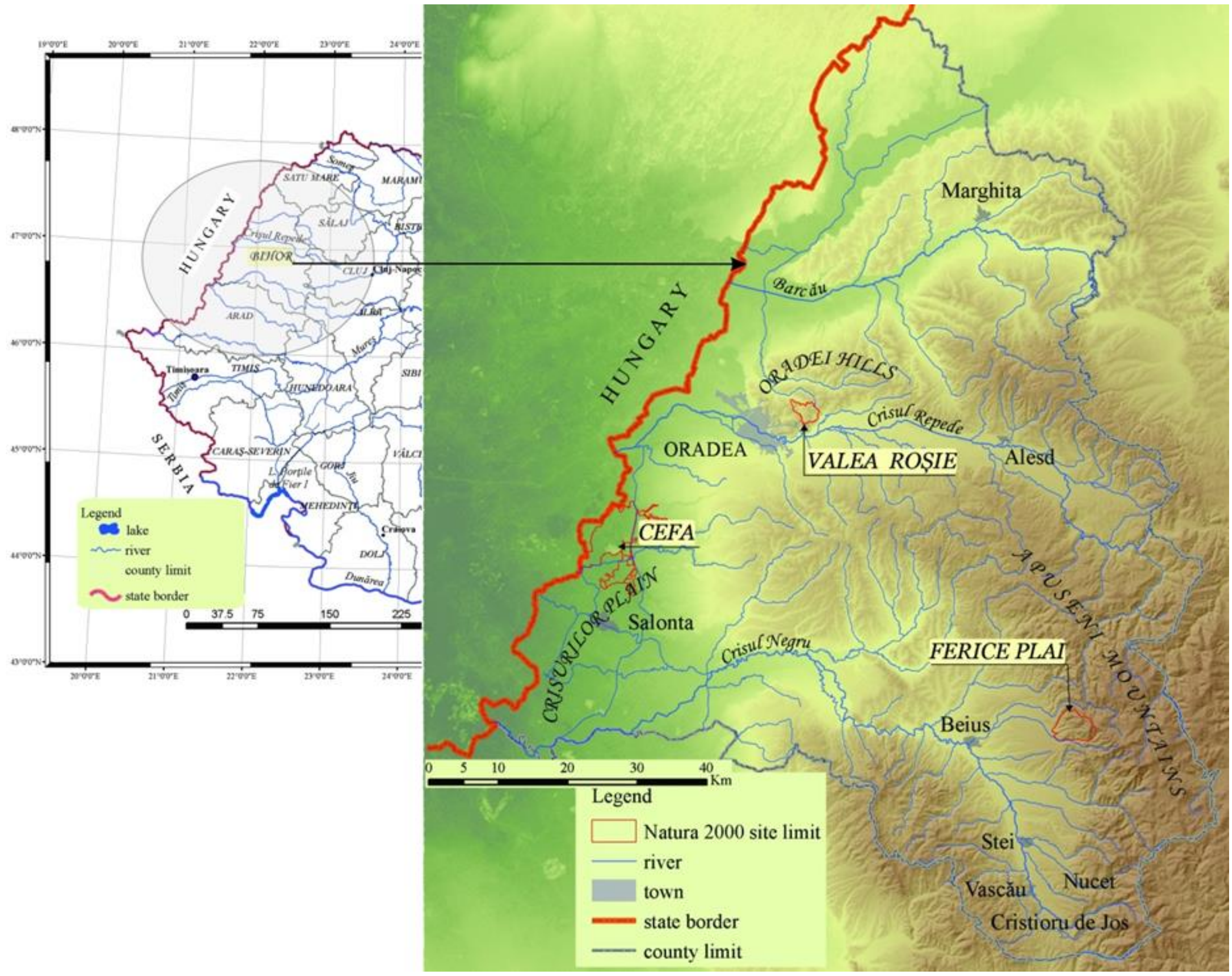

Fig. 1: Study area location

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Methods

The working methodology of this present study is based on standard working techniques to quantitatively estimate the tourism carrying capacity (TCC) in protected areas, and satellite data processing techniques.

Most of the papers in the academic literature that deal with this problem (Segrado et al., 2008; Zacarias et al., 2011; Lagmoj et al., 2013; Queiroz et al., 2014; Viñals et al., 2014) mention and/or use Cifuentens' methodology (1992), internalized and adopted by Ceballos-Lascuráin (1996). Nevertheless, we must state that, as early as 1986, Boullón (quoted by Shackley, 1996; Viñals et al., 2014) publishes a calculation formula for carrying capacity similar to the one of Cifuentes, except that it is not expressed on the three levels (physical, real, effective) become classical in the tourism research.

Hence, after Boullón (1986), the carrying capacity is expressed in the following manner:

$$CC = \frac{area\ used\ by\ tourists}{average\ individual\ standard} \times R_f$$

R_f - rotation coefficient

$$R_f = \frac{No.of\ daily\ hours\ area\ is\ open\ for\ tourists}{Average\ duration\ of\ visits}$$

Our modus operandi is based on Cifuentes' methodology (1992, 1996), with the suggested proper changes, that will be presented throughout the paper.

As we stated above, it demands an approach on three levels of accuracy and complexity regarding the indicator in discussion, with adaptations of the limiting factors taken into consideration (elements that reduce the carrying capacity), according to the local specific aspects of the analysed sites.

From our point of view, the reporting criteria for such an undertaking must also be determined from the start:

- type/form of tourism for which we carry out the estimation;
- essential elements with tourist value in area for the type of tourism taken into consideration.

We state all these because, in many of the protected nature sites, the landscape endmember variety is incredibly large, but, in general, for a particular type of tourism, only a few sets of component are relevant.

For the Natura 2000 sites considered in this study (Cefa, Valea Roșie, Ferice Plai), we selected two endmembers, vegetation and water, that we consider essential for the type of targeted tourist activity, namely hiking. Clearly, this does not mean that the rest of the tourist resources are completely ignored within the study area.

Physical Carrying Capacity (PCC)

It refers to the maximum number of tourists that can be on the area of the nature site, where the public access is allowed, in a determined time frame.

$$PCC = \frac{A}{A_u} \times R_f$$

A - available area for public use;
A_u - area available per user;
R_f - rotation factor (number of visits/day).

Real Carrying Capacity (RCC)

It is obtained by modifying the value obtained for PCC, based on some indices calculated for the so-called correction factors (correction factor, cf1, cf2 etc.):

$$RCC = PCC \times (cf_1 \times cf_2 \times cf_3 \times \dots cf_3)$$

The correction factors come off from the specific environmental, biophysical, social attributes of the sites, with local adaptations for each territory and type of tourism taken in consideration, in the sense that for their expression those natural and/or social elements are considered that limit the tourist activity.

For example, Amador et al. (1996) use as correction factors: erodibility, accessibility, precipitations, sunshine duration, floods, temporary closing of the site, while Figueras et al. (2011) use: social factor, precipitations, sunshine, wind, and Somarriba-Chang et al. (2006) take Cifuentes correction factors, eliminating sunshine duration and rains.

Their mathematical expression is the following:

$$C_{fx} = 1 - \frac{Ml_x}{Mt_x}$$

C_f - correction factor for variable x;
Ml_x - limiting magnitude of variable x;
Mt_x - total magnitude of variable x.

Effective Carrying Capacity (ECC)

The value of the RCC is corrected by a coefficient defined by a factor that takes into account the available managerial capacity, infrastructure related to the tourist facilities (trails, equipment), the qualified staff provided to the tourists, the financial investments, the regulations of the legal entities in the studied areas. There is no such infrastructure for the three Natura 2000 sites, not even legal regulations (management plans) are not finalized, so that the actual support capacity is equivalent to the real carrying capacity.

Results and Discussion

Physical Carrying Capacity (PCC)

The estimation of PCC implies, as can be seen from the corresponding formula, to obtain the values for A (available area for public use), Au (area available per user) and RF (rotation factor).

Naturally, A (area for tourist activities) can be easily obtained from the management documentations of Natura 2000 sites, and if there are no restrictions, it can be determined based on the distribution of the tourist resources taken in consideration, according to the tourist activity that we are interested in.

In Romania, however, there are situations where the management plans of the sites are on the anvil, therefore getting some official data of this kind is impossible. This is also the case of two out of the three protected areas that we previously presented (excepting Cefa, for which the existing documentation mentions a functional internal zonation, but which is not restrictive for hiking, as form of tourism).

Under these conditions, we determined the value of A based on the distribution of the two categories of components that we selected, with attributes of tourist resource (vegetation, water).

The effective way of extracting (A – ha) the area available for tourists in this study is based on a multispectral image processing technique, Linear Spectral Unmixing, by which the abundance, at pixel level, of the material geographic elements from an area is obtained. The term abundance must be understood as the participatory percentage share of an endmember on a predetermined area (for example, a value of 0,7 for the forest element indicates that 70% from the surface of a cell/pixel is occupied by this element). Other details concerning the Linear Spectral Unmixing will be offered throughout the presentation of the methodology for Real Carrying Capacity.

To validate the results, we used common techniques of vectorizing the ways of land use on orthophotoplans (1:5000, 2012), corrected on high resolution multispectral images (Pleiades, 2014, 160 cm resolution for Blue, Green, Red and NIR, respectively 40 cm for panchromatic, https://spacedata.copernicus.eu) and verified in field.

In fact, real problems concerning A appear in the case of Cefa site, because of the heterogeneousness of the land cover (Fig. 2).

And this is the reason why we also used LSU (the main reason for using LSU reside in the correction factors applied for RCC) for highlighting the compact areas occupied by water and forest vegetation (Fig. 3). Of the 5224 ha of Cefa site, according to the site's documentation and GIS data (http://www.mmediu.ro.articol/date-gis),the touristic value (estimated by summing up the rasters that express the abundance of vegetation and water) has 1027 ha, of which the area that can be used by tourists (A, resulted from the exclusion of the areas occupied by water) is of 232,35 ha (Fig. 3).

In Valea Roșie and Ferice Plai, the share of forest areas exceeds 90% (92.41% for Ferice Plai, 94.42% for Valea Roșie, according to the evaluation reports of the anthropic impact for the two sites in the year of 2016), thus their areas can be tantamout to the values of A.

Au (area available per user) is most often understood as the area used by a tourist (a group of tourists can also be taken into consideration, but then we must intervene with the distance between the groups as correction factor) so that he feels comfortable, which also implies the requirement of not intersecting with other persons or groups. In Cifuentes' methodology from 1992, it is expressed as a report (V/a), that has the value of 1, in the sense that it is considered that a tourist needs 1 m2 to move freely, value adopted by other studies too.

Ultimately, the value of Au depends on the type of tourist activity which we refer to. For example, Lagmoj et al. (2013) consider that, for an ecotourism recreation activity of 4 hours in a forest that has 19247 m2, a person needs 10 m2, while Queiroz et al. (2014) use the value of 1 m2 for estimating the carrying capacity in I-le Azore, at level of tourist routes.

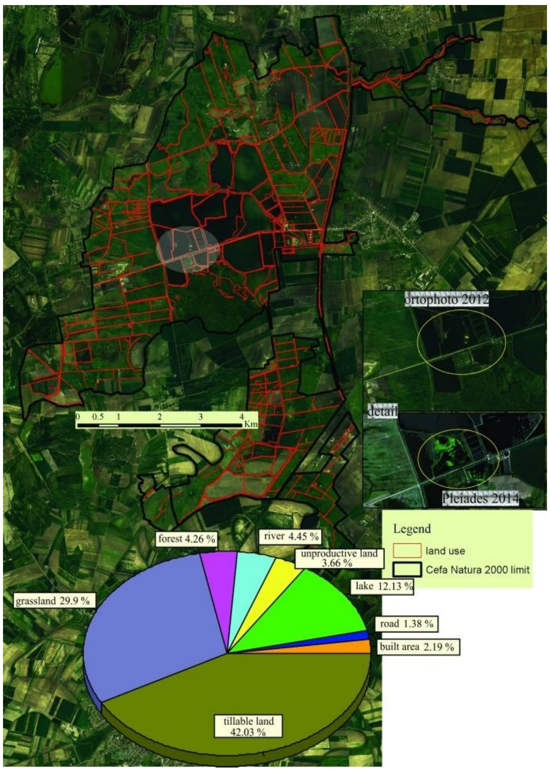

Fig. 2: Cefa Natura 2000 site. Land use (data sources: Ortophoto 2012, Pleiades 2014)

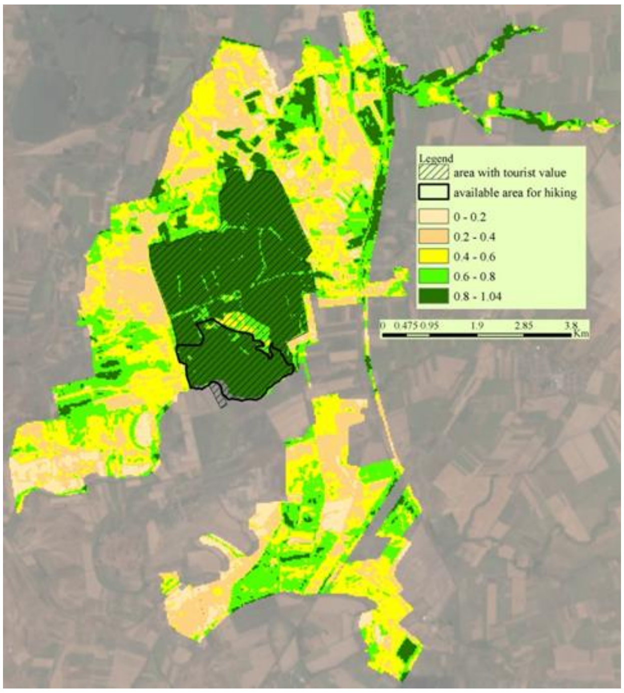

Fig. 3: Cefa Natura 2000 site. Sum for vegetation and water fraction images (background data source: Landsat 8 OLI 2014)

In Romania, the norm of space for walks in forests without visiting infrastructure, according to the National Tourism Research and Development Institute is 0.01 ha/person, that is also the space that a person needs for fishing or a walking in the park (http://smcse.incdt.ro/index.pl/ctsm_ro), a situation we cannot agree with, even considering the simple premise that hiking involves the movement of a person on a particular route. That is why we consider that a minimum value of 0.09 ha (900 m2, 30 * 30 m) is acceptable, in order to respect the principle of non-interference with other people.

R_f (rotation factor) is expressed as a report between the period of time when the site or tourist objective is open for public and the average duration of hiking:

$$R_f = \frac{open\ period}{average\ time\ of\ hiking}$$

Because in the case of the three protected areas there are not visiting hours established by the administration, the value of open period was obtained by averaging the monthly values of the daylight duration during a year, in the west of Romania (Table 1), based on the data from the ”Admiral Vasile Urseanu” Astronomical Observatory.

For this study, the average duration of a hiking is considered to be 4 h, after consultation with the persons from the administration of sites (custodians).

The results for Physical Carrying Capacity (Table 2) for the three sites surveyed indicate, as expected, higher values in the Valea Roşie and Ferice Plai sites, even if their total area is smaller than the Cefa site, because the area available to the public is important, which we have interpreted as an area of touristic value.

Although they appear to have high values (at Ferice Plai and the Valea Roșie), they actually indicate a maximum situation, which is the base for the actual estimation of the number of tourists, that can be supported by those areas, so that these sites are not affected by irreversible changes in the quality of the environmental factors.

Table 1: Average daylight duration in the west of Romania

J	F	M	A	M	J	J	A	S	O	N	D	Year
8,5	10,4	11,3	13,5	14,8	15,81	15,32	14,2	12	11,12	9,4	8,44	12,1

(Data source: http://www.astro-urseanu.ro)

Table 2: Physical Carrying Capacity

Site name	Total area (ha)	A - Available area for public use (ha)	A_u - Area available per user (ha)	R_F - Rotation Factor	PCC (visits/day)
Cefa	5268	232,45	0,09	3,025	7809
Valea Roșie	819	819	0,09	3,025	27527
Ferice Plai	1997	1997	0,09	3,025	67121

We mention that in the scenarios that take into account that 1 m2 (Au), from Cifuentes' initial methodology, the figures for the PCC are much higher, therefore even hypothetically these being unacceptable.

Real Carrying Capacity (RCC)

The correction factors used to obtain RCC are:

- vegetation abundance at pixel level;
- NDVI (Normalized Difference Vegetation Index);
- average number of days with frost;
- number of days with rains ≥0,1 mm;
- accessibility.

We consider necessary some explanations with value of argument for using the first two factors, which, in fact, are indices derived from the processing of satellite date in software packages for remote sensing.

By inserting them in a methodology of this kind, we wanted to quantify the qualitative environmental (health) state of the protected nature areas and thus to correct the value of TCC not only by indices that appeal to the tourist's need of comfort, but also by factors that take note of the possibilities of ecological carrying for sites. Parenthetically, this does not mean that TCC becomes a „Physico-ecological carrying capacity" (Zacarias et al., 2011), it remains a way (mean) of expressing the carrying capacity for a certain type of tourist activity, but indexed (corrected) by indices with ecological value.

As a matter of fact, in the academic community it is also known the much debated problem of unidirectional quantitative approach of TCC, stressing more the tourist's needs and less or not at all the needs of the protected areas, with suggestions of new methodologies, of which some with a descriptive character, but such debates do not make the object of this study.

Regarding the methodology of obtaining the first two factors of correction (vegetation abundance – VA and NDVI), we mention that these will be combined, at the end resulting an index that expresses the health state of the vegetation in a certain period of time.

In this regard, we used Landsat 8 OLI/TIRS multispectral satellite scenes of medium resolution from the year of 2014 (for NDVI, scenes from the months of March, June and August; and for LSU, scenes from the month of June), taken from https://earthexplorer.usgs.gov/ and applied standard operations of pre-processing in ENVI 5.3, respectively radiometric calibration and atmospheric correction, pointing out that for Landsat 8 OLI, according to the recommendation from Yale University, Center for Earth Observation (), it is possible to go directly to conversion from DN (digital number) into reflectance (ToA – Top of Atmosphere Reflectance). For atmospheric correction (a necessary operation to go from ToA to Surface Reflectance), we used Dark Subtraction and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes – FLAASH methods, comparatively. If the FLAASH module is used, a rescaling of the resulted raster will be necessary, because by this work flow implemented in ENVI, the final data are multiplied with the value of 1000 (Envi HELP), and the data stored in the reflectance raster must be between 0 and 1.

Linear Spectral Unmixing (LSU), as reflectance processing technique for highlighting vegetation abundance/pixel, is based on the principle that each pixel from an image consists of the spectral signature of several endmembers, and each pixel contributes individually to its configuration, thus being perceived separately by the remote sensing sensors (Adams et al., 1995).

The essential aspect of this undertaking, of which the quality of the final result depends, has to do with identifying and determining the spectral endmembers taken into consideration, with value of endmember (de Asis et al., 2007; Meusburger et al., 2010). The notion of endmember must be understood as a material endmember (area or type of land cover) that has a unique spectral signature.

The ground rule is that the number of endmembers to be smaller than the number of spectral bands of the spectral image that was used (ENVI EX User`s Guide).

We used five endmembers: water, vegetation, bare soil, built-up areas and roads. The spectral endmember (Fig. 4) was extracted directly from the calibrated satellite image (reflectance), previously being selected the pixels considered to be pure as regards composition, using Pixel Purity Index (PPI) from ENVI, followed by a close pixel evaluation, for which we used orthophoplans and spectral images of high resolution.

The data stored in the multispectral product that resulted must be comprised between the values of 0 and 1, having the significance that we already mentioned.

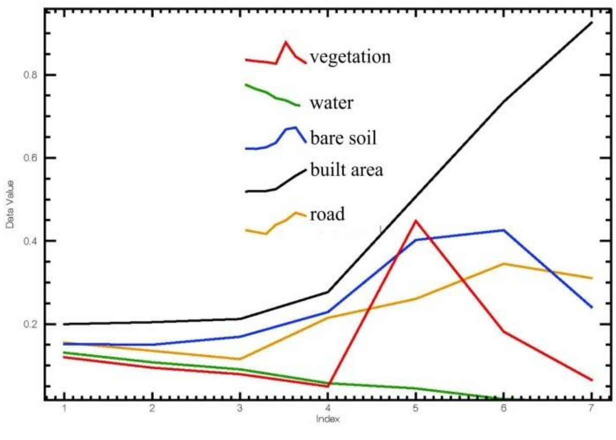

Fig. 4: Spectra for endmembers

4NDVI (Normalized Difference Vegetation Index) falls into the category of spectral indices that

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express the vegetation vigour and consistency, being known that the green plants (with chlorophyll) absorb radiation from the red domain and reflect radiation from the near infrared domain (Bannari et al., 1995).

Conceived by Rouse et al. (1973), it is one of the indices with the largest applicability in research, from evaluating and monitoring the ecological state of different vegetal associations (Pettorelli et al., 2011) to estimating the C factor from the universal equation of soil erosion (Van der Knijff et al., 2000; Lin et al., 2002), probably because of its simplicity too, as algorithmic way and processing technique.

$$NDVI = \frac{NIR - RED}{NIR + RED} = \frac{B_5 - B_4}{B_5 + B_4}\ (for\ Landsat\ 8\ OLI)$$

Its values are comprised between +1 and −1, and their interpretation is simple: the closer the values are to 1, the higher the vegetation vigour is, and its health state is better. On the contrary, low values indicate a precarious state of vegetal cover. Figures very close to 0 show that there is no vegetation, while the negative ones point to the presence of water. If temporal series of multispectral images are used (we used only three scenes), the results can be then averaged, which we did.

Evidently, interpreting values implies determining some thresholds for class delimitation, which means a good knowledge of the field, as well as a result checking based on some samples of high resolution satellite or aerial images.

The combination of the two factors expressed spatially and alphanumerically, by a simple operation of multiplication (VA * NDVI) in the Raster Calculator of ArcGIS, after they were previously exported in grid format from ENVI, permitted a correction as regards PCC with an index resulted from the real situation of the ground of the three sites (Fig. 5, 6, 7).

For the actual calculation of this index, that we shall name it CAV_NDVI, the rationale of the steps is the following:

- the operation of classifying/reclassifying data is executed, undertaking that involves determining values – threshold, according to the endmember reality of each site;
- for determining MI the class with the lowest values is taken into consideration, because this threshold expresses spatially and numerically the territory of site where vegetation has a weak consistency;
- the class with negative values and tantamount to 0 is not taken into consideration, because it identifies with water areas.

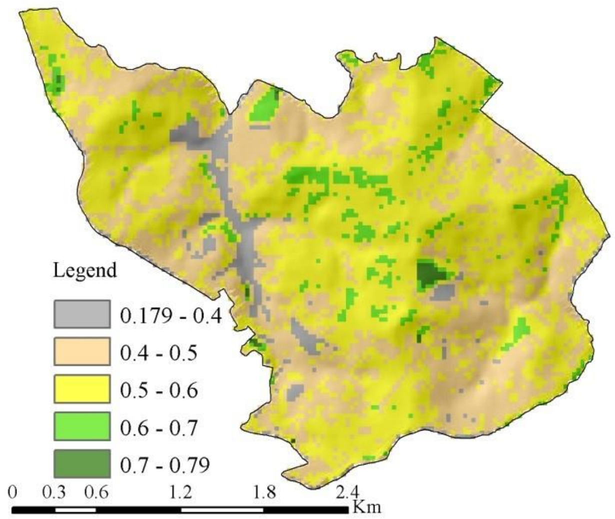

Fig. 5: ***VA*NDVI*** **for Valea Roșie site**

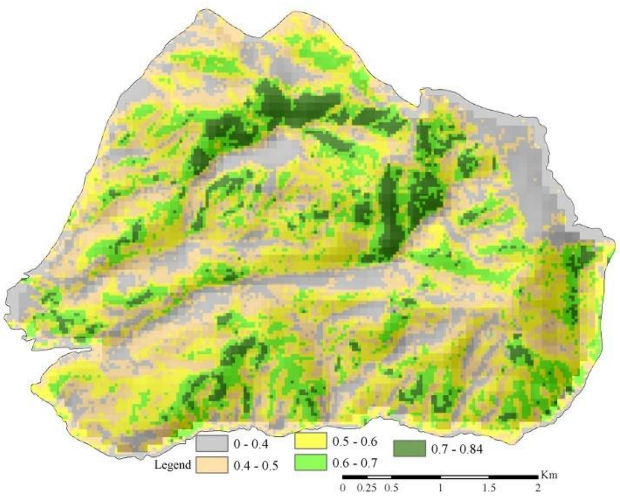

Fig. 6: ***VA*NDVI*** **for Ferice Plai site**

Forward, the way of obtaining CAV_NDVI integrates in the operational flow of standard methodology, i.e. we extracted the surface of the inferior class (e.g., for Cefa the class is [0,01 - 0,2]), relates to the surface of the site, and the resulted value is used for obtaining the correction index (Table 3):

$$C_{AV\_NDVI} = 1 - \frac{S_i}{S_t}$$

Si – surface of the class with inferior values;
St – total surface of the site;

Table 3: C_{AV_NDVI} values

Site Name	S_i (ha)	S_t (ha)	C_{AV_NDVI}
Cefa	3304	5268	0,37
Valea Roșie	37,68	819	0,95
Ferice Plai	371,79	1997	0,81

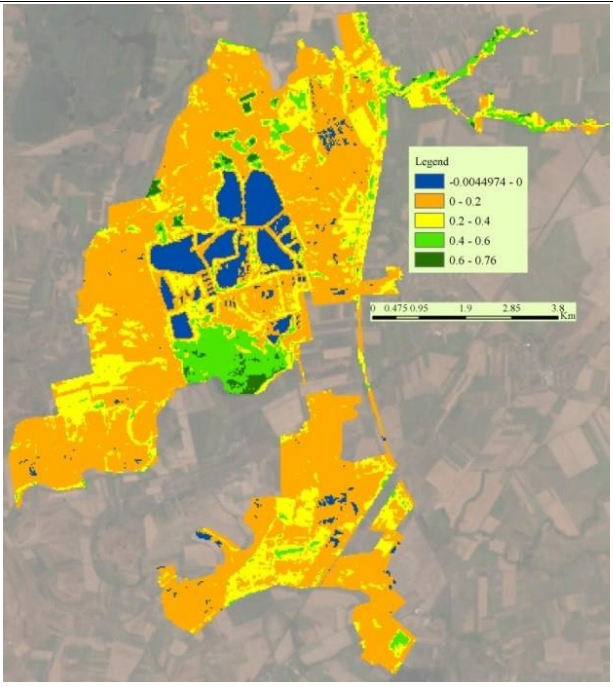

Fig. 7: *VA*NDVI* for Cefa site

The average number of frozen days in a year (the meteorological parameter expressing the average number of days with the minimum temperature ≤ 0° C) was chosen as a correction factor, starting from an elementary logic, that such days do not provide a positive motivational framework for the potential tourists. Its value was calculated based on data from the nearby weather stations, because throughout the sites there are no measurements recorded. Thus, for Cefa and Valea Roșie there were used the data from the Meteorological Station Oradea, processed by Dumiter (2007), and for Ferice Plai, the data from the Meteorological Station Ştei, mediated with the ones from Stâna de Vale (even if Stâna de Vale is an extreme case of evolution for many meteo-climatic parameters from Romania, it is very close to the eastern limit of the site - 3 km), processed by Gaceu (2005).

For Cefa and Valea Roșie the value of this factor is 0.73 (the average number of days with frost per year is 95.3) and for Ferice Plai of 0.62 (the average number of days with frost per year is 138, 15).

The average number of days with rains ≥0.1 mm, as a factor limiting tourist activity, has the same data source and logic of using the values as in the previous case, so we do not go into further details.

For Cefa and Valea Roşie, the meteorological parameter value is 131.4 days / year (Dumiter, 2007), and the value of the correction coefficient is 0.64.

For Ferice Plai, the average number of days with rain ≥0.1 mm is 166.65, the value of the correction coefficient being 0.54.

Accessibility is perceived in such studies as a way of assessing natural (physical-geographic) conditions inside protected areas that make travel difficult, considering the access of tourists. For Valea Roşie and Ferice Plai, the slope is the morphometric parameter that best quantifies the tourists' travel possibilities. It is not advisable to combine this parameter with hypsometry, because even if the mathematical slope is defined as the value of the angle made by the slope of the profile, with the horizontal of the place, geomorphologically it expresses how the altitude changes according to the distance, therefore by this parameter we synthesize the terrestrial elevation. At the Cefa site, the water and marsh areas restrict the movement of tourists.

The slope (Fig. 8, 9) was obtained by processing digital elevation models with a resolution of 15m, resulting from the interpolation of the digitized level curves on topographic maps, 1: 25,000 scale and 5m equidistance, and for aquatic and marshy areas, we used the water abundances raster, the documentation from the "Action Plan for taking into the administration the Cefa Natural Park with ROSCI0025 Cefa, ROSCI0387 Salonta, ROSPA0097 Cefa Fishing - Rădvani Forest and the Natural Reserve 2194 Colony of Birds from the Rădvani Forest, located in the North West Region of Romania" and the vector data taken from orthophotomaps (2012) corrected for 2014.

From the slope grids the highest values (25-39° - Ferice Plai, 17-21° - Valea Roșie) are considered as restrictive for hiking, and their surfaces were used to obtain the correction factor (Table 4).

Table 4: Ferice Plai, Valea Roșie. Accessibility

Site name	Slope class (°)	Area for slope class (ha)	Total site area (ha)	Correction Factor
Ferice Plai	25 - 39°	376,83	1997	0.81
Valea Roșie	17 - 21°	3,03	819	0.99

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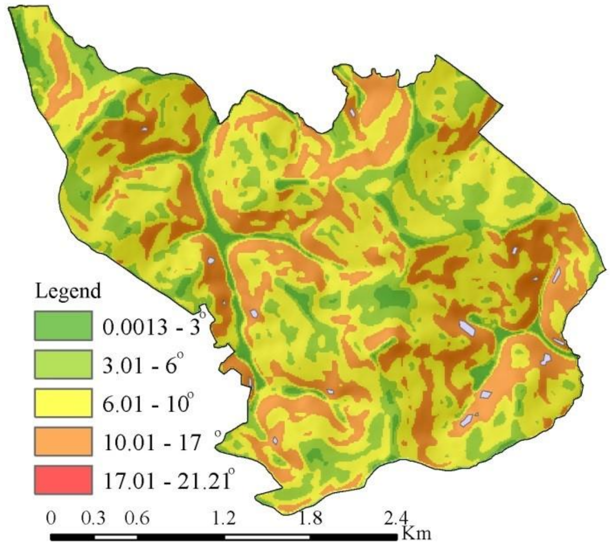

Fig. 8: Slope for Valea Roșie site

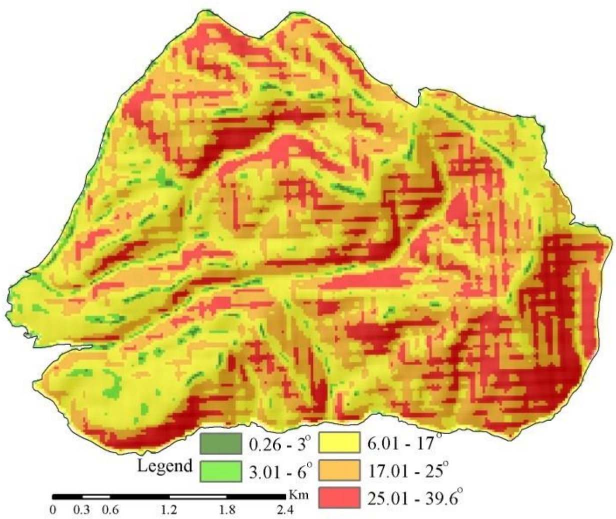

Fig. 9: Slope for Ferice Plai site

The values obtained for the aquatic areas of the three data sources range from 620 ha (LSU derived raster), 633.69 ha (GIS data), 689.46 according to the mentioned documentation. Any of them use only minor changes of the value of the correction factor (by 0.01, from one data source to another), but we will refer to the values considered official.

The result is a correction factor induced by aquatic and marshy areas of 0.87.

The coefficients of correction factors radically change the theoretical estimates of PCC and lead to Real Carrying Capacity (RCC) values, closer to the geo-environmental potential of sites (Table 5).

What draws the attention, even to a simple primary data evaluation is the value approximation of the results from the two sites (Ferice Plai and Valea Roșie) relatively homogeneous in terms of land cover (forest vegetation over 90%), but with very large differences in the area available for public use, e.g. 819 ha for Valea Roșie and 1997 ha for Ferice Plai.

In fact, the study of two sites, having a close structure of the vegetation formations, was made to understand whether and how significant, the differences caused by the correction factors that have more physical valences, not social (in this study), meaning that there is no room for re-interpretation or manipulation of the coefficients.

Clearly, the two figures for RCC (12095 visits / day, 14 744 visits / day) indicate the sensitivity of this indicator to the variables correctly taken into account, even if the coefficient variation value is quite small.

In the case of the Cefa site, which is also the most exposed to anthropogenic pressures due to tourist activities (based on a higher attractiveness), the reduced value of RCC is conditioned not only by A (available area for public use) but by the value of CAV_NDVI) as well.

If there were quantifiable attributes related to the management capability, even minimal (for the purposes of legal regulations embodied in approved management plans), the RCC values would diminish (probably significant for the Ferice Plai and Valea Roșie), thus receiving valences of ECC, therefore the research results would become a working tool in managing these protected areas.

Table 5: Real Carrying Capacity

Site name	C_{AV_NDVI}	Average number of days with frost /year	Average rainfall days ≥0,1 mm/year	Accessibility	RCC (visits/day)
Cefa	0,37	0,73	0,64	0,87	1174
Valea Roșie	0,95	0,73	0,64	0,99	12095
Ferice Plai	0,81	0,62	0,54	0,81	14744

Conclusion

Starting from the objectives of this analytical approach, we can make some statements with conclusion value.

Thus, with all the criticisms brought in the literature, Cifuentes' methodology remains a scientific inquiry, but also a viable working tool in the protected area management, if used correctly and integrated in coherent management flows.

Our (numerical) results should be understood as maximum values of the number of tourists that could be supported by these sites, considering hiking as a type of tourism. They have practical valences, if they are taken over by decision-makers and interpreted as starting elements in developing projects that relate to the infrastructure specific to the mentioned type of tourism.

Through the design mode, the CAV_NDVI correction factor, derived by means of remote sensing, has a flexible behavior and a sufficiently high sensitivity to induce quantitative changes in the tourist support capacity, consistent with the environmental status of the sites. Of all the correction factors we use, CAV_NDVI is the factor with the highest rate of change in the short periods of time, at the contemporary time scale, as demonstrated by studies that have dealt with NDVI changes on time series of satellite scenes.

CAV_NDVI can also be a tool to monitor the ecological status of sites, as ultimately, the quality of the environmental factors is best reflected in the behavior of vegetation.

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Analysis of geographic hierarchy from attributes of Local Government Area in Nigeria

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Abstract

Natural events and entities often create structure and as such exhibits scaling in their organisation in space and over time. Hierarchy is a common feature of natural and social systems. Analysis of the hierarchy could support a better understanding of the structure and the function of different places across a landscape, thus, informing better policy and interventions for sustainable development. The study examined the hierarchy in selected data at local government authorities (LGA) level. Population, road network, and boundary data were sourced, processed and analysed within ArcGIS Software to confirm agreement or otherwise with Zipf's law and showcase the structure formed by these attributes across the LGAs in Nigeria. Head-tail break was adopted to identify the hierarchy within the datasets. Results showed that population, area, population density, and road density exhibits scaling. For population, area, population density, and road density there are 6, 5,4 and 3 classes across the LGAs. These classes represent natural and dynamic classification which are rooted in the data. Evidently, the results clearly indicate that there are more classes than the usually dichotomous classification which reinforces dualism in development. The geographic hierarchy formed by these properties gave an insight into the socio-eco-political landscape revealing the unsustainable pattern of development across the country. In conclusion, using natural classification rooted in empirical data is suggested as a better way to classify authorities thereby enhancing discussion in policy formulation to address such inequalities evident in hierarchy currently established.

Keywords: *geographic hierarchy, spatial inequality, spatial structure, spatial function, sustainable development*

Analiza ierarhizării geografice rezultată din proprietățile LGA-urilor (unități teritoriale ale guvernelor locale) din Nigeria

Rezumat. Evenimentele naturale și entitățile creează adesea o structură care prezintă o scalare în organizarea acestora în spațiu și în timp. Ierarhizarea este o caracteristică comună a sistemelor naturale și sociale. Analiza ierarhizării poate determina o mai bună înțelegere a structurii și a funcției diferitelor locuri dintr-un peisaj, ducând astfel la o politică și intervenții mai bune pentru dezvoltarea durabilă. Studiul a examinat ierarhizarea din datele selectate la nivelul unităților teritoriale ale autorităților locale (LGA). Datele privind populația, rețeaua rutieră și limitele au fost furnizate, procesate și analizate cu software-ul ArcGIS pentru a se confirma sau nu legea lui Zipf și pentru a arăta structura formată de aceste atribute în toate LGA-urile din Nigeria. A fost adoptată o relație cap-la-coadă pentru a identifica ierarhia în seturile de date. Rezultatele au arătat că populația, suprafața, densitatea populației și densitatea rutieră au fost scalate. Pentru populație, suprafață, densitatea populației și densitatea rutieră există 6, 5,4 și 3 clase în LGA-uri. Aceste clase reprezintă clasificarea naturală și dinamică, și care sunt incluse în date. Evident, rezultatele indică clar că există mai multe clase decât clasificarea dihotomică uzuală, consolidând astfel dualismul în dezvoltare. Ierarhizarea geografică formată de aceste proprietăți a oferit o perspectivă asupra peisajului socio-eco-politic dezvăluind modelul nesustenabil de dezvoltare din cadrul întregii țării. În concluzie, utilizarea clasificării naturale inclusă în datele empirice este sugerată ca o modalitate mai bună de a clasifica autoritățile locale, sporind astfel discuțiile pentru formularea de politici care să abordeze astfel de inegalități evidente în ierarhizarea actuală.

Cuvinte-cheie: *ierarhizare geografică, inegalitate spațială, structură spațială, funcție spațială, dezvoltare durabilă*

Introduction

Natural and human-coordinated events often create structure and within such, there is scaling to the organisation in space and over time and most likely a hierarchy will be established. Essentially, it could be said from this understanding that majority is most likely trivial while the minority is essentially to be the most important (Jiang & Liu, 2012) This could be referred to as the Pareto Principle or the scaling Law (Zipf, 1949). The understanding of the important and the trivial could support a better understanding of the structure and the function of different places across a landscape.

Hierarchy is a common feature of natural and social systems (Oliveira, Bastos-Filho, & Menezes, 2017; West, 2017). Such complex systems have many interacting components, the aggregate of activities within the system is non-linear and usually has a property of being hierarchical self-organizing.

Human population and their activities represent one of the major sources of change on the planet. Therefore, understanding of the dynamics and the structures created by these and its manifestation in the social, economic and political sphere is pertinent. To this end, this study examined the hierarchy in the recent data on population and road network to provide an insight into the spatial pattern of order and, the potential implication for economic growth and development. Such understanding could support planning for relevant social and economic incentives influence the observed structure for positive development and stimulate economic growth.

Lucas (1988) argued that human capital has the potential to contribute to faster economic growth i.e., larger human capital creates faster economic growth. But this is not a given if adequate investment in the human capital is not made to improve productivity (i.e., education, training, health facilities, public health protection, etc.). Thus, a large population as seen in Nigeria and many other low- and middle-income countries require proper investment for such human capital to be able to contribute to economic growth. Essentially, a superficial analysis could provide an understanding of distribution, but provides nothing on the hierarchy which exists within this distribution. Such an understanding could serve to understand the level of inequality and support planning for sustainable and inclusive development.

Spatial representation and analysis of pattern and dynamics of human activities, most especially population and economic activity, have a potential for supporting sustainable planning and development. It can provide the opportunity for incorporation of the economic dimension into the analysis of various aspects of development e.g. impact of climate change, vulnerability and resilience assessment, land use/land cover change, economic planning, etc. For example, the spatial representation of global economic activities has revealed that there is a shift in the global centre of economic activities towards the east (Kandogan, 2014; Quah, 2011). While this is interesting, the other interesting question that needs to be answered will include, what is the hierarchy of these economic centres (both new and old)?

Human activities and habitation are directly impacted by location and this interrelationship and dependencies often lead to the increasing agglomeration of businesses and industries at specific locations (e.g., established urban centres). This same process leads to the tendency for segregation of people with a similar culture, tradition, behaviour, social class, etc. across different region and locations. This spatial clustering impact economic activity, leading to spatial irregularities and inequalities. A huge body of work exists which showcased the importance of location in social and economic development, e.g. Mellinger, Sachs, and Gallup (2000); Allen, Bourke, and Gibson (2005); Sachs (2003). Although, it should be noted that social and political factors, as well as their interaction, plays a significant role in determining long-term economic growth. Therefore, exploration of the interaction among location, demographic and socio-economic factors could provide new insight into the potential for economic development.

By extension, the examination of the multiplier effect or the circular cumulative causation– CCC (Myrdal, 1944, 1968) presents an interesting dynamic on the evolution of the social system across the human settlement. The theory posits that the system may stagnate or move up or down, however, the dynamics of the system is governed by the circular causation. Therefore, changes in one of the endogenous factors will cause feedback on the other factors and a ripple is generated across the system i.e. conditions and changes are interdependent. From this perspective, one could argue that location or regions with advantage either in income, industrial agglomeration or any other socio-economic advantage will continue to move upwards and inequality will increase. A new industry in an area or its expansion spurs growth and development in other industry – a multiplier effect which could eventually spread through the entire economy. The same could also be said of corruption, poverty and other social and economic ills. This effect could also explain the difference between high-, middle- and low-income economies and even across different household types within regions and localities thereby increasing inequalities. This effect is also evident in the development of growth poles, major cities, innovation hubs, etc. across the world.

From the foregoing, it is evident that location, spatial processes, human activities shape the relevance and importance of places. With the implication that such can bring about designation and classification by agencies and institutions of government which further exacerbate inequality in development (creating a vicious cycle). It is therefore pertinent that a definite effort is made at understanding geographical hierarchy created by social and economic attributes of local authorities (governmental unit closest to the people). This help in supporting the achievement of SDG 8 (Decent work and economic growth) and 11 (Sustainable cities and communities), through the analysis of relevant data taking cognisance of the spatial context of the development at the local level. To this end, it is important that the hierarchy of the LGAs is examined thereby identifying how current attributes of these authorities is likely to influence the development and achievement of the SDGs highlighted in Nigeria. This study, therefore, explored the geographic hierarchy of the LGAs in Nigeria using selected socio-economic attributes of the LGAs. This is intended to highlight the pattern of the hierarchy across the country, thereby supporting the identification of location-specific policies and measures to curtail backwash effect and ensure the expansion of the spread effect in development and growth. The study is also geared towards creating a framework for data-driven classification of LGAs for the country. Furthermore, the hierarchy derived analyses could help in the understanding of the spatial interaction among these elements (LGAs) within the landscape and as such could support the identification of current functions. Thus, supporting the design of changes which could impact the function and subsequently supporting balanced growth and development across the LGAs.

Data and methods

Data for this study include population, road network, and LGA boundary data. These datasets were then used in the computation of population density and area for each of the LGAs. Population and boundary data were sourced from the ESRI Demographics and Boundaries Dataset for Nigeria. The population (2016) estimate is based on data from the National Bureau of Statistics.

Road network data were sourced from the Open Street Map dataset and downloaded from Geofabirk website (http://download.geofabrik.de/africa/nigeria.html) for April 20th, 2019.

The boundary and road network data were projected to the World Geodetic System 1984 (WGS84) Universal Transverse Mercator (UTM) Zone 32N, from the horizontal datum of the World Geodetic System 1984 (WGS84 – Geographic).

Projected datasets were then used in the computation of area for each of the LGAs, population density, road density. All spatial operations and visualisation were carried out within the ArcGIS platform (ESRI, 2019). Area for each LGAs was computed in Km2 and population density was computed as persons/Km2. To calculate road density, the sums of the road length within each LGA were computed and divided by the area of the respective LGA.

Rank-size plots were constructed within Microsoft Excel, to do these the natural log of the rank and the values for each of the attributes were computed and utilised in plotting this representation of the Zipf's Law. To identify the natural classification within each of the attributes the method proposed and utilised by Jiang (2013) was adopted. Descriptive statistics were computed using the Statistical Package for the Social Sciences (IBM, 2015).

Results and discussion

LGA Hierarchy by Population

Examination of the population and the rank of the population for the LGAs revealed that the distribution is skewed (heavy-tailed distribution). From Figure 1, the Zipf's plot shows that there are two parts to the distribution - the slanted (upper) and the vertical (lower) portion. This gave an indication that there are two types of LGA based on their populations.

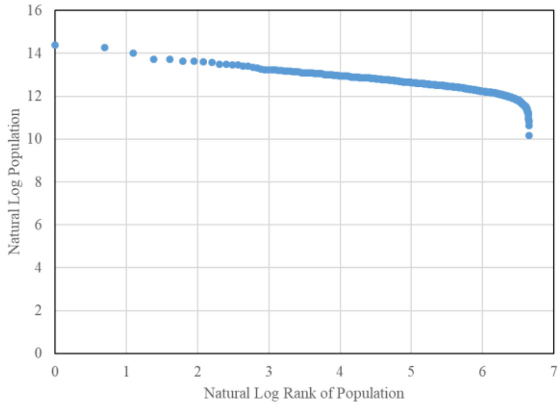

Fig. 1: Rank-size relation of the total population at the LGA level

This shows that despite that fact that the LGA boundaries are manmade, the agglomeration of the population within them self-organize to create a hierarchy, a property of a complex system. This clearly indicates that the pattern of population distribution across the LGAs in Nigeria follows Zipf's Law. A close look at the distribution of the total population (Table 1), shows that there is a coherent structure to the total population within the LGAs. Essentially, most people are living in a small number of LGAs.

Table 1: Non-exclusive levels of population hierarchies and their descriptive statistics

Levels	Mean	Standard Deviation
Top 1 %	1,105,528	369,420
Top 20 %	442,877	199,505
Bottom 80%	191,182	58,375
Bottom 20%	115,539	25,307

Source: Author's computation

Examination of non-exclusive levels within the data set (Table 1) revealed that the top 1% of the LGAs have an average population of about 1.1M and the total population for these LGAs amount to about 4.7% of the total population of the country. More so these LGAs are also highly variable in their population (High SD). The top 20% LGAs by population has an average population of 442,877 persons and accounts for about 36.7% of the total population. These LGAs have a relatively high variation in the population figures. The bottom 80% of LGAs have an average population of 191,182 persons representing about 63.3%, of the total population. However, this group has a lower variation (SD value) in population compared to the previous groups. The bottom 20% has an average of 115,539 persons and amounted to a total of 9.6%

and shows considerably lower variation (low SD) in population among the LGAs in the group.

Considering the Head/tail breaks proposed and formulated by Jiang (2013), it is possible to visualize the hierarchy of the LGAs based on their population (Figure 2). There are far less populated LGAs than the highly populated ones. Using a decision rule of 40% in the Head and 60% in the tail and from the Head/Tail break, we arrived at a total of 6 classes. Effectively, this shows that there are 6 levels within the LGAs in relation to their population. Thus, instead of the dichotomous classification of rural and urban LGAs, we should have the natural classifications of 6 classes. Thus, policy formulation can be designed around such natural classification or places rather than the rigid dichotomy of urban and rural.

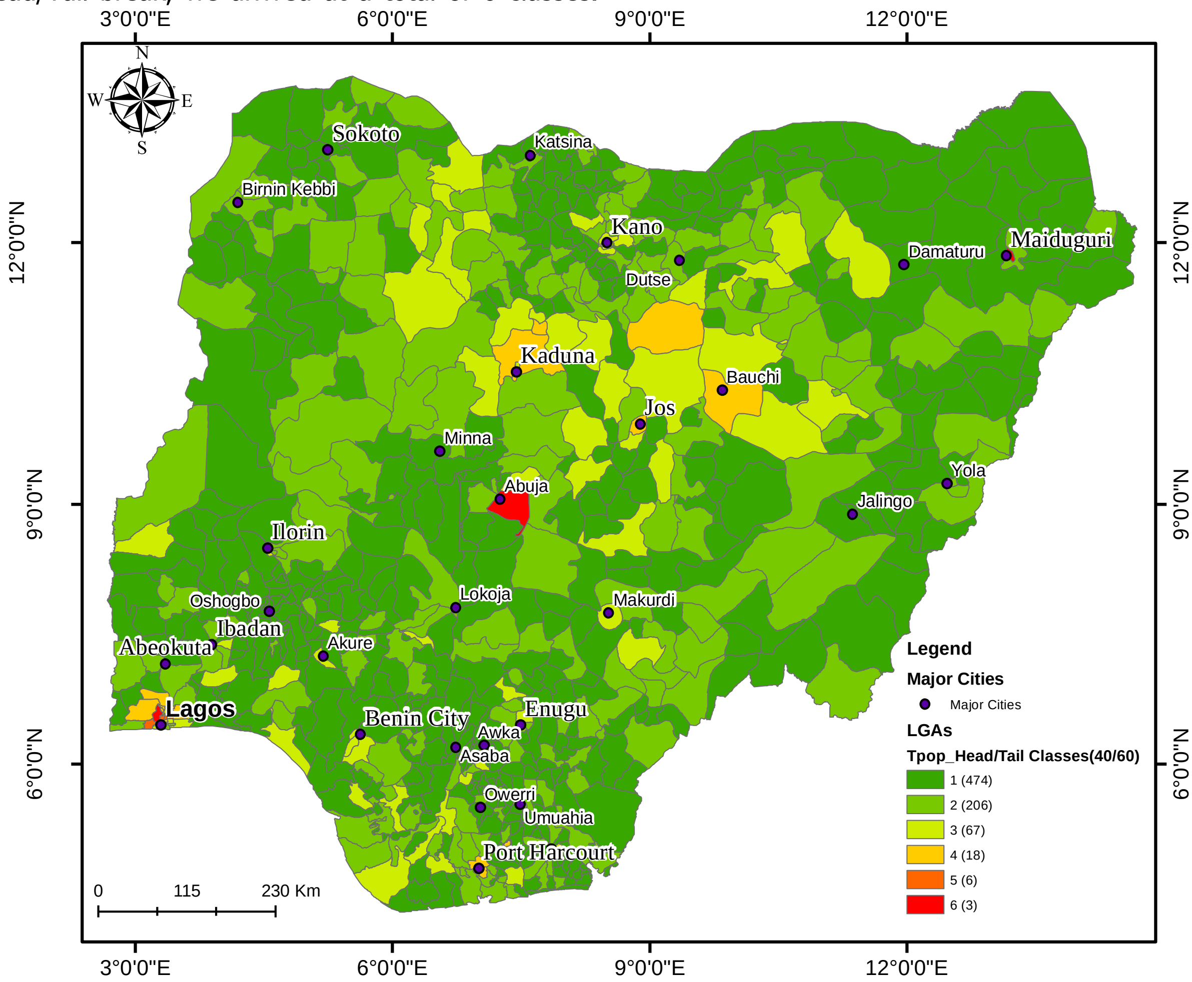

Fig. 2: Hierarchy of LGAs based on total population

The three most populated LGAs (Abuja Municipal, Alimosho and Maiduguri Metro) are at the top of the hierarchy. Clearly, within the highly populated urban LGAs, there are still classes (Class 6-4) while the Class 3 may signify a bridge between the urban and the rural LGAs and the remain Classes (2 and 1) indicate other types of rural LGAs based on their population.

Hierarchy of Total Area of Local Authorities

The total area (Km^2) was examined to check for the hierarchy formed by this administrative boundary (LGA). Examination of the total area and their ranks revealed that the distribution is skewed. From Figure 3, the Zipf's plot shows that there are two parts to the distribution - the slanted (upper) and the vertical (lower) portion.

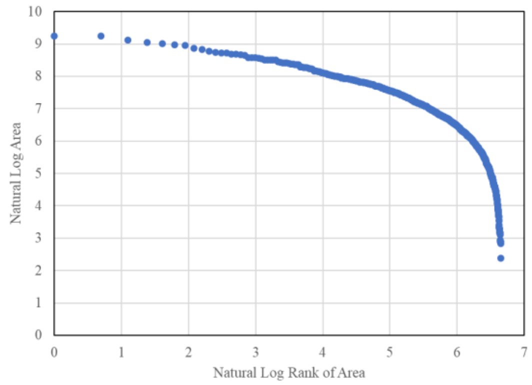

Fig. 3: Rank-size relation of total area (Km^2) of LGAs

However, the vertical portion was considerably longer compared to that observed for the population (Figure 1). The Zipf's plot further highlights the presence of two types of LGA based on their area (those in the head and those in the tail). Essentially the area of the LGAs approximate to the Zipf's Law with most of the LGA having a small extent compared to very few with large coverage.

Table 2: Non-exclusive levels of area hierarchies and their descriptive statistics

Levels	Mean	Standard Deviation
Top 1 %	8674.65	1209.00
Top 20 %	3419.74	1713.79
Bottom 80%	616.44	478.54
Bottom 20%	109.57	58.30

Source: Author's computation, values are in Km^2

The examination of the non-exclusive levels within the dataset showed that the top 1% account for about 7.6% of the total area for the country. These are the largest LGAs with average of about 8,675Km2 (± 1,209Km2). The top 20% accounted for about 58% of the total area of the country and this group has a mean area of 3,419Km2 (± 1,713km2). The third non-exclusive level considered (made up of all LGAs below the 80th Percentile in terms of their Area), has an average area of 616Km2, covering a total of about 42% of the total area of the LGAs. This group has a moderate level of variation (SD when compared to the earlier highlighted groups. The bottom 20% accounts for just about 2% of the total area, with an average area of 109Km2. This group has a low level of variation and corresponds to the smallest LGAs in the country.

Using the same techniques as highlighted previously, the Head/tail break was used to visualize the hierarchy of the LGAs based on their area (Figure 4).

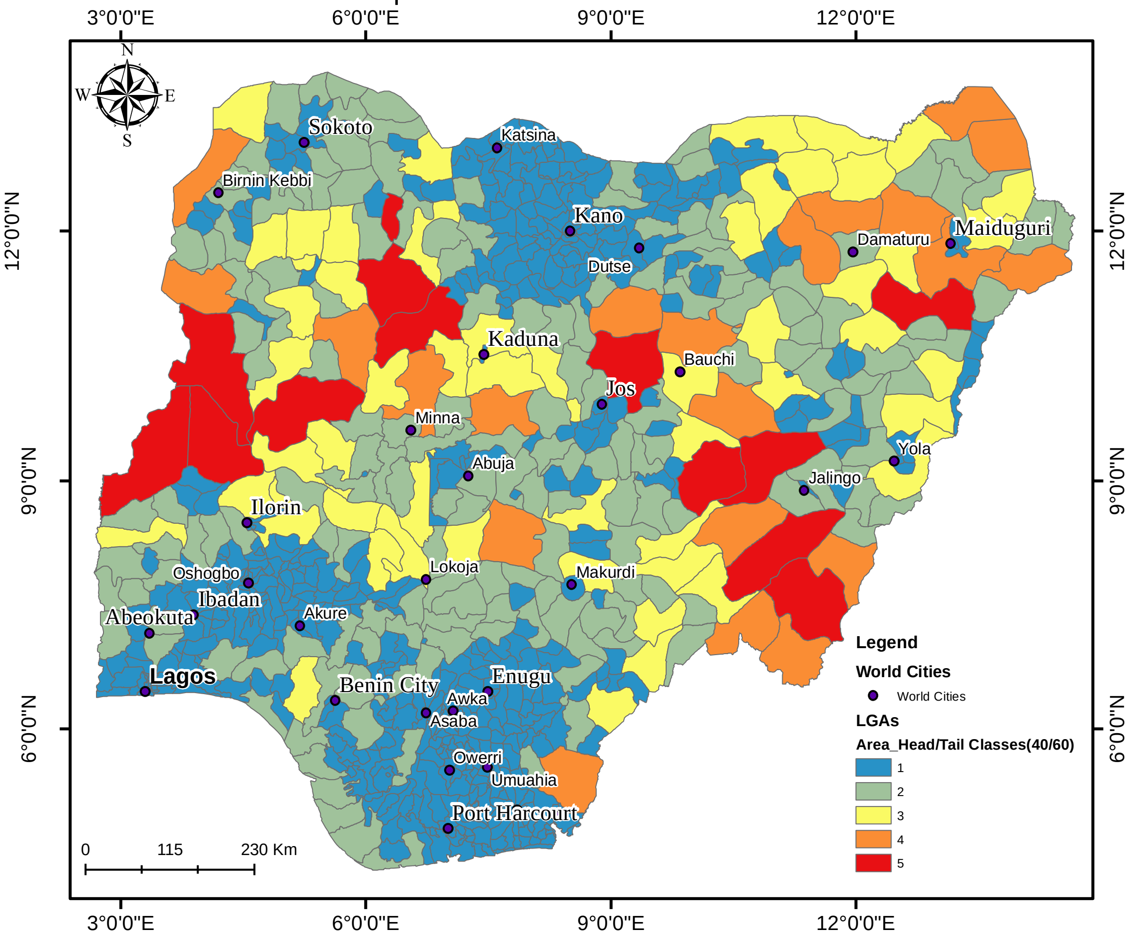

Fig. 4: Hierarchy of area of the LGAs in Nigeria

Results showed that there are far more small-size than large-size LGAs. Using the decision rule of 40% in the Head and 60% in the tail, a total of 5 classes or hierarchy were derived from the dataset. Essentially, by the size or area of these local government authorities, there are 5 levels. Thus, there are more than just large and small-sized LGAs there are other sizes in between. Similarly, these classes represent natural classification which could be used for policy decision and planning instead of arbitrary classifications which could create animosity.

In the highest rank (Class 6 Figure 4), there are 12 LGAs, spread across the middle belt, Northcentral and the North Eastern region (geopolitical zones) of the country. Class 3 could be designated as medium-sized LGA, while class 2 and 4 are intermediate between very small and very large LGAs respectively.

Population Density Hierarchy for Local Authorities

Combining the area and the population, the population density across the LGAs was compared to their respective ranks. The rank-size plots (Figure 5) clearly indicate that the distribution of the population density is heavy-tailed just as the population and the area distribution. Similarly, there are two parts to the distribution (the head and the tail). Thus, there are more LGAs with low population density compared to those with high population density.

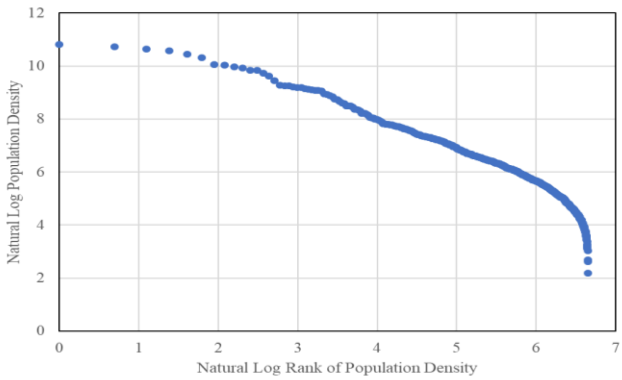

Fig. 5: Rank-size relation of population density at the LGA level

From the perspective of the non-exclusive levels derived from the dataset (Table 3), the most populated LGA are likely to be highly urbanized LGAs with the top 1% having a mean density of 35,896 persons/Km2 (± 10,003). The average density for the top 20% LGA stands at 5,267 persons/Km2 (± 8,457) still shows a considerably high population density. However, the bottom 80% has an average density of 289 persons/Km2 (± 219 persons/Km2) and the bottom 20% has a mean population density of mean 70 persons/Km2 (± 25persons/Km2) clearly indicating that the bottom 80% of the LGAs are the least populated LGAs.

Table 3: Non-exclusive levels of population density hierarchies and their descriptive statistics

Levels	Mean	Standard Deviation
Top 1 %	35,896	10,030
Top 20 %	5,268	8,458
Bottom 80%	290	219
Bottom 20%	70	25

Source: Author's computation NB. Values are in persons/Km2

In deriving the hierarchy based on the population density of the LGAs, the Head/tail break was adopted (Figure 6). With the decision rule of 40% in the Head and 60% in the tail, there are four classes, and Class 4 as the top rank, with top rank (Class 4) having 12 LGAs spread across Oyo (1), Lagos (7) and Kano (4). The lowest rank has the highest proportion of the LGA (84.1%) of the total LGA while 11.7% and 2.6% belong to Class 2 and 3 respectively found. Evidently, there are more than just the conventional urban and rural LGAs based on the population density, there are shades in between. Thus, the classification of LGAs to two classes based on population density is not a natural classification, and for planning evidently, there are 4 natural classes based on recent population data.

Hierarchy of Road Density of Local Authorities

Using the area of the LGAs and their total length of roads with each of them, the road density (Km/Km2) captures another dimension (extent of human activity from volunteered geographic information) which could be used to classify the LGAs. The plot of the road densities and their respective ranks shows that the distribution is like what was observed for all the other characteristics examined. The distribution is skewed (Figure 7), with a head and a tail, however, there were outliers (Akuku Toru, Calabar South, LGA without road, i.e. no volunteered information is available to compute the road density for these LGA).

Despite the outlier, the road density of the LGAs still approximates to the Zipf's Law, as indicated by the shape of the rank-size plot (Figure 7). Thus, indicating that there are likely to be more LGAs with lower road density than those with high density.

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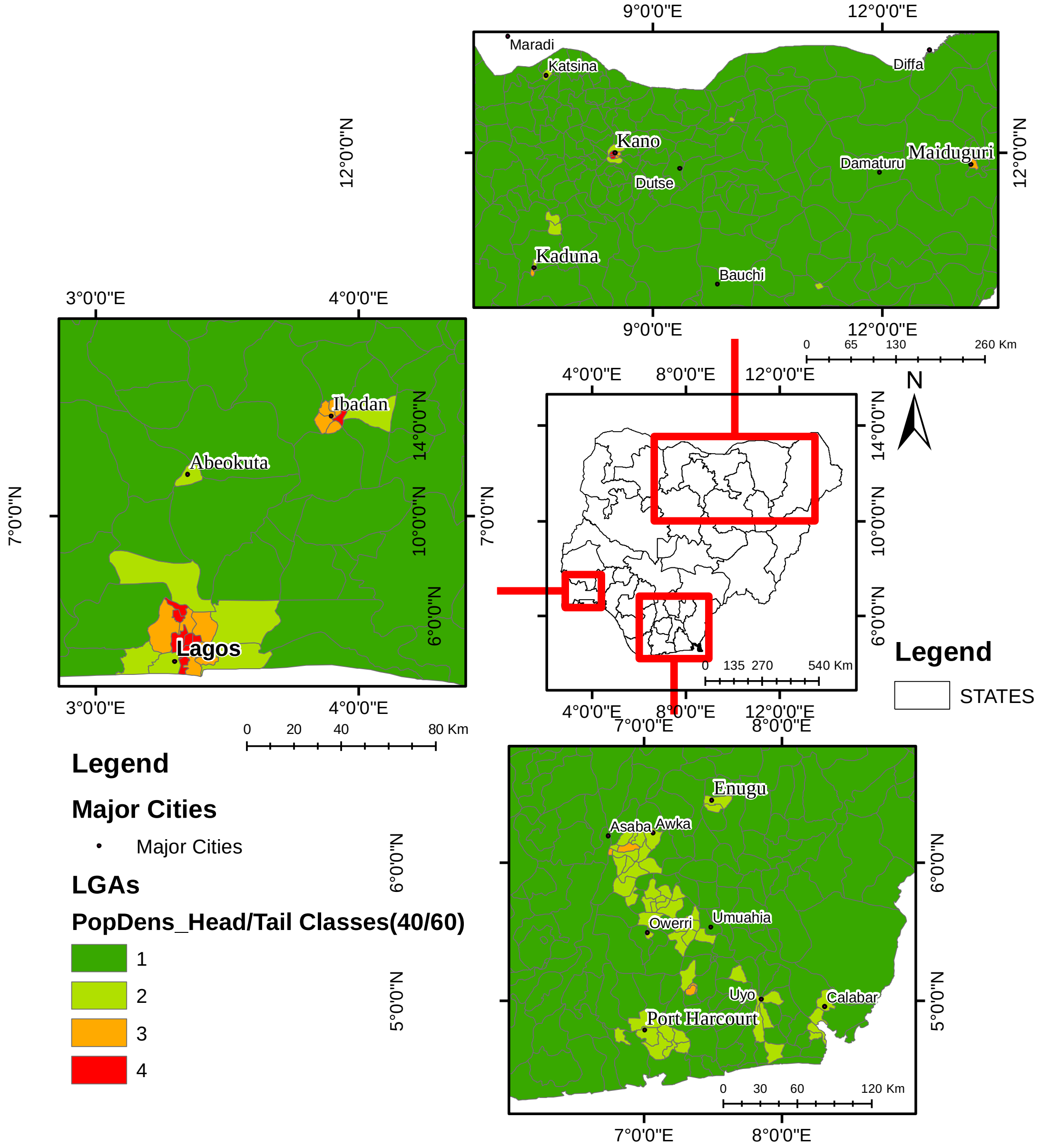

Fig. 6: Hierarchy of population density at LGA level

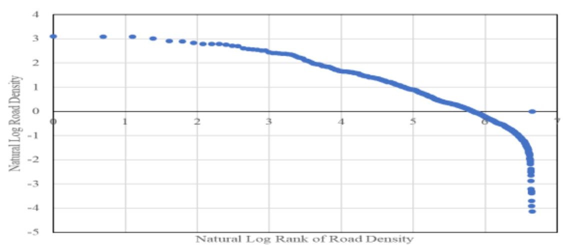

Fig. 7: Rank-size relation of road density (km/km2) of LGAs

From the computation of the non-exclusive levels (Table 4), the top 1% LGAs have an average of 19.48Km/Km2 (±2.36Km/Km2) with about 0.53% of the total road length across the country (i.e. as captured by the OSM database). The top 20% (155 LGAs) has an average of 6.11Km/Km2 (±4.57Km/Km2) and constitutes about 23% of the total road length across the study area.

Table 4: Non-exclusive levels of road density hierarchies and their descriptive statistics

Levels	Mean	Standard Deviation
Top 1 %	19.48	2.36
Top 20 %	6.11	4.57
Bottom 80%	0.79	0.52
Bottom 20%	0.26	0.10

Source: Author's computation, values are in Km/Km^2

The average road density for the bottom 80% and 20% are considerably low (0.77 and 0.26 respectively). The indication from these is that some LGA gets a lot of attention and disproportionately get more of their road network captured. More so, LGA that are less accessible (difficult to access due to terrain, security or other reasons) are likely to have data captured for them.

To identify the natural hierarchy across the LGAs in respect of road density, the Head/tail break classification (decision rule of 40% in the Head and 60% in the tail) was carried out (Figure 8).

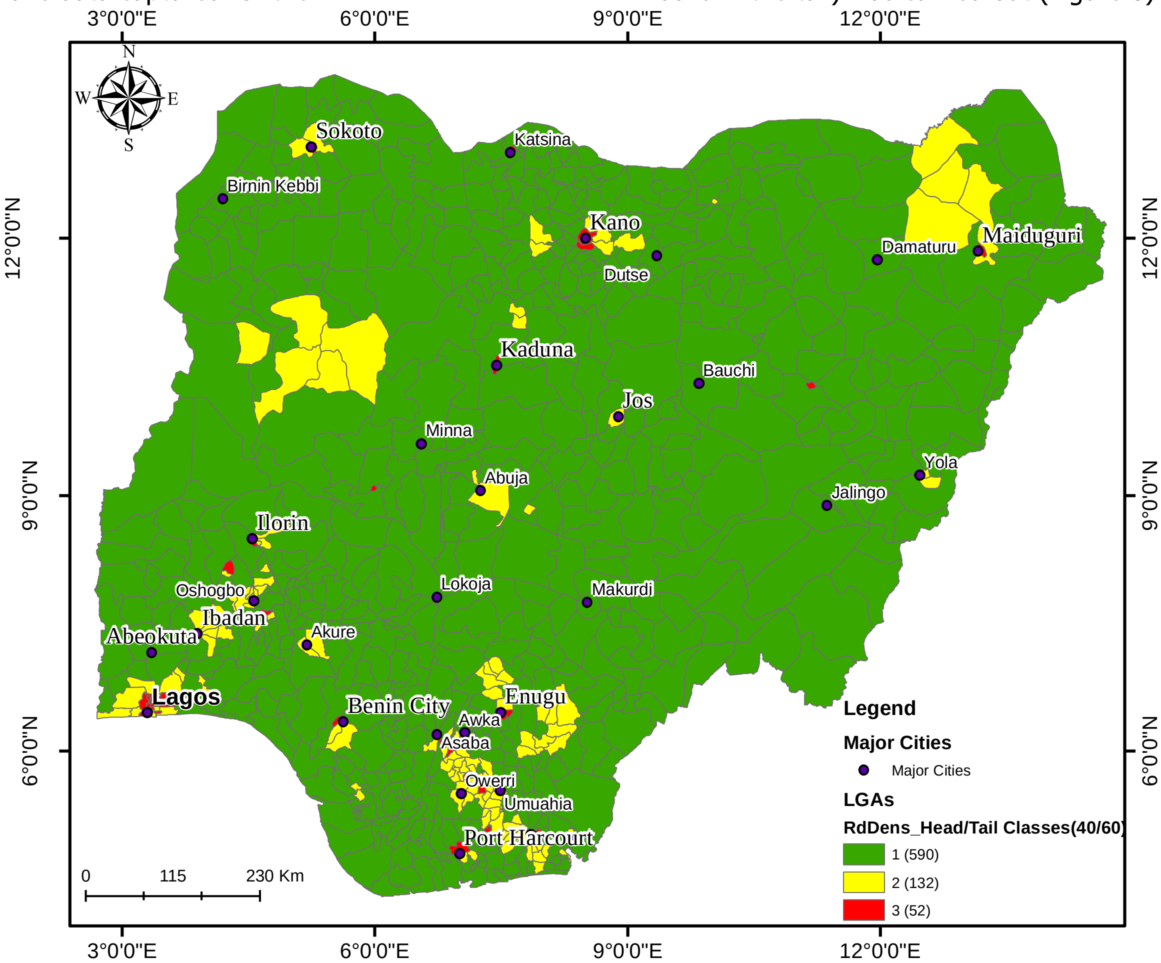

Fig. 8: Hierarchy of LGAs based on road density

The result showed that there are 3 classes, and far more LGAs (76%) have a relatively low road density, while about 7% of the LGAs have very high road density values. From Figure 8, it is evident that most of the moderate to highly connected (moderate to high road density values) are often occurs on urbanized LGAs as well as small-sized LGAs. Essentially, by the road density of the LGAs, there are 3 levels. Thus, apart from the least and the well-connected LGAs, there is another group in between. Similarly, these classes represent natural and dynamic classification which are rooted in the data (observation rather than static classification) which could be used for policy decision and planning.

Discussion

The analyses showcased an example of knowledge discovery from open data and big data sources. With the growing amount of open data as well as archived data available from different sources, it is important that such data are analyzed to provide new understanding and knowledge. This would guide planning and policymaking to support the achievement of the Sustainable development goal.

Examination of the scale of various characteristics of the local authorities in Nigeria revealed some in-depth insights into the structure and the pattern created that the hierarchy of this geographic designation (LGA boundaries). The hierarchies identified has some implications for socio-economic development as well as natural resource management. For example, the classification of LGAs (places or settlements) as either rural or urban is not empirically supported by available data. Essentially, there are more than two types of LGAs, thus for effective management, there is a need to reconsider such dichotomous classification. According to the National Urban Development Policy of 2006 all States and LGAs headquarters are regarded as urban, this is a faulty assumption and type of "urbanization" is not based on the understanding of the social and economic forces which could foster development. While population size is important, centrality and function (most especially economic) are also important in designating a place as urban (Pacione, 2013), thus there is a need to review the way we look at geographic space and boundaries. With Nigeria predicted to be the Third most populous country in the world according to the World Population Prospect (United Nations Department of Economic and Social Affairs Population Division, 2013), there is a clear need to re-examine the national policy on the designation of urban and rural areas to ensure that development is guided by evidence and not political reasons.

All the properties considered shows a heavy-tailed distribution, thus a representation of such need to take into consideration the inherent attribute of the data. The exploration of these datasets also reveals that there is an underlying hierarchy within the dataset. Evidently, there are more than just the conventional two classes – well-connected and less connected; urbanized and rural, highly populated and sparsely populated, large and small LGAs. The dichotomy often used in the many policymaking spheres has created a dualism in social and economic development. However, despite this, the social and economic systems being complex systems have self-organized, forming a hierarchical structure which could be harnessed to stimulate and spread social and economic development. According to the CCC theory previously discussed, if the dualism persists backwash effect will continue to drain the less developed area of human capital and other resources and concentrate the positive effect only in the developed areas unless there is an intervention. According to Myrdal (1968) - The Institutional Reform Theory, effort must be made to curtail dualism (divergence) in development as such balanced development should be the focus of any nation. Thus, one of the first a place to start is putting an end to the dichotomous classification of places and areas in the national, while this may make policymaking easy it does not make it efficient or effective in fostering economic or social development. Myrdal proposal - the Institutional Reform Theory, highlights that all efforts must be focused on ending dualism, therefore institution needs to be reformed to bring advantages of planning to the general populace. Further, the theory identified balanced regional development as a mean of correcting some of the ills of free-market policies (which often increase divergence growth). Thus, government intervention is required to promote capital goods and import substitution industries which will stimulate simultaneous development outside the sphere of large-scale industries. Thereby, the creation of employment should be the main measure for addressing the issue of poverty (sponsored growth approach). And there are indications that import substitution industrialization is already creating some development momentum across some countries in Africa with Africa's manufacturing production doubling between 2005 and 2014 (Félicité, 2018).

Characteristics examined in this study are relevant to economic and social development. For example, understanding from the hierarchy of total population and population density at the LGA level could help in identifying which economic functions and resources should be allocated to each LGA. The understanding of the pattern of this structure could support the decision on how to ensure the spread of economic benefit this demographic attribute. The concentration of resources and effort only on where most people are is not a sustainable one as it further entrenches divergent economic growth (an unsustainable development). If we consider, the entire country as a landscape (socio-eco-political landscape) the interaction among the properties such as function (interaction between spatial elements) and structure (the spatial relationship between distinctive patches) will bring about change which will iterative modify the function and the structure of the landscape (Lawal, 2009).

Following the recent work e.g. Han, Hao, Wang, and Zhou (2011); Jiang and Liu (2012); Oliveira et al. (2017), this study has demonstrated that even within human-created systems (in this case constituted border or boundaries) the scaling law still holds and this manifestation could help in understanding the structure and hierarchy of these entities within a nation (a socio-eco-political landscape). The understanding from this exploration could provide an underlying classification which could support data-driven and effective policymaking, resources allocation and function designation for sustainable and balanced development.

Conclusion

The study revealed that the Pareto principle of unequal distribution (i.e. vital few and trivial many) holds even for selected properties of LGAs (manmade boundaries) in Nigeria. From the exploration of these properties, it could be concluded that the dichotomous classification of these spatial entities is inadequate and as such natural classification often shows that there are more than two classes.

The hierarchy derived from the head/tail break provides an opportunity to understand the spatial interaction among these elements within the landscape and as such could support the identification of current functions. From these, changes could be designed and sponsored (sponsored growth from Institutional Reform Theory) to support balanced development which will curtail divergent growth and reduce spatial inequality and promote sustainable development.

To this end, the study recommends that in order to change the current pattern observed to stimulate widespread development there is a need to:

a. Change structure or influence from uniform to non-uniform i.e. change the uniform classification (urban or rural) to a more robust classification, thus curtailing unequal development which heightens backwash effect - so we need to look beyond duality, and

b. Identify, examine and realign the functions of LGAs in line with their connectivity, economic and demographic attributes, essentially making each part of the system fulfil different and useful function (organization's divisions governed by process instead of functions or customized solutions for each class of LGA – Doing everything, everywhere).

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Authors' Contributions

O.L. (University of Port Harcourt) was responsible for conceptualization, collation, analysis and writing up the article. S.B.A. (University of Port Harcourt) reviewed the methodology and the write-up.

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