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AND VETERINARY MEDICINE OF BUCHAREST**

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SECTION 01
ENVIRONMENTAL SCIENCE
AND ENGINEERING

STUDIES ON THE ROLE OF FILAMENTOUS FUNGI IN TERRESTRIAL ECOSYSTEMS

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Abstract

The role of filamentous fungi in terrestrial ecosystems is highlighted by numerous studies and research conducted by researchers around the world. Among the many roles they play we can list a few: filamentous fungi break down organic matter, produce enzymes of biotechnological, agricultural and industrial interest, they are used as biological agents to control plant diseases caused by microorganisms such as bacteria or fungi, phytophagous insects, fungi can establish cooperative relationships with plants – mycorrhiza, and last but not least, fungi have a role in depollution.

This paper aims to draw the attention of all people regardless of social category, age, sex or living environment on the importance of the role of filamentous fungi in terrestrial ecosystems. Studying the literature available on online search engines we created a questionnaire with sixteen various questions that highlight the importance of filamentous fungi. In this case study we present a questionnaire addressed to people from different social categories, who have completed gymnasium, bachelor's, master's or doctoral studies, such as pupils, students, masters, doctoral students. The study shows us the extent to which they know about the importance of filamentous fungi in terrestrial ecosystems, the role and benefits of these organisms around us. The poll has accumulated a total of forty-seven responses

Key words: filamentous fungi role in terrestrial ecosystems, opinion poll, questionnaire evolution.

INTRODUCTION

The roles of filamentous fungi in terrestrial ecosystems are varied and numerous. Among the many roles they play we can list a few:

1. filamentous fungi break down organic matter

Filamentous fungi are ubiquitous in nature, with an important role in maintaining the ecosystems' status quo through decomposition of organic matter, nutrient recycling, and symbiotic interactions (Ferreira et al., 2020).

Filamentous fungi are phylogenetically diverse; however, members of three groups, namely ascomycetes, basidiomycetes, and zygomycetes, are mostly found in association with pollution mitigation research studies, or commercial exploitation, using high-quality medium recipes. Their dominant ecological role, extensive use in research, and commercial exploitation are related to the macroscopic filamentous growth, phylogenetic diversity, array of extracellular and intracellular enzymes, range of potential value-added products, production of surfactants, cell wall sorption, and

synergistic possibilities in co-culture approaches (Troiano et al., 2020).

In support of this statement Troiano et al. in the article "Status of filamentous fungi in integrated biorefineries" highlights the role of fungi: waste biomass is complex but may be completely valorized using filamentous fungi; biological methods for biomass conversion are environmentally advantageous; filamentous fungi convert biomass into a myriad of valuable products; filamentous fungi may enhance the economic viability of biomass operations (Troiano et al., 2020).

Fungi have the ability to transform organic materials into a rich and diverse set of useful products and provide distinct opportunities for tackling the urgent challenges before all humans. Fungal biotechnology can advance the transition from our petroleum-based economy into a bio-based circular economy and has the ability to sustainably produce resilient sources of food, feed, chemicals, fuels, textiles, and materials for construction, automotive and transportation industries, for furniture and beyond. Fungal biotechnology offers solutions

for securing, stabilizing and enhancing the food supply for a growing human population, while simultaneously lowering greenhouse gas emissions. Fungal biotechnology has, thus, the potential to make a significant contribution to climate change mitigation and meeting the United Nation's sustainable development goals through the rational improvement of new and established fungal cell factories (Meyer et al., 2020).

2. filamentous fungi produce enzymes of biotechnological, agricultural and industrial interest

Many enzymes produced by fungi have relevant biotechnological applications in several industrial areas. The team of researchers coordinated by Guimaraes collected and isolated filamentous fungi from soil and humus, plants and sugar cane bagasse of different regions of the Sao Paulo state. Forty isolates were examined for their ability to produce xylanase, glucose-oxidase, alkaline phosphatase, acid phosphatase, phytase, pectinase and amylase. Among these, twenty three isolate exhibited enzymatic potential. The xylanases produced by two of these isolates (*Aspergillus caespitosus* and *A. phoenicis*) showed good potential for pulp bleaching. Among seventeen isolates, at least three produced high levels of glucose-oxidase, being *Rhizopus stolonifer* and *A. versicolor* the best producer strains. *A. caespitosus*, *Mucor rouxii*, and nine others still not identified were the best producers of phosphatases in submerged fermentation. Pectinase was best produced by IF II and C-8 belong *R. stolonifer*. Significant levels of amylase were produced by *Paecilomyces variotii* and *A. phoenicis*. A remarkable enzyme producer was *Rhizopus microsporus* var. *rhizopodiformis* that produced high levels of amylase, alkaline and acid phosphatases, and pectinase. Some morphological structures of this fungus were illustrated using light microscopy (LM) and scanning electron microscopy (SEM). This study contributes to catalogue soil fungi isolated in the state of Sao Paulo, and provides additional information to support future research about the industrial potential of these microorganisms that may produce enzymes and, eventually, also secondary metabolites with

anti- microbial or anti- parasitic activities (Guimaraes et al., 2006).

3. filamentous fungi are used as biological agents to control plant diseases caused by microorganisms such as bacteria or fungi, phytophagous insects

Currently, more than two billion tons of pesticides are used every year all over the world. These pesticides include fungicides, bactericides, herbicides, insecticides and others that are used to eliminate undesirable agents, mainly fungi, weeds and insects, which are considered crop pests, with the aim to guarantee a high yield. The cost of this practice is not only financially high, but also environmentally, because the excessive use of pesticides leads to water bodies, groundwater and soil contamination in addition to affecting human and other animals' health due the toxicity, recalcitrance and the carcinogenic potential of many of these compounds. The biological control of pests has been recognized as an alternative to the use of pesticides (Baron et al., 2019).

In many cases, the control of pathogens can involve direct interaction between fungi and plants. In this case, the fungi are able to act as plant pathogen antagonists, i.e., they can use several different mechanisms, such as the production of metabolites (antibiotics, volatile compounds - ammonia, cyanide, alcohols, esters, ketones, etc. - or enzymes), competition (for space, C, N or mineral sources), parasitism, or the induction of systemic resistance in the plant or an increase in its growth response, resulting in a reduction in the pathogen's activities (Baron et al., 2010)

Insects are the main class of the Arthropoda phylum and are among the most diverse living beings on the planet. Even only a small portion of this group contains species known as agricultural pests; they are responsible for causing considerable damage to crops, devastating approximately 20% of the global annual production. In this context, it arises the practices of biological control using entomopathogenic fungi, a group formed by several species that are able to infect and cause disease in insects and other arthropods (Pell et

al., 2010; Roy and Pell, 2000; Schrank and Veinstain, 2010; Thomas and Read, 2007)

4. fungi can establish cooperative relationships with plants - mycorrhiza

Most land plants form symbiotic associations with arbuscular mycorrhizal (AM) fungi. These are the most common and widespread terrestrial plant symbioses, which have a global impact on plant mineral nutrition. The establishment of AM symbiosis involves recognition of the two partners and bidirectional transport of different mineral and carbon nutrients through the symbiotic interfaces within the host root cells. Intriguingly, recent discoveries have highlighted that lipids are transferred from the plant host to AM fungus as a major carbon source (Wang et al., 2017).

Arbuscular mycorrhizal fungi are a kind of beneficial microorganisms in soils, which can establish symbiotic association with ~80% of terrestrial plants, namely, arbuscular mycorrhizas. The symbiosis possesses bidirectional roles in mycorrhizal fungi and host plants: host plants provide photosynthates for the fungal partner; mycorrhizal fungi absorb water and nutrients from soils to plant partner. Mycorrhizal symbiosis has a typical effect on growth performance of host plants. In general, arbuscular mycorrhizas show a promoted effect on plant growth by means of increasing water and nutrient acquisition, soil improvement, phytohormone regulation, and root morphological improvement (Lu et al., 2018).

5. and last but not least, fungi have a role in depollution

In support of this statement Kues in the article "Fungal enzymes for environmental management" highlights the role of fungi in terrestrial ecosystems: basidiomycetes produce enzymes useful to attack toxic persistent organic pollutants; mainly laccase and peroxidases are considered for water and soil decontaminations; bioreactor processes with immobilized enzymes for water purification are in tests; bioaugmentation and biostimulation use living fungi and their enzymes *in situ*; but effects on ecosystem functions and local biodiversities are still largely unstudied (Kues, 2015).

Fungal ligninolytic enzymes have broad biotechnological applications. Particularly laccases and certain fungal class II peroxidases from white-rot basidiomycetes are considered in

degradation of persistent organic pollutants. Promising processes with reusable immobilized laccases in special reactors have been developed up to pilot scale for degradation of pollutants in water. Bioremediation of chemically complex soils with their large indigenous microbial communities is more difficult. Living fungi and their enzymes are employed. Bioaugmentation, introduction of for example white-rots for enzyme production into a polluted soil, and biostimulation of suitable resident organisms by nutritional manipulations are strategies in degradation of pollutants in soil. Bioaugmentation has been successfully implemented on small scale for soils in biobeds and for specific materials such as olive mill wastes (Kues, 2015).

MATERIALS AND METHODS

Create the Google Drive form and questionnaire

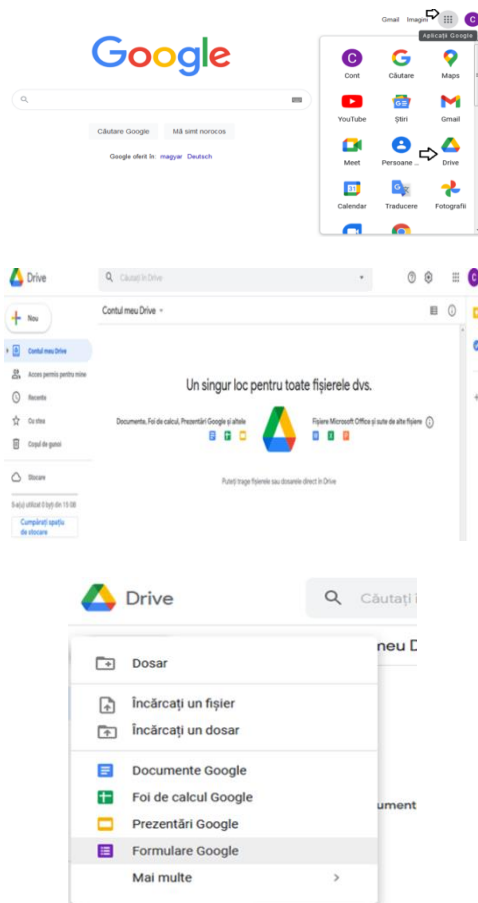
Step 1

With the browser I created a Google user account, then I went to the G-mail page to create a new account using the "Create an account" option and entered all the necessary data to register and benefit from all Google services offered.

Step 2

To enter Google Drive, I clicked the button called "Google Apps". After displaying its window, I clicked on the "New" button that offers the submenus: "File"; "Upload a file"; "Upload a file"; "Google Docs"; "Google Spreadsheets"; "Google Presentations"; "Google Forms"; "More".

I accessed the "Google Forms" window and added the necessary information.

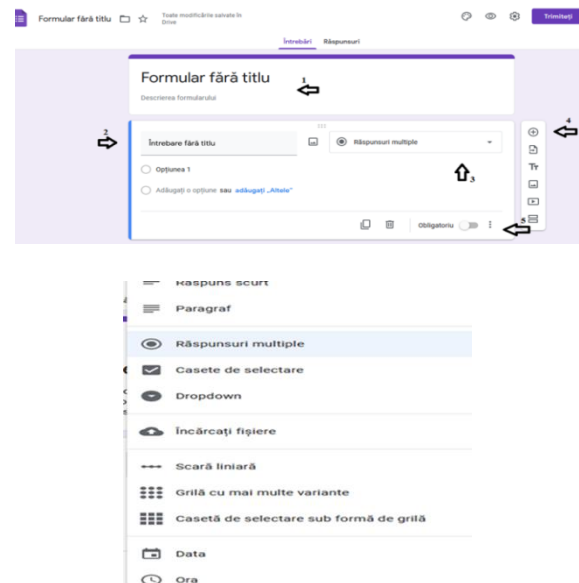


Step 3

In this stage, I filled in the title of the topic in the column where it says "Untitled form" (1), then I wrote the question and how many answer options we have (2). In the "Multiple answers" box we have several options on how we want to make the answers (3).

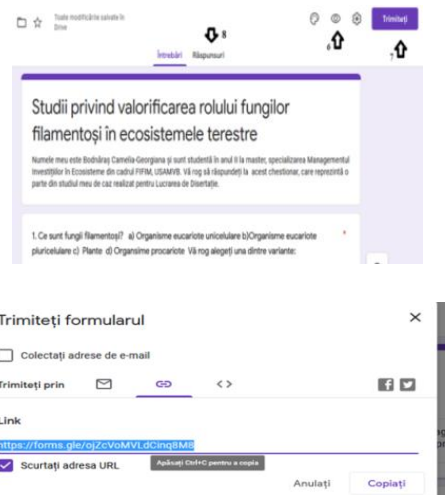
To add more questions we have to press the button with the circled plus sign (4).

If we want the question to be optional, this means that the respondent will answer it only if he wants, we do not tick the "Mandatory" button, but if we do not want to skip the question, we tick the button (5).



Step 4

After completing the questionnaire, we can see what it looks like by clicking on the eye icon (6) and if we see that everything is well written we can send it for completion by the general public (7). We have the option to send it by e-mail, on social networks or by creating a link. Finally, to see the number of people who completed the questionnaire, we must click on the Answers option (8).



Step 5

By accessing the Answers option, we see how many people answered the questionnaire and we have the option to see an overall

summary drawn in a diagram or we can see how each person answered these questions.



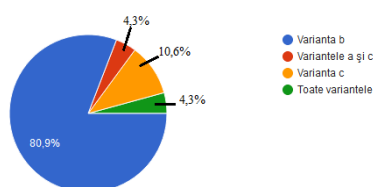
RESULTS AND DISCUSSIONS

In this case study we present a questionnaire addressed to people from different social categories, who have completed gymnasium, bachelor's, master's or doctoral studies, such as pupils, students, masters, doctoral students. The study shows us the extent to which they know about the importance of filamentous fungi in terrestrial ecosystems, the role and benefits of these organisms around us. The poll has accumulated a total of forty-seven responses. The first question was, "What are filamentous fungi?"

- a) Unicellular eukaryotic organisms
- b) Multicellular eukaryotic organisms
- c) Plants
- d) Prokaryotic organisms

The answer variants are: variant b; variants a and c; variant c; all variants.

1. Ce sunt fungii filamentoși? a) Organisme eucariote unicelulare b) Organisme eucariote pluricelulare c) Plante d) Organisme procariote Vă rog alegeți una dintre variante:
47 de răspunsuri



We found out that: 80.9% of the respondents answered variant b; 4.3% of respondents answered variants a and c; 10.6% of respondents answered variant c; 4.3% of respondents answered all variants.

The correct variant to this question is variant b. 80.9% of the respondents answered correctly and 19.2% of the respondents answered incorrectly.

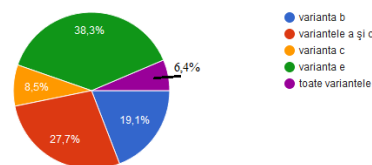
The second question was, "What is the role of filamentous fungi in an ecosystem?"

- a) Primary producers

- b) Primary consumers
- c) Secondary consumers
- d) Tertiary consumers
- e) Decomposers

The answer variants are: variant b; variants a and c; variant c; variant e; all variants.

2. Care este rolul fungilor filamentoși într-un ecosistem? a) Producători primari b) Consumatori primari c) Consumatori secundari d) Consumatori terțiari e) Descompunători Vă rog alegeți una dintre variante:
47 de răspunsuri



We found out that: 19.1% of the respondents answered variant b; 27.7% of respondents answered variants a and c; 8.5% of the respondents answered variant c; 38.3% of the respondents answered variant e; 6.4% of respondents answered all variants.

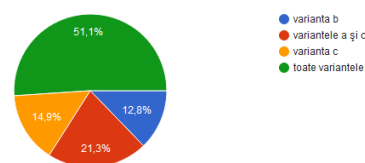
The correct variant of this question is variant e. 38.3% of the respondents answered correctly and 61.7% answered incorrectly.

The third question is, "What are the functions of ecosystems?"

- a) The energetic function
- b) The circulation function of matter
- c) The self-regulation function

The answer variants are: variant b; variants a and c; variant c; all variants.

3. Care sunt funcțiile ecosistemelor? a) Funcția energetică b) Funcția de circulație a materiei c) Funcția de autoreglare Vă rog alegeți una dintre variante:
47 de răspunsuri



To this question: 12.8% of respondents chose option b; 21.3% of the respondents chose variants a and c; 14.9% of the respondents chose variant c; 51.1% of respondents answered all variants.

The correct variant of this question is all variants. 51.1% of respondents answered correctly and 49% of respondents answered incorrectly.

In the fourth heading, the statement is worded as follows:

Filamentous fungi:

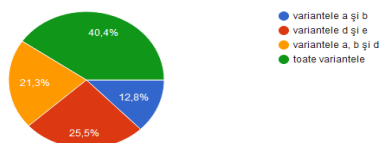
- a) They break down organic matter

- b) They produce enzymes of biotechnological interest
 c) They produce mycorrhizae (symbiosis with plant roots)
 d) They are used as biological control agents - bioinsecticides and biofungicides
 e) They have a potential role in bioremediation processes (depollution)

The answer variants are: variants a and b; variants d and e; variants a, b and d; all variants.

4. Fungii filamentoși: a) Descompun materia organică b) Produc enzime de interes biotehnologic c) Produc micorize (simbioză cu rădăcinile plantelor) d) Sunt utilizați ca agenți biologici de control- bioinsecticide și biofungicide e) Au un potențial rol în procese de bioremediere (depoluare) Vă rog alegeți una dintre variante:

47 de răspunsuri



In this case, the percentages are as follows: 12.8% of respondents answered variants a and b; 25.5% of the respondents answered variants d and e; 21.3% of the respondents answered variants a, b and d; 40.4% of respondents answered all variants.

The correct variant of this question is all variants. 51.1% of respondents answered correctly and 49% of respondents answered incorrectly.

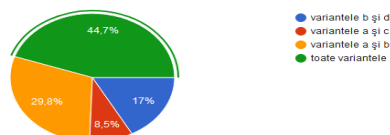
Question number five is the following: "What are ecosystem services?"

- a) Assistance service
 b) Regulation service
 c) Supply service
 d) Cultural service

The variants are: variants b and d; variants a and c; variants a and b; all variants.

5. Care sunt serviciile ecosistemelor? a) Serviciul de asistență b) Serviciul de reglare c) Serviciul de aprovizionare d) Serviciul cultural Vă rog alegeți una dintre variante:

47 de răspunsuri



The percentage in question five is as follows: 17% of respondents answered variants b and d; 8.5% of respondents answered variants a and c; 29.8% of respondents answered variants a and b; 44.7% of respondents answered all variants.

The correct answer to this question is all the options. 44.7% of respondents answered

correctly and 55.3% of respondents answered incorrectly.

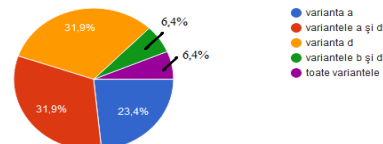
The sixth question is: "What are ecosystem services?"

- a) The totality of the tangible and intangible benefits that natural or anthropogenic ecosystems provide to society
 b) The benefits that terrestrial ecosystems offer to humanity
 c) The benefits obtained from the exploitation of a forest
 d) The many and varied benefits that humans freely gain from the natural environment and from the proper functioning of ecosystems

The answer variants are: variant a; variants a and d; variant d; variants b and d; all variants.

6. Ce reprezintă serviciile ecosistemelor? a) Totalitatea beneficiilor tangibile și intangibile pe care ecosistemele naturale sau antropice le furnizează societății b) Beneficiile pe care ecosistemele terestre le oferă omenirii c) Beneficiile obținute din exploatarea unei păduri d) Beneficiile numeroase și variate pe care oamenii le câștigă în mod liber din mediul natural și din funcționarea în mod corespunzător a ecosistemelor Vă rog alegeți una dintre variante:

47 de răspunsuri



The results are: 23.4% of the respondents answered variant a; 31.9% of the respondents answered variants a and d; 31.9% of the respondents answered variant d; 6.4% of the respondents answered variants b and d; 6.4% of respondents answered all variants.

The correct variant to this question is variant d. 31.9% of the respondents answered correctly and 68.1% of the respondents answered incorrectly.

To the seventh question: "In ecosystem services, what role do you think filamentous fungi play?" ; people have the option to write what they think is the role of filamentous fungi.

Given this aspect, the answers are: they produce enzymes; decompose organic matter; decomposers, recycle nutrients, produce enzymes, participate in mycorrhizal associations; primary producers; role of primary consumers; soil restoration and regeneration; consumers; infection; the role of producing proteins that help form enzymes; degradation of organic matter; of production; the decomposition of organic matter, food for other organisms, balances the ecological system; adjustment; decompose rotten trees; provides self-regulation function; bring water and

nutrients to the plants to the roots; produce plant food; produce plant diseases; decompose dead plants; they are decomposers; a primary role; the role of regulating air and soil quality because they can decompose organic matter; obtaining useful products, natural selection factors; can reduce pollution; assistance services; I do not know.

7. În cadrul serviciilor ecosistemelor ce rol considerați că îndeplinesc fungii filamentosi?
47 de răspunsuri

Produc enzime
Important
Descompun materia organica

Descompunatori, recicleaza substantele nutritive, produc enzime, participa la asociatii tip micorize
Da
Nu stiu
Producători primari.
Rol de consumatori primari
Refacerea și regenerarea solului.
Consumatori
Infectie
Rolul de a produce proteine, care ajuta la formarea enzimelor.
Degradarea materiei organice
Descompun materia organică și produc enzime
De productie
Descompunerea materie organice, hrană pentru alte organisme, echilibrează sistemul ecologic.
Reglare
Descompun copacii putreziti
Asigură funcția de autoreglare
Aduc apa si nutrienti plantelor la radacini
Descompun substante organice
Produc hrana plantelor
Produc boli la plante
Descompun plantele moarte
Sunt descompunători.
Un rol primar.
Hranesc plantele

-----'

Produc enzime, micorize

Sunt descompunatori
Rolul de a regla calitatea aerului și a solului, deoarece ei pot descompune materie organica.
Obținerea de produse utile; factori de selectie naturala
Pot reduce poluarea
Rol in procesele de reglare
servicii de asistenta
Au rol in reglare
Nu știu
Nu stiu

The correct answer is: filamentous fungi have a role in the decomposition of organic matter, produce enzymes of biotechnological interest,

can be used as biological agents to control plant diseases, insects, can be used as biopesticides have the role of producing mycorrhizae and not least row have a role in depollution. 24 respondents answered correctly and 23 respondents answered incorrectly.

Question eight is worded as follows: "What are bioinsecticides?"

a) Products containing plant extracts, viable spores of bacteria or fungi

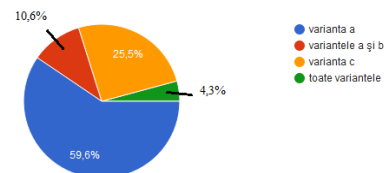
b) Products that are difficult to degrade in nature

c) Products that protect phytopathogenic and phytophagous insects

The answer variants are: variant a; variants a and b; variant c; all variants.

8. Ce sunt produsele bioinsecticide? a) Produse ce conțin extracte din plante, spori viabili de bacterii sau fungi b) Produse care se degradează greu în natură c) Produse care protejează insectele fitopatogene și fitofage Vă rog alegeți una dintre variante:

47 de răspunsuri



We have the following results: 59.6% of the respondents answered variant a; 10.6% of respondents answered variants a and b; 25.5% of the respondents answered variant c; 4.3% of respondents answered all variants.

The correct variant of this question is variant a. 59.6% of respondents answered correctly and 40.4% of respondents answered incorrectly.

Question number nine is: "What are biofungicides?"

a) Products containing plant extracts, viable spores of bacteria or fungi

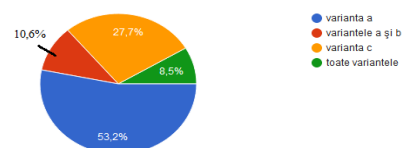
b) Products that are difficult to degrade in nature

c) Products that protect phytopathogenic fungi

The variants to choose are: variant a; variants a and b; variant c; all variants.

9. Ce sunt produsele biofungicide? a) Produse ce conțin extracte din plante, spori viabili de bacterii sau fungi b) Produse care se degradează greu în natură c) Produse care protejează fungii fitopatogeni Vă rog alegeți una dintre variante:

47 de răspunsuri



The results are: 53.2% of the respondents answered variant a; 10.6% of respondents answered variants a and b; 27.7% of the

respondents answered variant c; 8.5% of respondents answered all variants.

The correct variant to this question is variant a. 53.2% of the respondents answered correctly and 46.8% answered incorrectly.

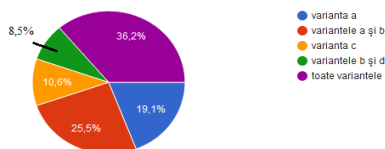
Question number ten is: "In your opinion, what ingredients should bioinsecticides contain?"

- a) Viable spores of filamentous entomopathogenic fungi (entomophagous)
- b) Plant extracts (pyrethrin, neem oil, etc.)
- c) Viable spores of entomopathogenic bacteria
- d) Potassium soap

The variants are: variant a; variants a and b; variant c; variants b and d; all variants.

10. În opinia dvs. ce ingrediente ar trebui să conțină produsele bioinsecticide? a) Spori viabili de fungi filamentoși entomopatogeni (entomofagi) b) Extracte din plante (piretrină, ulei de neem, etc.) c) Spori viabili de bacterii entomopatogene d) Săpunul de potasiu Vă rog alegeți una dintre variante:

47 de răspunsuri



We have the following answers: 19.1% of the respondents answered variant a; 25.5% of the respondents answered variants a and b; 10.6% of respondents answered variant c; 8.5% of respondents answered variants b and d; 36.2% of respondents answered all variants.

The correct variant of this question is all variants. 36.2% of respondents answered correctly and 63.7% answered incorrectly.

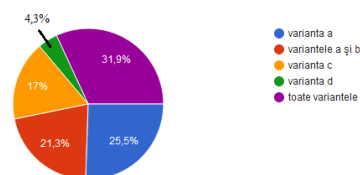
Question number eleven: "In your opinion, what ingredients should biofungicide products contain?"

- a) Viable spores of bacteria with antifungal properties
- b) Plant extracts (macerated plants from spontaneous flora)
- c) Viable spores of filamentous fungi with antifungal properties
- d) Vegetative yeast cells with antifungal properties

The variants are: variant a; variants a and b; variant c; variant d; all variants.

11. În opinia dvs. ce ingrediente ar trebui să conțină produsele biofungicide? a) Spori viabili de bacterii cu proprietăți antifungice b) Extracte din plante (macerate din plante din flora spontană) c) Spori viabili de fungi filamentoși cu proprietăți antifungice d) Celule vegetative de levuri cu proprietăți antifungice Vă rog alegeți una dintre variante:

47 de răspunsuri



The answers obtained are: 25.5% of the respondents answered variant a; 21.3% of the respondents answered variants a and b; 17% of respondents answered variant c; 4.3% of respondents answered variant d; 31.9% answered all variants.

The correct variant is all variants. 31.9% of respondents answered correctly and 68.1% answered incorrectly.

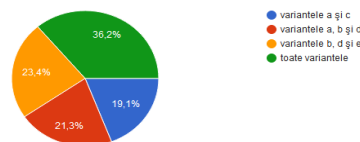
To question number twelve, people must choose one of the options: Anthropogenic activities result in a number of compounds that pollute the environment. Filamentous fungi can be used to depollute different environments due to:

- a) The extracellular and intracellular enzymes they produce
- b) The biosurfactants they produce
- c) Biosorption properties of cell walls
- d) Their great metabolic diversity
- e) The fact that they are ubiquitous and have key roles in the recycling of nutrients

People can choose one of these options: options a and c; variants a, b and d; variants b, d and e; all variants.

12. Activitățile antropice au ca rezultat o serie de compuși care poluează mediul. Fungii filamentoși pot fi utilizați pentru a depolua diferite medii datorită: a) Enzimelor extracelulare și intracelulare pe care le produc b) Biosurfactanților pe care îi produc c) Proprietăților de biosorbție a pereților celulari d) Marii lor diversități metabolice e) Faptului că sunt ubicvitori și au roluri cheie în reciclarea substanțelor nutritive Vă rog alegeți una dintre variante:

47 de răspunsuri



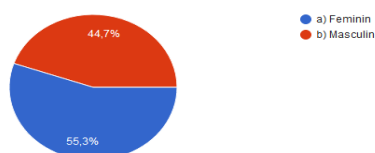
The answers received are: 19.1% of the respondents answered variants a and c; 21.3% of the respondents answered variants a, b and d; 23.4% of the respondents answered variants b, d and e; 36.2% of respondents answered all variants.

The correct variant is all variants. 36.2% of respondents answered correctly and 63.8% answered incorrectly.

Question thirteen concerned the gender of the person completing the questionnaire, female or male.

We find that 55.3% of respondents are female and 44.7% of respondents are male.

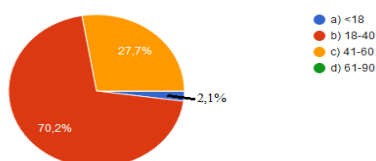
13. Care este sexul dumneavoastră?
47 de răspunsuri



The next question with number fourteen concerns the age category of the person completing this questionnaire.

Here we have a percentage of 2.1% of respondents are under 18, 70.2% who fall between the ages of 18 and 40 and 27.2% of respondents are between 41 and 60 years old.

14. În ce categorie de vârstă vă încadrați?
47 de răspunsuri

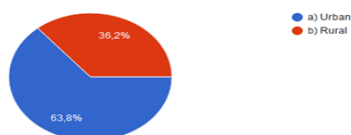


Question number fifteen is, "In what environment do you live?"

The variants are urban and rural.

63.8% of respondents live in urban areas and 36.2% of respondents live in rural areas.

15. În ce mediu locuiți?
47 de răspunsuri



The last question number sixteen concerns the last studies completed.

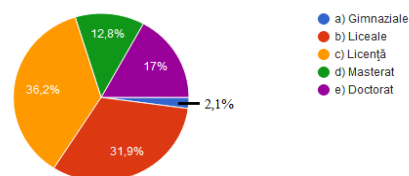
They can choose between:

- a) Gymnasium
- b) High school
- c) Bachelor's degree
- d) Master's degree

e) Doctorate

- 2.1% of respondents answered middle school
- 31.9% of respondents answered high school
- 36.2% of respondents answered license
- 12.8% of respondents answered master's degree
- 17% of respondents answered doctorate

16. Care sunt ultimele studii absolvite?
47 de răspunsuri



This concludes the questionnaire with the 16 questions related to the knowledge or not about the importance and role of filamentous fungi in the terrestrial ecosystem.

CONCLUSIONS

This study is part of the first part of the Dissertation, the documentation part and the study of the specialized literature, and the questions of the questionnaire are based on the study of the specialized literature.

Basically, the goal is to see the degree of knowledge and perception of humans about the role of filamentous fungi in terrestrial ecosystems.

Following this aspect, it is found that most of the respondents who completed the questionnaire know what role filamentous fungi play in an ecosystem, how these organisms interact and what benefits they bring to the soil and plants. Filamentous fungi are important because they have a potential role in bioremediation processes; produce mycorrhizae and are used as biological control agents- bioinsecticides and biofungicides.

In conclusion, respondents understand the importance of filamentous fungi.

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STUDIES ON FINDING RENEWABLE SOURCES OF PLANT BIOSTIMULATION – BIOACTIVE MACERATED EXTRACTS FROM WEEDS

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Abstract

In the scientific literature, there are several definitions of biostimulants. According to Chojnacka et al. 2014 which quotes on Vernieri et al. 2006 and Schmidt et al. 2008: biostimulants are environmental friendly, natural substances which are able to promote vegetative growth, mineral nutrient uptake, plant response to different pedoclimatic conditions and tolerance to abiotic stresses, biostimulants are organic materials that, when applied in small quantities, enhance plant growth and development such that the response cannot be attributed to application of traditional plant nutrients.

*In this paper we present the results obtained from experiments that took place both in the laboratory, greenhouse and in the field. Through these experiments we wanted to test the capacity of bioactive macerated extracts from weeds, plants from the spontaneous flora of Romania, such as comfrey - *Symphytum officinale*, horsetail - *Equisetum arvense*, nettle – *Urtica dioica*, dandelion – *Taraxacum officinale*, to stimulate the germination, growth and development of pepper seeds and tomato seedlings. We made the macerates from the plants from the spontaneous flora from our country according to the data found in the specialized literature with small differences and adaptations that we present to Materials and methods.*

The results obtained by us are encouraging because finding renewable sources of plant biostimulators is important in the context of modern agriculture, which seeks non-polluting solutions to replace polluting products - synthetic chemical fertilizers, pesticides, etc.

Key words: *bioactive macerated extracts, comfrey - *Symphytum officinale*, dandelion – *Taraxacum officinale*, germination, horsetail - *Equisetum arvense*, nettle – *Urtica dioica*, plant stimulation, renewable sources, weeds.*

INTRODUCTION

Anthropogenic climate change, namely climate alterations induced by human activities, is causing some issues to agricultural systems for their vulnerability to extreme events. Forecasts predict a global population increase in the near years that will exacerbate this situation, elevating the global demand for food. It will pose severe concerns in terms of natural resource usage and availability. Agriculture is one of the anthropogenic activities that will be more affected in the future. Climate extremes menace to affect the quantity and quality of crop production severely. Drought, water and soil salinity are considered among the most problematic factors that anthropogenic climate change will increase. This complex and worrying scenario requires the urgent implementation of sustainable measures which

are capable of improving crop yield and quality, fostering the robustness and resilience of cropping systems (Del Buono, 2021).

Del Buono in his paper emphasizes the importance of finding quick solutions to counteract the negative anthropogenic effects on agriculture. Among the more current methodology, the use of natural plant biostimulants has been proposed to improve plant resistance to abiotic environmental stresses. The advantage of using these substances is due to their effectiveness in improving crop productivity and quality.

In the scientific literature, there are several definitions of biostimulants. According to Chojnacka et al. 2014 which quotes on Vernieri et al. 2006 and Schmidt et al. 2008 biostimulants are environmental friendly, natural substances which are able to promote vegetative growth, mineral nutrient uptake, plant response to

different pedoclimatic conditions and tolerance to abiotic stresses, biostimulants are organic materials that, when applied in small quantities, enhance plant growth and development such that the response cannot be attributed to application of traditional plant nutrients.

Plant biostimulants attract interest in modern agriculture as a tool to enhance crop performance, resilience to environmental stress, and nutrient use efficiency. Plant biostimulants encompass diverse organic and inorganic substances (humic acids and protein hydrolysates) as well as prokaryotes (e.g., plant growth promoting bacteria) and eukaryotes such as mycorrhiza and macroalgae (seaweed). Global demographic pressure on agricultural production calls for novel and sustainable approaches toward satisfying the ever-growing demand for plant biomass destined for human food, animal feed, and energy production (Puglia et al., 2021). Conventional agricultural practice has relied overwhelmingly on non-renewable inputs of fertilizers and pesticides (Panfili et al., 2019). Although their introduction has allowed substantial progress for humankind, agro-chemicals also pose a serious, unresolved threat to human health and the environment. Moreover, supply and application of these inputs is becoming increasingly costly because of resource depletion and the increasing global demand for mineral fertilizers. Finally, the use of chemical inputs in agriculture is restricted by a tightening legal framework because of mounting public concern. Plant biostimulants can play a pivotal role in addressing sustainability challenges because they can reduce dependency on fertilizers, especially on off-farm chemical inputs. Moreover, plant biostimulants are also useful to improve yield and its stability under environmental stress (Chiaiese et al., 2018, De Pascale et al., 2018). Preparation of plants, weeds in our case, for experimental purposes is an initial step and key in achieving quality research outcome. It involves extraction and determination of quality of bioactive constituents before proceeding with the intended biological testing. Although the extracts, bioactive fractions, or compounds obtained from plants are used for different purposes, the techniques involved in producing them are generally the same irrespective of the intended biological testing. The major stages

included in acquiring quality bioactive molecule are the selection of an appropriate solvent, extraction methods, phytochemical screening procedures, fractionation methods, and identification techniques. The nitty-gritty of these methods and the exact road map followed solely depends on the research design. Solvents commonly used in extraction of plants are polar solvent (e.g., water, alcohols), intermediate polar (e.g., acetone, dichloromethane), and nonpolar (e.g., n-hexane, ether, chloroform). In general, extraction procedures include maceration, digestion, decoction, infusion, percolation, Soxhlet extraction, superficial extraction, ultrasound-assisted, and microwave-assisted extractions (Abubakar and Haque, 2020). Maceration is an extractive technique that is conducted at room temperature. It consists of immersing a plant in a liquid (water, oil, alcohol, etc.) inside an airtight container, for a variable time based on the plant material and liquid used. Before being processed, the plant must be properly washed and separated from foreign material such as topsoil, pebbles or rocks and materials non-suitable for extraction. The plant material can be used fresh or dry based on the desired product. In order to increase contact between the plant material being extracted and the liquid (solvent), the plant needs to be cut into small pieces. The pieces should not be too big, otherwise the solvent will not be able to penetrate the innermost cells. They also should not be reduced to powder; that would result in losing the volatile active ingredients (essential oils) contained inside the plant, and also losing the difficult separation by filtration of the plant material from the liquid used once maceration is completed. The solvent must be chosen based upon the chemical nature of the compounds contained within the plant. Solubility and the desired use of the extraction should be considered when choosing the solvent. That is, recognizing their solubility and the desired use of the extraction. Generally, alcohol is the most used substance because it is able to extract a greater part of the molecules (active ingredients) contained within the plant, including molecules which are hydrophilic, soluble in water, or lipophilic and therefore, soluble in oil or other organic solvents. One uses a vegetable oil when one wants to isolate only the lipophilic components (fats), while water is used to extract

only hydrophilic ingredients. (<https://albrigiinherba.com/contacts/extraction/maceration/>)

MATERIALS AND METHODS

Making organic fertilizer based on macerated plants from spontaneous flora

In order to make ecological fertilizers based on macerates from plants from spontaneous flora, bioactive macerated extracts from weeds, we went through the following steps:

1. we chopped the plants (comfrey - *Symphytum officinale*, horsetail - *Equisetum arvense*, nettle – *Urtica dioica* and dandelion – *Taraxacum officinale* leaves) put them in a bucket, then added water and covered with a lid.
2. Mixing daily the maceration for aeration.
3. The mixture is left to soak for a few days to 1 week until the fermentation process ceases, a process that depends on the outside temperature.
4. After fermentation ceases, the plant material is allowed to decant and then it can be used as such or diluted for foliar applications to tomatoes, eggplants, peppers, etc., in the field, greenhouse, solarium or lab.

***In vitro* experiments**

For in vitro experiment we used organic fertilizer based on bioactive macerated weed extracts in the Ecology and Microbiology laboratory of the F.I.F.I.M. within the U.S.A.M.V. Bucharest to demonstrate the power of stimulating the germination and development capacity of some capsicum seeds. The laboratory experiment was conducted in 2019 starting with March and was carried out as follows:

1. In two containers we put forest soil from Băneasa forest that contained microorganisms (bacteria, fungi, etc.) with a role in stimulating the growth and development of plants by producing enzymes, growth hormones and 100 capsicum seeds.
2. After sowing, the control was watered two or three times a week with sterile distilled water, and the sample was watered with the ecological fertilizer obtained by macerating the plants from

the spontaneous flora, bioactive macerated extracts from weeds.

Determination of N, P, K concentrations of organic fertilizer obtained from plant macerates from spontaneous flora

Using the Hanna Instruments analysis kit, we determined the N, P, and K concentrations of the organic fertilizer obtained.

***In vivo* experiments**

The in vivo experiments took place in a vegetable garden in Tamasi village, Corbeanca commune, Ilfov county. The aim of the in vivo experiments was to achieve an organically grown tomato crop and to highlight the ability of plant bioactive macerated extracts from weeds, herbal macerates from spontaneous flora, to feed plants properly and to fight phytopathogenic fungi of the species *Phytophthora infestans* that cause manna to plants in tomatoes, a disease that is frequently recorded in solariums, greenhouses and in the field and that causes significant damage to crops, the affected plants must be removed and destroyed.

The tomato variety chosen for this experiment was the Cristal F1 hybrid, which is an early tomato variety, with undetermined growth, intended for cultivation in greenhouses and solariums, but which we cultivated in open space in the garden, not in protected space, to test its ability to adapt to outside conditions. For planting we used F1 Crystal seedlings, which were planted in the garden between April 23 and April 25, 2020.

RESULTS AND DISCUSSIONS

Making organic fertilizer based on macerated plants from spontaneous flora



Figure 1. Mixing chopped plants with water



Figure 2. Daily mixing for aeration of the macerate



Figure 3. The accumulation of foam on the surface of the container marks the maximum of the maceration fermentation process

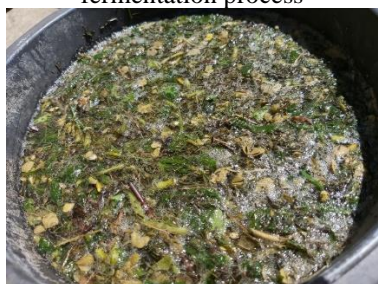


Figure 4. Cessation of the fermentation process



Figure 5. Decantation of plant material



Figure 6. Preservation of organic fertilizer based on bioactive macerated weed extracts in recyclable containers

In vitro experiments



Figure 7. Germination of Control pepper seeds



Figure 8. Germination of pepper seeds Sample



Figure 9. Control capsicum seeds in forest soil containing microorganisms with a role in stimulating plant growth and development



Figure 10. Sample of capsicum seeds treated with organic fertilizer based on macerates from plants from spontaneous flora and forest soil containing microorganisms with a role in stimulating plant growth and development



Figure 11. Control (left) and Sample (right)

Determination of N, P, K concentrations of organic fertilizer obtained from plant macerates from spontaneous flora

Using the Hanna Instruments analysis kit, we determined the N, P, and K concentrations of the organic fertilizer obtained. The images below show the results of the laboratory tests using the Hanna Instruments colorimetric analysis kit for

the qualitative determination of N (nitrogen), P (phosphorus), K (potassium or potassium).

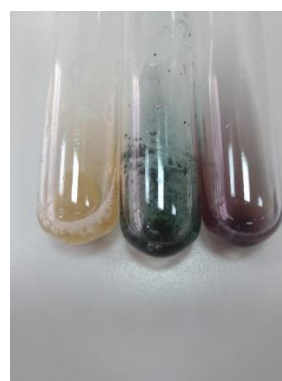


Figure 12. Determination of N, P, K from right to left

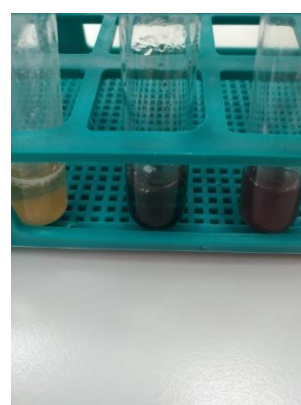


Figure 13. The stand with the test tubes for determining N, P, K from right to left

The results of the analyzes N, P, K show us that the ecological fertilizer based on plant macerates from the spontaneous flora obtained is rich in these macroelements essential for the healthy and harmonious growth and development of plants.

By testing the germination capacity of capsicum seeds and the growth and development of seedlings we demonstrated the effectiveness of organic fertilizer, observing from the photos of the experiments the big differences between Control containing only forest soil with beneficial microorganisms in the category PGPM (Plant Growth Promoting Microorganisms) and Sample containing in addition to the same type of soil and organic fertilizer based on plant macerates from spontaneous flora.

In vivo experiments

Carrying out cultural treatments - application of vegetable fertilizer and phytosanitary treatments

We used the fertilizer thus obtained in the garden for foliar spraying on tomato plants of the variety Cristal F1 diluted 1: 2, 1 part fertilizer and 2 parts water and undiluted to water the soil from each nest at the base of the package of tomato plants.

We performed a leaf spray and one at the base of the plants 5 days after the time of planting the seedlings, then when the flowers began to appear, then when the plants began to bear fruit and a last treatment when the fruits began to ripen. So in total we performed four spray treatments.

For the protection of plants against phytopathogenic fungi of the species *Phytophthora infestans* that cause late blight of tomatoe, a particularly dangerous disease with very great economic damage, we used Bordeaux juice (bouille-Bordelaise), which is a highly effective cupric fungicide containing 20% copper metallic and 80% neutralized copper sulfate. Being perfectly neutralized, micronized, it has a long effectiveness and is one of the phytosanitary products accepted in organic farming.

We applied phytosanitary treatments as preventive foliar to tomato plants 10 days after planting the seedlings, then immediately after the first signs of attack appeared on the leaves of some tomato plants. We prepared a Bordeaux juice solution using 75 g of blue powder mixture in 10 liters of water. With the solution thus obtained we sprayed all the plants with the help of vermorel.

Next we will present the experimental field with Cristal F1 tomatoes grown in the garden in an uncovered space in an ecological system.



Figure 14. Cristal F1 tomato plants grown organically (the first 4 floors with the fruits formed on each plant can be observed)



Figure 15. Detail tomato bunches on the “first floor”



Figure 16. The first signs of attack with *Phytophthora infestans* (top right - leaf affected)



Figure 17. Application of phytosanitary treatment with Bordeaux mixture at the first signs of attack with late blight of tomato



Figure 18. Growing and ripening tomatoes from the first floor of the Cristal F1 variety grown organically



Figure 19. The harvest was very rich due to the treatment with bioactive macerated extracts from weeds

CONCLUSIONS

Our experimental studies testing the action of bioactive macerated extracts from several weeds, under open-field, greenhouse and lab conditions, have demonstrated that they stimulate germination, seedling growth, shoot, and root biomass in crops such as tomato and pepper.

In the coming years, research efforts should focus on: elucidating the bioactive macerated extracts from weeds \times plant species \times environment interaction, in order to select optimal combinations; optimizing application parameters (timing, mode, rate of application, and plant developmental stage); quantitative and qualitative characterization of microbial communities as modulated by bioactive macerated extracts from weeds utilized as plant biostimulants; determining the persistence of effects subsequent to bioactive macerated extracts from weeds foliar application; the impact of climatic (radiation and relative humidity) and plant morphological factors (cuticle thickness and leaf permeability) on the effectiveness of bioactive macerated extracts from weeds.

In this paper we present the results obtained from experiments that took place both in the laboratory, greenhouse and in the field. Through these experiments we wanted to test the capacity

of bioactive macerated extracts from weeds, plants from the spontaneous flora of Romania, such as comfrey - *Symphytum officinale*, horsetail - *Equisetum arvense*, nettle – *Urtica dioica*, dandelion – *Taraxacum officinale*, to stimulate the germination, growth and development of pepper seeds and tomato seedlings. We made the macerates from the plants from the spontaneous flora from our country according to the data found in the specialized literature with small differences and adaptations that we present to Materials and methods.

The results obtained by us are encouraging because finding renewable sources of plant biostimulators is important in the context of modern agriculture, which seeks non-polluting solutions to replace polluting products - synthetic chemical fertilizers, pesticides, etc.

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SHORT REVIEW OF MUNICIPAL SOLID WASTE RECYCLING IN ROMANIA AND IN THE EU

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Abstract

Waste management includes all activities of collection, transport, treatment, recovery and disposal of waste, including supervising of such operations. The framework law that regulates waste management activities in Romania is Law no. 27/2007, approving Government Emergency Ordinance no. 61/2006, amending and supplementing Government Emergency Ordinance no. 78/2000 on waste regime. This paper presents the importance of waste recycling, a comparison between Romania and other EU countries. With waste recycling we save a lot of energy, we can reduce the amount of waste to save our nature.

Key words: municipal waste, recycling, Romania's situation, selective collection.

INTRODUCTION

Waste recycling saves energy, reduces pollution, reduces the waste quantity and conserves our planet. Any individual or resident can call the local authorities to install waste collection containers.

The problem is that in Romania selective waste collection is not so popular. According to the Council Directive (1975) of the European Union (art. 1 Directive 442/75), waste is defined as any substance of various nature (organic/ inorganic solids/ liquids /gases, or combinations thereof), resulting from industrial processes, agricultural activities, road or water flows, household activities/municipal or domestic activities or objects which the holder discards or intends to throw/make a collection space for storage transport.

The technological progress in the field allowed, according to the concept of sustainable development, to make a fundamental change in considering waste as garbage (things/objects to be thrown away). During time, this definition has changed in terms of consistency, so that the Waste Framework Directive (EC Directive, 2008) sets the fundamental concepts and definitions associated to waste management, such as definitions of waste, recycling, recovery.

This framework generates the opportunity to consider waste as a source of raw materials and renewable energy.

MATERIALS AND METHODS

Of all European countries, Romania recycled only 14% of its municipal waste for the last 8 years; the rest was thrown in landfills.

Regarding the management of waste in Romania we can distinguish three main categories of waste and this can be divided into three categories:

Municipal and similar waste: the totality of waste generated in the urban and rural areas, which comes from households, institutional and commercial sources, service providers (household waste), street waste collected from public spaces, streets, parks, green spaces, construction and demolition waste, sludge from the treatment of urban waste waters;

Production waste: the totality of waste generated by industrial activities; it falls into two categories: non-hazardous production waste and hazardous production waste;

Waste generated by medical activities: this is waste generated in hospitals, clinics, medical offices and it falls into two categories: - hazardous medical waste which includes infectious waste, medical sharps, pathological

wastes, including organs, waste coming from infectious disease departments, etc. and - similar wastes, including other categories of waste outside the categories mentioned above, falling into the category of similar wastes.

During the last years, the ratio between the first two categories varied from one year to another, the average values being 29% municipal waste and 71% production waste.

RESULTS AND DISCUSSIONS

Waste sorting and recycling is increasing annually; by 2013 the aim was to reach European standards. The goal was to reach a 38% by 2009, 42% by 2010, 46% by 2011. In 2010 paper recycling was 60%, 14% plastic, 44% glass and 50 % metal recycling. If Romania would have missed its targets, risked to be fined with a daily 200.000 Euros. Since 2005, Romania is required by European law to recycle a certain percentage of waste. Being a member of the EU has to collect and recycle 80.000 tons of waste annually coming from electric and electronic waste-WEEE (4kg of WEEE/capital). Since 2007, the Ministry of Environment of Romania initiated a movement, the National Campaign of Collecting WEEE waste under the name of 'The Great Disposal'. The largest IT and electronic recycling factory in Romania is owned by GreenWEEE, in Fasinu, near Buzau. The recycling capacity is 50.000 tons of waste. According to the National Agency of Romania for Environmental Protection, in 2007, the total amount of packages placed on the market was over 1.25 million tons, out of which nearly 400.000 tons were recycled (about 30%- the objective was 28%).

The amount of municipal waste coming from the Romanian people is 8 million tons yearly:

- 210.500 tons of glass;
- 235.200 tons of paper and cardboard;
- 236.500 tons of plastic;
- 104.700 tons of metal;

In 2007, 60% of waste packaging came from the population. In 2005 the amount of packaging on the market was 1.14 million tones, 305.000 tones out of it, 26,6% was recovered, and 265.000 tones were recycled, 23% recycling rate. The amount of recovered packaging in 2006 increased to 525.00 tones.

In 2009, EU legislation obligates merchants to take back and salvage 45% of all packaging placed on the market, this led to a 60% of all packaging in 2013.

The first National Waste Management Strategy was elaborated in 2003, and published in early 2004, as a result of the transposition of European legislation in the area of waste management and according to the provisions of the Emergency Government Ordinance no.78/2000 on the regime of waste, approved in 2001. The strategy is based on the principle of protection of primary resources, the prevention principle, 'the polluter pays' principle correlated with the principles of producer and user responsibility, the substitution principle, and the principle of proximity correlated with the principle of autonomy.

In 2004, the National Waste Management Plan was elaborated accompanied, in 2006, by the Regional Waste Management Plans for the eight Romanian regions, so as to ensure all the required measures to achieve the objectives of the strategy. The waste situation in Romania is under the supervision of the Ministry of Environment and Climate Change and the National Environmental Agency.

The responsibility for the collection and management of municipal solid waste belongs to the municipalities (Almasi, 2013; Schiopu et al., 2012). In a report prepared for the European Environment Agency, Almasi (2013), showed that, "by 2009, 63% of the population in Romania benefited from collection services; this consisted of 4 % in the urban areas and only 38% in rural areas. A total of 6 296 000 tonnes of waste was collected and treated in 2009".

By 2015, Romania should have closed 150 old municipal landfills and 1,500 illegal dumpsites, and should have established 30 national integrated solid waste management (SWM) systems.

The EU legislation and standards for waste management were transposed into national legislation, with some transition periods for full compliance: 2017 for municipal landfills; 2009 for temporary storage of hazardous industrial waste; and 2013 for non-hazardous industrial waste.

Around 90 percent of urban residents, but only 6.5 percent of the rural population have access to organized solid waste management services. Government cost estimates for meeting EU

norms are EUR1.8 billion—or investments of about EUR25-30 million per county, creating a funding gap of at least EUR870 million. ERDF grants will provide only up to EUR930 million to execute the municipal waste axis of OP Environment.

There are 13 organizations in the country responsible with put into action the extended manufacturer liability policy for packaging placed on the Romanian market, known as OIREPs. Among them are names like Clean Recycle, Eco Synergy, Fepra International, Greenpoint Management, and Enviro Pack Consult.

OIREPs work with Intercommunity Development Associations (ADIs); there are currently 39 ADI organizations founded in Romania for integrated waste management at county level. In most counties, ADIs are organized by the county councils and town halls, the institutions dealing with waste management in their areas.

County councils are the beneficiaries of Integrated Waste Management System (SMID) projects, while ADI manage project implementation. At the country level, 32 integrated waste management projects have been approved to finance prevention, separate collection, waste treatment, recycling, recovery and disposal, simultaneously with the closure of non-compliant landfills.

Through the SMID projects carried out in most of Romania's counties, investments were made in sanitation infrastructure, specifically in waste collection equipment, individual composting units, composting plants, treatment plants, TMB installations, sorting plants, transfer stations and compliant warehouses.

The tasks of ADIs regarding SMID projects are to implement proposals by establishing or extending, organizing, managing, and operating services for the common interest, including delegating management based on the conditions of delegation contracts or public procurement procedures, in accordance with the law.

While defining the roles and responsibilities of ADIs and OIREPs within the extended manufacturer liability schemes, OIREPs must assure the recycling/recovery of municipal packaging waste, which gets collected, transported, and sorted by the Administrative Territorial Unit (UAT) based on an official

collaboration agreement. OIREPs must pay the UAT/ADI the full amount of the net costs related to the separate collection, transport, and sorting of municipal packaging waste as well as to the financing of awareness campaigns to promote waste recycling/recovery.

In the case of UATs, for some types of sorted packaging waste, which represent materials with a negative market value, the responsibility lies entirely with the OIREPs, which must provide recycling/recovery of materials, including transport logistics, at their own expense.

The collaboration between ADIs and OIREPs is deficient, mainly as a result of the misinterpretation or non-application of legislative requirements and a misunderstanding of each party's responsibilities.

The main issues identified in the collaboration between UAT/ADIs and OIREPs are: the separate tariffs for recyclable waste management, used to calculate the net costs paid by OIREPs, are not correctly substantiated; OIREPs only pay for the amount of packaging waste that actually gets recovered and not for the full amount that gets collected and sorted, which leads to lower revenues for UAT/ADIs, given the very low recycling/recovery rates; UAT/ADIs do not calculate users' separate revenues, ultimately paying more for the management of recyclable waste than for the management of other types of waste. In this context, only 7 ADIs – Arges, Calarasi, Iasi, Mures, Olt, Salaj, and Sibiu – have contracts in place with OIREPs.

CONCLUSIONS

Therefore, now, the recycling rate of municipal waste reached 13.89 percent, totalling 739,384 tonnes, according to the Annual Report on the State of the Environment for 2018 issued by the National Environmental Protection Agency (ANPM). According to the information available in the National Waste Management Plan (PNGD) during the analysis period, the degree of separate collection of municipal waste varied between 3.2 percent and 5.3 percent. Both the ANRSC (National Regulatory Authority for Community Public Utility Services) and the GNM (National Environmental Guard) performed checks among UATs regarding the application of waste management legislation.

The SMID master plan has been developed and approved in the following counties: Alba, Arad, Arges, Bacau, Bihor, Bistrita Nasaud, Botosani, Braila, Calarasi, Caras-Severin, Cluj, Constanta, Covasna, Dambovita, Dolj, Giurgiu, Gorj, Harghita, Hunedoara, Iasi, Maramures, Mehedinti, Mures, Neamt, Olt, Prahova, Satu Mare, Salaj, Sibiu, Suceava, Teleorman, Timis, Tulcea, Vaslui, Valcea, and Vrancea.

In conclusion, according to the Environment Ministry, there are 12 municipal landfills that still need to be closed. Ten administrative-territorial units (UATs) have requested funding to shut down their landfills through the designated programme, which is managed by the Environmental Fund Administration (AFM), and all these applications have already been approved in 2019, the GNM carried out 39,429 inspections related to pollution control and biodiversity, biosecurity, and protected natural areas, reaching a 110 percent completion rate for its initial inspection plan for the year.

As a result of the checks, 1,575 warnings and 3,288 fines were handed out, to the total of RON 55.6 million. Furthermore, 219 shutdown orders

and 44 criminal complaints resulted from the inspection operations.

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THE ROLE OF THE SOIL MICROBIOTA IN PROVIDING ECOSYSTEM SERVICES

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Abstract

Ecosystem services are the many and varied benefits that people freely gain from the natural environment and the proper functioning of ecosystems. Such ecosystems include, for example, agroecosystems, urban ecosystems, forest ecosystems, pasture ecosystems and aquatic ecosystems, etc. Collectively, these benefits are known as ecosystem services.

In this paper we wanted to highlight the very close link between the relationships of soil microorganisms, soil microbiota and the optimal functioning of agroecosystems, which is reflected in the rich harvest obtained in both households presented as case studies.

Due to the systems of good agricultural practices which are respected in both households presented in the case study, the functioning of agroecosystems is optimal and this is reflected both in soil health - expressed as biodiversity and the functioning of microorganisms and in plant health.

Key words: ecosystem services, soil microbiota.

INTRODUCTION

Ecosystem services concept - ecosystems have potential to supply a range of services that are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et al., 1997; Millennium Ecosystem Assessment (MEA), 2005; TEEB Synthesis, 2010). Different ways of defining ecosystem service have been developed so far – they can be described as the benefits that people obtain from ecosystems (MEA, 2005) or as the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). More recent publications define the ecosystem services (ES) as contributions of ecosystem structure and function (in combination with other inputs) to human well-being (Burkhard et al., 2012; Burkhard B. & Maes J. Eds., 2017). Ecosystem services, outputs, conditions, or processes of natural systems that directly or indirectly benefit humans or enhance social welfare. Ecosystem services can benefit people in many ways, either directly or as inputs into the production of other goods and services. For example, the pollination of crops provided by bees and other organisms contributes to food production and is thus

considered an ecosystem service (Johnston, 2018).

Aislabie and Deslippe discussed the roles of microbes in the ecosystem services provided by soils to humans. The diversity of microbes in soil is enormous and they drive many soil services. They examined the functional, metabolic, and phylogenetic diversity of soil bacteria, archaea, and fungi. The roles of these soil microbes are highlighted in the cycling of major biological elements (C, N, P), in the recycling of wastes, and the detoxification of environmental pollutants. Microbes play a pivotal role in the cycling of nitrogen; they exclusively mediate nitrogen fixation, denitrification, and nitrification. They also discussed recent theoretical advances in understanding of ecosystem processes that were made possible through explicit consideration of the roles of soil microbes (Aislabie and Deslippe, 2013).

Soil is considered as one of the most competent ecosystems for subsistence of microorganisms. Soil microbial community structure and activity depend largely on structure and status of soil habitat. Diverse heterotrophic microbial communities in soil along with their complex

web of interaction facilitate the cycling of micro- and macro-nutrients in soil ecosystem. The demand of sustained plant productivity is achieved through managing soil fertility. The dynamic relationships between different components, living or nonliving, of agroecosystem control the richness of plants or crops. In turn, soil organic matter is influenced by the inputs from plants and also their chemistry makes each ecosystem somewhat unique in its microbial community. Though the role of soil microbiome is widely known, we still have limited understanding of its complexity. Thus, understanding the microbial diversity will enhance our ability of increasing agricultural production (Baliyarsingh et al., 2017).

The soil consists of a plethora of both biotic and abiotic matter and provides the medium for plant growth, habitat for microorganism, which plays an important role in maintaining and contributing to the ecosystem service. The soil microbial community is an important component as they are involved in organic matter decomposition, nutrient cycles, and soil health. Likewise, enzymes in soil are also known for substantial role in energy transfer, catalyzing reactions necessary for all life processes, and also used as indicator of soil health. Soil microbes and enzyme are co-dependent with one another enhancing soil fertility by increasing the nutrient availability for plant growth. For instance, microbes like bacteria, fungi, and algae form association with soil rhizosphere like plant growth-promoting rhizobacteria which regulate plant growth by producing hormones and protect plant from disease-causing pathogen. (Jamir et al., 2019)

In this paper we wanted to highlight the very close link between the relationships of soil microorganisms, soil microbiota and the optimal functioning of agroecosystems, which is reflected in the rich harvest obtained in both households presented as case studies.

Due to the systems of good agricultural practices that are observed in both households presented in the case study, the functioning of agroecosystems is optimal and this is reflected both in soil health - expressed as biodiversity and the functioning of microorganisms and in plant health.

MATERIALS AND METHODS

Chemical analysis of soil samples

For the analysis of soil samples from the two households in the case study we used the colorimetric and turbidimetric qualitative analysis kit from Hanna Instruments pH. Soil can be acid, neutral, or alkaline. Each plant has a range of pH in which it thrives and most plants prefer conditions near the neutral mark (pH 5.5-7.5). There are however plants that prefer acid or alkaline environments. The solubility of the nutrients, that is the ability of the plants to absorb them, depends largely on their pH value. The soil microbiological activity is also pH dependent. Most bacteria, especially those putting nutrients at the plants' disposition, prefer moderately acid or slightly alkaline conditions. The pH level hence influences the fertility of the soil.

Nitrogen (N). Nitrogen is an indispensable element for the growth of vegetation and is a key factor in fertilization. A correct quantity of Nitrogen allows a healthy growth of the entire structure and in particular creates a thriving and greener plant. An excess of Nitrogen on the other hand, weakens the plant's resistance creating an unbalanced relationship between the green parts and the stems and trunk.

Phosphorus (P). Phosphorus contributes to the formation of buds, roots and blooming as well as lignification. A lack of phosphorus results in a stifling of plant.

Potassium (K). Potassium plays an important role in how much water is absorbed by the roots and the regulation of cellular activity. In addition, Potassium makes plants more resistant to disease and yields a positive effect on the color and fragrance in flowers.

Test procedure

Reading the Color-Card The pH, phosphorus (P₂O₅), and nitrogen (NO₃) tests use colorimetric methods of testing. The color developed corresponds to the soil fertility. To figure out the fertility, the color which appears must then be compared against the Color-card. To match the color, hold the tube containing the test solution approximately 2 cm away from the color-card. Stand with a light source behind the card and match the test tube color to that of the Color-card to read: Trace, Low, Medium or

High. If the color of the test tube falls between two standard colors, e.g. between Medium and High, the test result is then Medium-High. Eight different readings are possible, Trace, Trace-Low, Low, Low-Medium, Medium, Medium-High, High, and very-High.

The potassium (K_2O) test utilizes a turbidimetric method. To obtain the test results, rest the tube against the Color-card over the reading area. Stand with the light source behind your back. Start at Trace, look through the tube, and go to Low, Medium or High until you see the white line in the middle of the reading area of the Color-card. The test result is obtained in Trace, Low, Medium or High.

Performing the test

General Extraction Procedure

Add the following to a clean Berzelius jar:

Field soil: 1.5 cup of soil and 8 cups of water

Garden soil: 1 cup of soil and 8 cups of water

Greenhouse soil: 1 cup of soil and 16 cups of water For best results, use bottled or distilled water. Stir or shake gently for at least one minute and make sure that all the soil is moistened. Allow to stand until the soil settles (from 30 minutes to 24 hours depending on the soil texture). The clearer the extract becomes, the better the results, however, a little cloudiness will not affect the accuracy of the test.

Nitrogen (NO_3) test. Use the pipette to transfer 2.5 mL of the clear general soil extract (above) to a clean test tube. Add the content of one packet of HI 3895N-0 Nitrogen reagent to the tube, replace the cap and shake well for 30 seconds to dissolve the reagent. Allow the tube to stand for 30 seconds, match the pink color with the Nitrogen color-card.

Phosphorus (P_2O_5) test. Use the pipette to transfer 2.5 mL of the clear general soil extract (see above) to a clean test tube. Add the contents of one packet of HI 3895P-0 Phosphorus reagent to the tube, replace the cap and shake well for 30 seconds to dissolve the reagent. Match the blue color against the Phosphorus color-card for the P concentration.

Potassium (K_2O) test. Use the pipette to add 0.5 mL of the clear general soil extract (above) to a clean test tube. Fill the tube to the lower graduation mark (2.5 mL) with water. Add the content of one packet of HI 3895K-0 Potassium reagent to the tube, replace the cap and shake well for 30 seconds to dissolve the reagent.

Match the test tube against the Potassium reading-card.

Fertilizers used as inputs for household vegetable crops

Fertilizers used as inputs are manure from cattle - compost used as maceration or diluted with water, or as such, wood ash, eggshells and nettle maceration

Nettle macerate

One kg of nettles to 10 liters of water, then leave to soak for a week, then put a liter of macerated to 9 liters of water and water the plants at the root or sprinkle with foliar applications.

RESULTS AND DISCUSSIONS

The in situ and in vivo experiments were performed in two households, one of the Nicula family from Aldești village, Golești commune, Vâlcea county and the other of the Niculae family from Crivăț village, Crivăț commune, Călărași county, and the in vitro experiments were performed in the laboratory of Ecology and Microbiology within the Faculty of Land Improvements and Environmental Engineering of the University of Agronomic Sciences and Veterinary Medicine Bucharest, which is equipped with the apparatus, equipment and reagent kits necessary to perform microbiological, ecological, biochemical and biophysical determinations.

Microbiological analysis of soil samples



Figure 1. Microscopic image of the soil sample highlights the presence of bacteria, protozoa and yeast in

addition to soil particles used as fertilizer based on microorganisms



Figure 2. Microscopic image of the soil sample highlights the presence of bacteria, yeasts and fungi used as fertilizer based on microorganisms



Figure 3. Microscopic image of the soil sample highlights the presence of bacteria, yeast and fungi used as fertilizer based on microorganisms

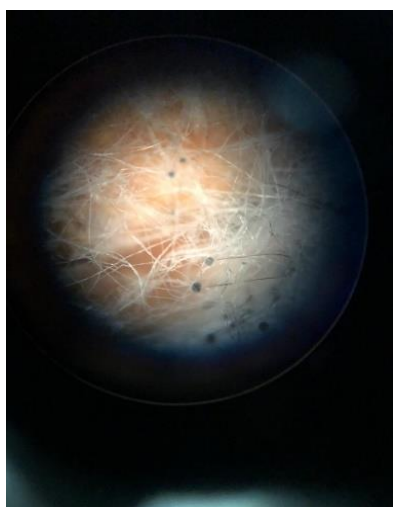


Figure 4. Stereomicroscopic image of the soil sample highlights the presence of hyphae and fruiting bodies - conidiophores of edaphic fungi

Results of chemical qualitative analyzes of soil samples

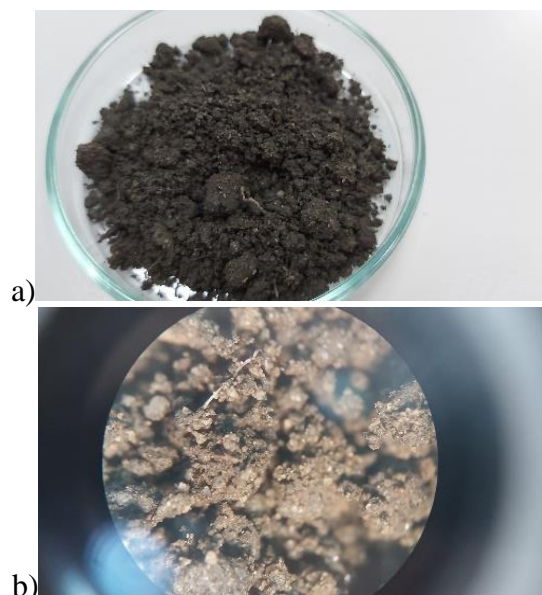


Figure 5. Soil samples a) macro b) stereomicroscopic



Figure 6. Oana Roxana Niculae during the qualitative determinations at the soil samples in the laboratory

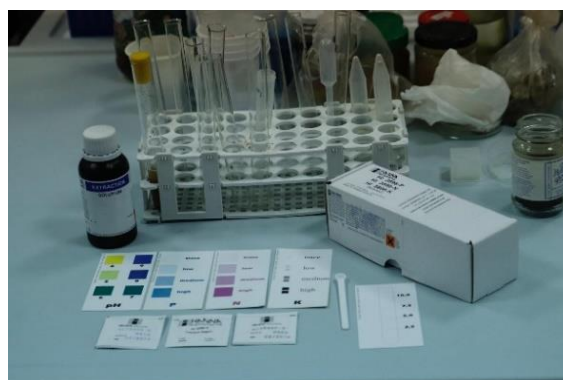


Figure 7. Hanna Instruments N, P, K analysis kit for soil sample analysis

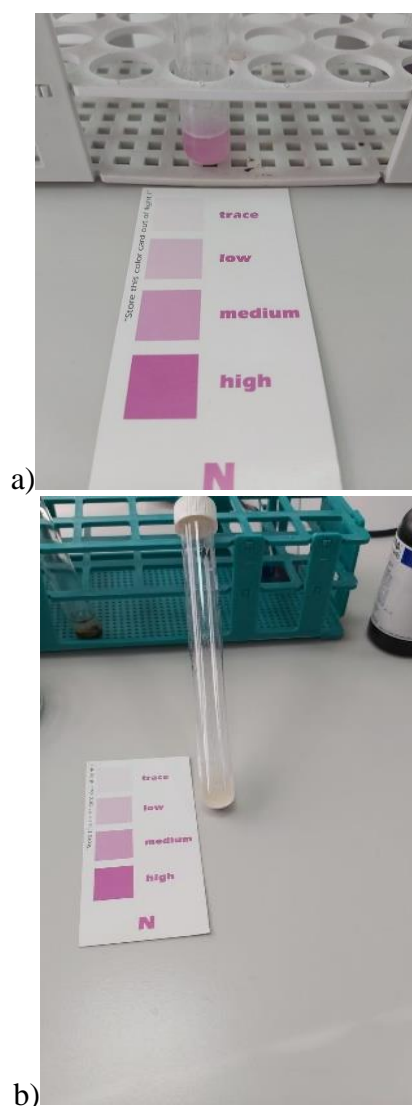
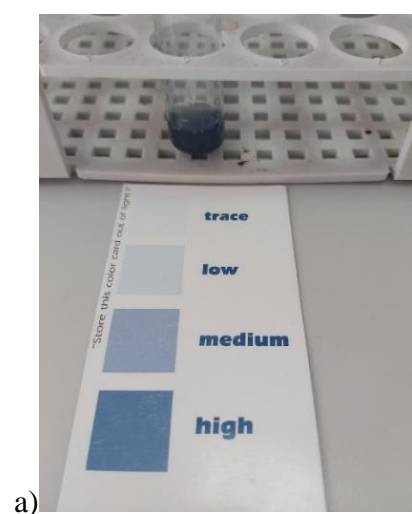
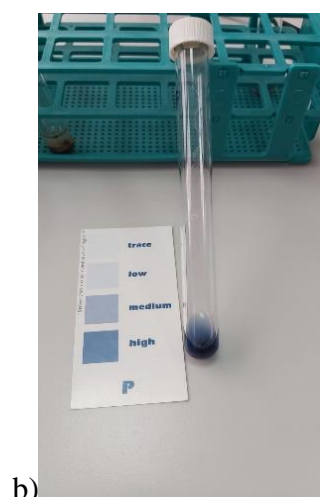


Figure 8. Results of chemical qualitative analyses of soil samples - nitrogen (N)
a) soil sample from the Nicula family household, 2020
b) soil sample from the Niculae family household, 2021



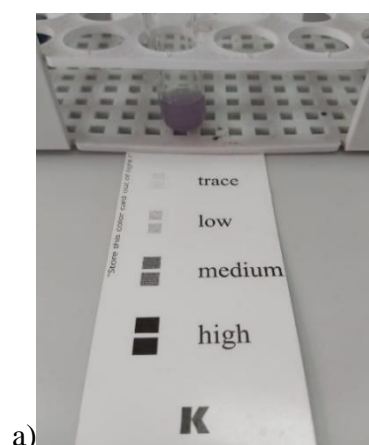
a)



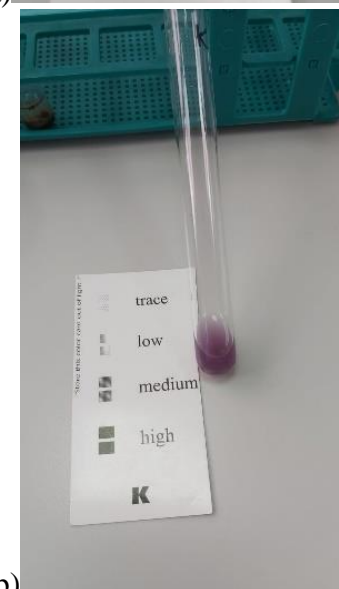
b)

Figure 9. Results of chemical qualitative analyses of soil samples - phosphorus (P)

a) soil sample from the Nicula family household, 2020
b) soil sample from the Niculae family household, 2021



a)



b)

Figure 10. Results of chemical qualitative analyses of soil samples - potassium (K - Kalium)

a) soil sample from the Nicula family household, 2020
b) soil sample from the Niculae family household, 2021

Results of electrochemical analysis of soil samples



Figure 11. Results of electrochemical analysis of soil samples from the Nicula family household, 2020
- pH determined with WTW laboratory pH meter

Fertilizers used as inputs for household vegetable crops

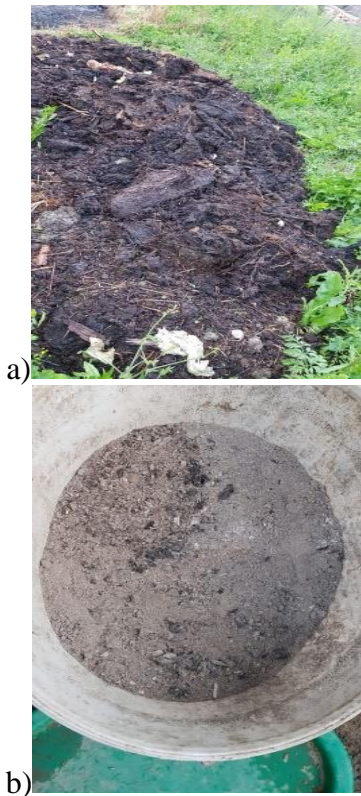


Figure 12. Organic fertilizers used in the household – cow compost and wood ash

Establishment of vegetable crops in the protected area - greenhouse and in the field, 2020, the household of the Nicula family



Figure 13. Onion and pepper crops



Figure 14. Cucumber and tomato crops in the solarium

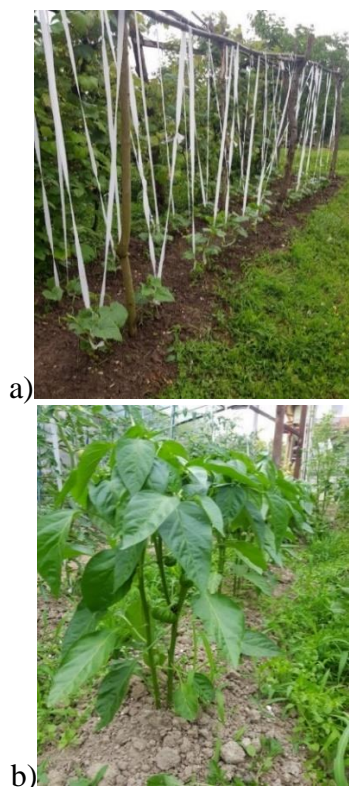


Figure 15. Cucumber and pepper crops

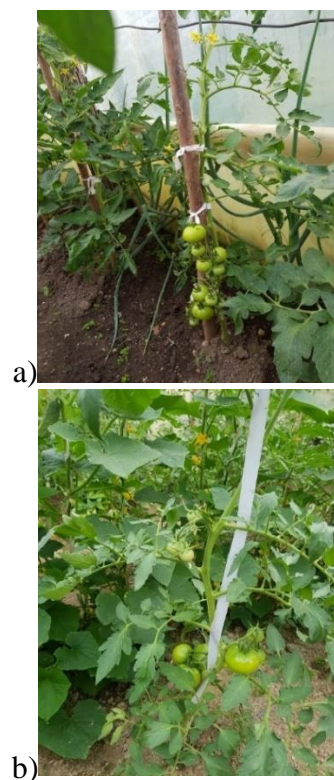


Figure 17. Tomatoes in the solarium

Establishment of vegetable crops in the protected area - greenhouse and in the field, 2021, the household of the Niculae family

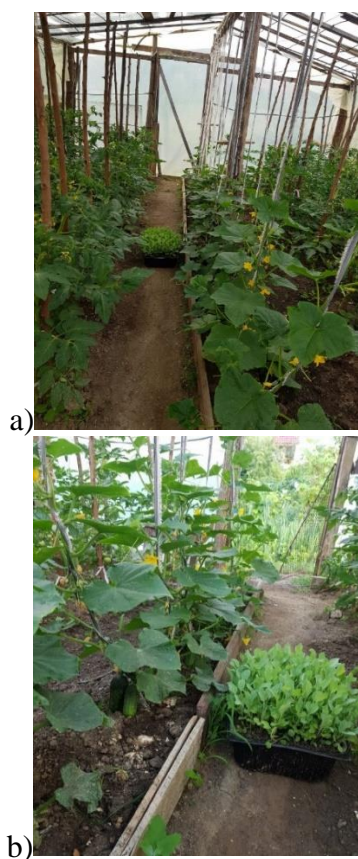


Figure 16. Cucumbers, tomatoes and cabbage seedlings in the solarium



Figure 18. Land preparation for planting a) tomato culture b) radish culture

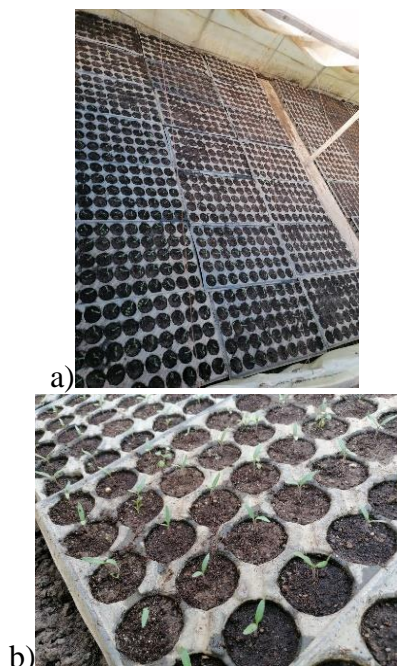


Figure 19. Alveoli with tomato seedlings in the greenhouse

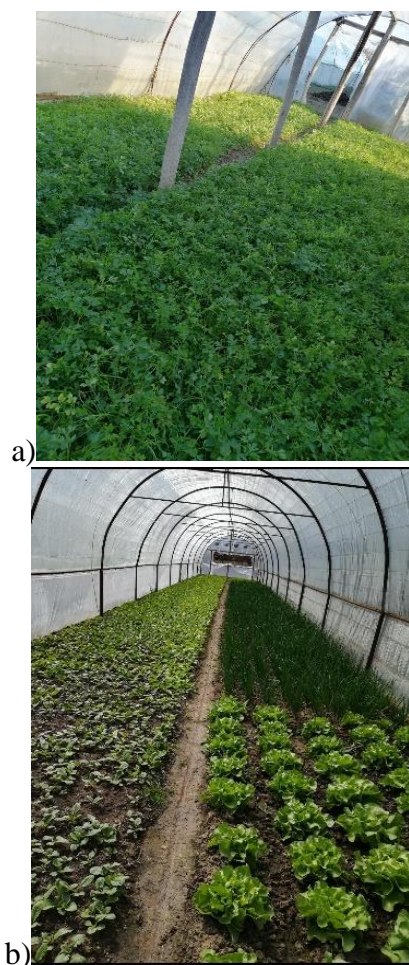


Figure 20. Parsley, radish, lettuce and onion crops in the solarium



Figure 21. Cultivation of radishes in the greenhouse

CONCLUSIONS

The delivery of ecosystem goods and services depends on the structure and functioning of ecosystems, which are affected by (global) environmental changes and the effects of land management on soil biota. In order to understand and finally be able to manipulate the relationships between soil biota and the provision of ecosystem goods and services, the usefulness of the concept of “functional groups” of soil biota is limited.

Functional groups are usually defined only at a trophic level (eg fungal feeders), and the relationship between such groups and the functioning of the ecosystem is not simple. There is evidence that the type, range and relative abundance of functional traits of organisms and species in biotic communities exercise control over different ecosystem functions, which means that there are multiple associations between ecosystem traits and services at different trophic levels.

From a functional ecological perspective based on features, existing agro-ecosystems can be analyzed in terms of sustained delivery of ecosystem goods and services. Such analyzes will be helpful in designing resource-efficient agro-ecosystems and agricultural landscapes. A number of entry points for the biological management of such systems are available for the sustainable production of ecosystem goods services.

From the microbiological analyzes to the soil samples performed in the laboratory experiments we obtained the following results:

- Very high diversity of microorganisms in soil samples from households of the Nicula family located in Aldești village, Golești commune in Vâlcea county and Niculae in Crivăț village, Crivăț commune, Călărași county highlighted by microscopes from the laboratory of Ecology and Microbiology to the University of Agronomic Sciences and Veterinary Medicine of Bucharest through the usual microbiological techniques shows that the soil is healthy and this is reflected in the quality vegetable products that families obtain, sustainably capitalizing on the resources of agroecosystems.

From the potentiometric analyzes at the soil samples we obtained the following results:

- The pH of the analyzed soil samples had a value of approximately 6.65 pH units, which means that the soil reaction is weakly acidic to neutral, an optimal value for the development of microorganisms and plants.

From the physico-chemical analyzes to the soil samples performed in the experiments we obtained the following results:

- to determine the nitrogen in the soil, a pink compound with a medium concentration is obtained, the color being directly proportional to the amount of nitrogen in the soil sample in the case of this qualitative chemical analysis, performed using the Hanna Instruments kit for determining nitrogen in the soil;
- for the determination of phosphorus in the soil, a blue compound with a high concentration is obtained, the color being directly proportional to the amount of phosphorus in the soil sample, in the case of this qualitative chemical analysis, performed using the Hanna Instruments kit for determining phosphorus in the soil;
- to determine the potassium in the soil, a blue compound with a high turbidity is obtained, the turbidity being directly proportional to the amount of potassium in

the soil sample in the case of this nephelometric analysis, performed using the Hanna Instruments kit to determine potassium in the soil.

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- ***<http://teebweb.org/publications/teeb-for/research-and-academia/>

A SHORT REVIEW REGARDING RENEWABLE RESOURCES EXPLOITATION IN TODAY'S EUROPEAN BUILDINGS CONSTRUCTION

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Abstract

Renewable resources are important sources of energy with increasing interest recently, given that the current activities of the population, but also the expansion of industries, are irreversibly affecting exhaustible energy. Currently renewable resources are not sufficiently exploited, hence they are still of great interest to researchers, engineers and builders. This paper aims to provide an overview of the technologies based on renewable resources in nowadays construction. Given the impossibility of recovering consumed energy, the innovative solution for reducing energy use and its storage is the development of novel solutions of integration and involvement of renewable resources in construction. This should be performed from the design stage, construction using renewable materials, recycled or with minimal energy consumption, and up at the stage of building entirely green houses. Among the technologies based on the use of renewable energy resources used in construction, solar water heating systems, photovoltaic systems, heat pumps or heat recovery systems are frequently used.

By involving these renewable resources in construction, the aim is to reduce energy consumption by stimulating primarily energy production and improving the following main sectors: economic, ecological, medical and last but not least the considerable improvement of personal comfort, thus respecting the rules imposed by the European Union in 2020 on operational energy conservation.

Key words: buildings, renewable energy, renewable resources.

INTRODUCTION

Nowadays, buildings have a high environmental impact on the society not only in terms of land occupation, but also of water, electric and thermal energy and materials consumption in Europe. This is the main reason why the builders and engineers have started to develop the green buildings, which are using renewable energy including solar energy, wind energy, biomass and geothermal energy. Choosing green buildings aims to reduce the emission and pollution in order to create sustainable buildings or even zero energy buildings.

However, the possibility of applying renewable energy in buildings construction varies significantly, depending on the renewable energy types, energy quantification strategy, geographical area, climates differences or/and building characteristics. Renewable energy systems have started to be used for improving electric and thermal performance in sustainable buildings, replacing energy obtained from fossil

fuels and nuclear energy. Most frequently used renewable energy systems are photovoltaic, evaporative cooling, wind turbines and solar heating systems (Albatayneh et al., 2018).

The aim of this paper is a short review regarding the use of renewable resources in buildings construction.

MATERIALS AND METHODS

The present paper represents a scientific literature review from public domain. The relevant websites consulted were: Science direct, PubMed, Mendeley, Google Scholar, Research Gate, NCBI (The National Center for Biotechnology Information). In this study, only the research articles from the last few years, starting with 2018 were selected. For this short-review were consulted more than 50 papers, the most relevant to the subject being selected.

RESULTS AND DISCUSSIONS

The use of renewable energy resources in buildings is a large domain with various applications as will be presented further.

Solar energy systems in buildings

Solar energy in buildings could be used as passive or active solar systems. The passive solar systems use the solar energy for daylighting, heating, cooling, distillation for drinking water, water pumping. More examples of passive solar heating systems and passive solar cooling systems were presented by Chel and Kaushik (Chel and Kaushik, 2018).

A positive influence of different variants of photovoltaic systems on the energy performance indicators as primary energy indicator, delivered energy indicator, and the CO₂ emissions was demonstrated by Marchwinski (Marchwinski and Kurtz-Orecka, 2020) in the case of a nursery building from Warsaw. More, from the economic point of view, integrated photovoltaic systems used as building envelope material for the whole buildings facades with various direction or orientation and flat roofs, is a favourable option due to the fact that it could reimburse the investment costs and could be seen as a source of income for the building (Gholami and Røstvik, 2020). Moreover, the integration on a prefabricated low-energy house of photovoltaic/thermal roof systems coupled with a water-to-water heat pump has a positive effect on the annual electrical and thermal performance (Rounis et al., 2018). Also, positive effects and high energetic performance were demonstrated in the energy renovation of an existing building from Cyprus, using building integrated photovoltaic/thermal systems and a corridor type double façade system (Theokli et al., 2021).

A solar cooling system application in cooling and domestic hot water production was examined in summer Mediterranean climate for residential buildings. The optimization process of this kind of cooling system showed the possibility to work up to 83% renewable energy (Bilardo et al., 2020).

Many design options for building integrated photovoltaic systems on roofs and facades showed the positive impact on the German energy system (Kuhn et al., 2021).

Studies show that, in the last period, in Germany, Denmark, Sweden the interest even in

seasonal thermal energy storage increased, and in this direction were developed and installed seasonal thermal energy storage systems in solar district heating, in order to offer a balance between summer-winter temperature variations (Ochs et al., 2020). Of great interest is the possibility of a building to obtain positive energy, becoming a positive energy building which could sustain house operation and activities and even to sustain charging electrical vehicles, which are more and more commune.

Wind energy systems in buildings

Wind energy in buildings could be used also as passive systems (passive cooling) or active systems (wind turbines), the latest being able to be integrated into the buildings, also. Several researchers and engineers have started to develop many hybrid renewable energy systems. In one example was studied the potential of photovoltaic and battery systems with additional micro-generation wind turbines (10.5 kW) in two countries from Central Europe (Germany and Czech Republic) to supply electricity of residential users (Camargo et al., 2019).

In a study conducted by Calise and colleagues, in 2020, a hybrid renewable system was developed, consisting of building integrated photovoltaic panels coupled with small size wind turbines (20 kW) and double-stage heat pumps, for a hotel building from Italy. This hybrid system offers the possibility to enhance the stability of the renewable energy production (Calise et al., 2020).

Geothermal energy systems in buildings

Geothermal energy is a renewable resource energy involved in heating and/or cooling of houses (even greenhouses). Geothermal energy systems could be applied as heat pumps, heat pipes and in-well heat exchangers, but the most found in buildings is as heat pipes. The soil temperature transferred by water or air could also be used for cooling in the summer and heating in the winter (Yüksek and Karadağ, 2021).

A geothermal system containing two ground-coupled heat pumps was developed for an office building in Hamburg, as a heat source, heat sink or for cooling the building (Duus and Schmitz, 2021). Also, geothermal energy was used as a heat source for a neighborhood of existing

residential buildings from Netherlands, (Pinto and Carrilho da Graça, 2018).

A hybrid renewable energy system, based on geothermal and solar energy, in a building from Portugal, was implemented by Palmero-Marrero and colleagues to diminish energy consumption and increase the building energy efficiency (Palmero-Marrero et al., 2020).

Hydrogen energy systems in buildings

Hydrogen energy could be exploited as well as the renewable resources discussed above for heating buildings, but also for cooking or generating electricity. Hydrogen energy is a renewable resource produced from solar, wind or geothermal resources. So, in this manner many hybrid systems were developed.

The energy efficiency of an office building located in Greece was increased by adopting a hybrid system to cover the electrical needs of the building functionality, for heating and cooling. Primarily, the energy is collected from solar panels and wind generators. So, this hybrid system converts the excess energy (the unconsumed energy by office buildings) to gaseous hydrogen which could be used as an energy storage system (Peppas et al., 2021).

In a study conducted by Lokar and Vrtič was studied the possibility of hydrogen integration with photovoltaic and battery storage systems in order to cover the energy needs in residential buildings (Lokar and Vrtič, 2020).

Biomass energy systems in buildings

Biomass, also, is a renewable resource, produced from organic matter and biological mass as wood, oilseeds plants, fiber plants, carbohydrate plants, animal and urban wastes. The biomass energy systems are used to produce electricity and as biofuels.

In this direction, for renovated and non-renovated residential buildings and multi-family houses a hybrid system (solar-biomass system) was implemented by Palomba and colleagues in 2020, for heating, cooling and electricity in various European areas and climates as Madrid, Berlin and Helsinki (Palomba et al., 2020).

The vegetable fibers as barley straw and olive tree waste mixed with sodium silicate solution were studied to create panels for buildings

thermal insulation in two different climatic areas as Bari and Bilbao (Liuzzi et al., 2020).

Recently, more and more renewable multi-energy systems have been adopted, due to the possibility of their efficient implementation in buildings and their help in the fight against decarbonisation.

As could be remarked, solar energy is more often used in buildings, both residential and institutional buildings, than other renewable energy resources.

CONCLUSIONS

This review on European research studies indicated that buildings are responsible for a high percentage of global carbon dioxide emissions, therefore adoption of renewable energy and materials in buildings construction or restoration (even historical and heritage buildings), converts construction industry into a sustainable domain.

In the last years, many possibilities of using renewable energy resources in buildings were developed with remarkable results as presented. Nowadays, construction engineers and architects are interested in designing buildings integrating renewable resources with lower costs and higher quality.

ACKNOWLEDGEMENTS

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SUSTAINABLE AGRICULTURE, SOIL QUALITY: A MINI-REVIEW

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Abstract

Soil quality is the competence of soil to perform necessary functions that are able to maintain animal and plant productivity of the soil. Soil consists of various physical, chemical, and biological parameters, and all these parameters are involved in the critical functioning of soil. There is a need for continuous assessment of soil quality as soil is a complex and dynamic constituent of Earth's biosphere that is continuously changing by natural and anthropogenic disturbances. Any perturbations in the soil cause disturbances in the physical (soil texture, bulk density, etc.), chemical (pH, salinity, organic carbon, etc.), and biological (microbes and enzymes) parameters. These physical, chemical, and biological parameters can serve as indicators for soil quality assessment. However, soil quality assessment cannot be possible by evaluating only one parameter out of physical, chemical, or biological. So, there is an emergent need to establish a minimum dataset (MDS) which shall include physical, chemical, and biological parameters to assess the quality of the given soil.

Diagnosis of soil pollution risk and carrying out measures to recover contaminated soil requires a thorough study of the degree of determination of soil function. Enzymatic activity reveals disturbances of the ecosystem, enzymes can indicate, along with other physico-chemical properties, soil quality. In this mini-review paper, we analyze the effects of modern, industrial agriculture, the effects of soil pollutants (pesticides, nitrate) and the effects of cultivation techniques. Further research is needed to establish the quantitative relationships between the physico-chemical properties of the soil and the enzymatic activity.

Key words: agriculture, pollution, recycling, soil.

INTRODUCTION

Soil quality is the competence of soil to perform necessary functions that are able to maintain animal and plant productivity of the soil. Soil consists of various physical, chemical, and biological parameters, and all these parameters are involved in the critical functioning of soil. There is a need for continuous assessment of soil quality as soil is a complex and dynamic constituent of Earth's biosphere that is continuously changing by natural and anthropogenic disturbances. Any perturbations in the soil cause disturbances in the physical (soil texture, bulk density, etc.), chemical (pH, salinity, organic carbon, etc.), and biological (microbes and enzymes) parameters. These physical, chemical, and biological parameters can serve as indicators for soil quality assessment. However, soil quality assessment cannot be possible by evaluating only one parameter out of physical, chemical, or biological. So, there is an emergent need to

establish a minimum dataset (MDS) which shall include physical, chemical, and biological parameters to assess the quality of the given soil (Maurya et al., 2020).

The problem of soil pollution that is contaminated and affected by various human activities, such as industrial activities, waste storage, industrial agriculture, monocultures, deforestation and oil palm planting, is a global problem.

Soil is a natural environment consisting of a mixture of organic and inorganic components present in the soil in the form of solid, liquid and gaseous. We can say that soil is a large reservoir of nutrients that support the growth of plants and microorganisms that serve as food for humans and animals.

Soil quality can represent the ability and functions of this to maintain productivity and durability, the environment of growth of

different plants, microorganisms, the maintenance of air and water quality.

Diagnosis of soil quality can be determined by using indicators and comparing with changes that have occurred over time.

Soil health means an appropriate balance between organisms and the environment, such a fragile balance on which all that life means. Balance we should keep at all costs.

MATERIALS AND METHODS

Soil respiration: Measures the amount of CO₂ released from the soil. Respiration is an indicator of biological activity.

- Infiltration: Measures how fast water can infiltrate into the soil. Infiltration is an indicator how easily water will infiltrate, pond, or runoff during rainfall or irrigation.
 - Bulk density: Measures the weight of the soil per volume of soil. Bulk density is an indicator how well plant seedlings can emerge and how well air can circulate through the soil.
 - Electrical conductivity: Measures how well an electrical current travel through the soil water. Electrical conductivity is an indicator of how much salt is present in the soil.
 - pH: Measures the activity of hydrogen ions in soil water. pH is an indicator of whether the soil is acidic, neutral, or basic.
 - Nitrate: Measures the amount of nitrate in the soil. The amount of nitrate is an indicator of the availability of the important plant nutrient- nitrogen.
 - Aggregate stability: Measures the ability of soil aggregates to resist disintegration when immersed and shaken continuously in water.
- Aggregate stability is an indicator of how well water can infiltrate into the soil during rainfall or irrigation and how easily soil is washed off or blown away.
- Slaking: Measures how fast soil particles disperse in water. Slaking is an indicator of whether and how fast soil will form a slurry during rainfall or irrigation.
 - Earthworm counts: Measures the number of earthworms in soil. Earthworms generally

enhance microbial activity, soil fertility and physical properties.

- Penetration resistance: Measures the force required to insert a metal rod into the soil. Resistance is an indicator of how easily roots can grow in the soil. (Markus et al., USDA 2015)

Regarding agriculture and cultivation techniques, water erosion, wind and agricultural soil preparation works; compaction, decrease in the amount of organic carbon in the soil and soil biodiversity the chemicals used and what effects these techniques have in the long term, complement the work with the study of pesticides.

Pesticides are chemicals used to protect plants from pests, they include, among other things, herbicides for weed staunry, fungicides against diseases and insecticides for killing insects. These pesticides are used to influence plant growth or the preservation of plant products.

Pesticides work by attracting and then destroying or mitigating pests. Pests can be defined as "plants or animals that endanger food, health and/or comfort". Pesticide use has increased many times in recent decades. According to an estimate, about 5.2 billion kilograms of pesticides are used annually worldwide. Pesticide use dates back to ancient times, when people used to burn sulfur to kill pests and used salts to fight weeds. In the 1600s, a mixture of honey and arsenic was used to control ants.

RESULTS AND DISCUSSIONS

Pesticide use comes with a package of threats to the environment. Pesticides threaten aquatic biodiversity by entering the water through soil leaks or can be applied directly into water, contaminated water can affect aquatic plants, decrease oxygen dissolved in water and cause physiological and behavioral changes on fish populations. In terms of terrestrial biodiversity, pesticide use can have a devastating impact on the productivity of non-target crops, spontaneous plant communities, reduces the quality of seeds, increases the risk of diseases in plants. Populations of cockroaches and bees can be considerably reduced by using insecticides

with broad spectrum, such as carbamates, organophosphates and pyrethroids.

When it comes to human beings, who are extremely vulnerable to the effects of pesticides. According to the World Health Organization, every year, about 3,000,000 pesticide poisonings and 220,000 cases of reported deaths in developing countries (WHO, 2012).

We can liken the soil to a tank of CO₂, by the plowing of the land, CO₂ is released into the atmosphere, hastening the process of global warming. Long-term ploughing and continuous use of heavy machinery can create hard, deep, and compacted layers of soil. These can prevent root growth and infiltration of water and nutrients.

The basement aims to restore the lost properties of the soil and involves the compacted by soil deeper than ploughing, without overturning them. The working depth of the depth of the furrow should be determined according to the degree of compaction and the moisture content of the soil at this depth. (FOA 2000)

Sustainable agriculture, or we can call it durable agriculture, is based on agricultural practices that do not endanger ecological cycle relationships, promoting economically viable, environmentally friendly and public health-protecting methods and practices (Union of concerned scientists, 2017). Agriculture is not based solely on the economic aspect, of profit, it should not be seen only as a business, agriculture must be an activity that contributes to the increase of the productivity of uncontaminated food, which leads over time to the increase of the farmer's standard of living. Sustainable agriculture helps farmers innovate and use recycling methods, apart from the conventional advantages of agriculture. A very good example of recycling in sustainable agriculture is the use of harvest waste and grain garbage as a fertilizer that leads to improved soil health. Another method that can be used is polyculture (Tanja Folnovic), the growth of several species of crops in an area, these species often complement each other. High biodiversity makes the systems more resistant to weather fluctuations, promotes a balanced diet and applies natural mechanisms to preserve soil fertility. Crop rotations prevent the occurrence of diseases in crops, according to the studies carried out (Allmaras et al., 1998).

Diseases such as crown rot and tanned stain can be controlled. Also, pests such as Septoria, phoma, etc. can be eliminated by crop rotation techniques. Because diseases are crop-specific, crop rotation can work wonders. Collecting water by sewerage and its use through irrigation is also an example of sustainable agricultural practices.

CONCLUSIONS

Due to the close relations between human settlements and the environment, the desolation process has induced important changes in its structure. The quality of air and water, soil and biosphere, first zonal, and then on a planetary scale, were affected, one by one.

Over time people have gathered information about soil quality, agriculture, the effects of industrial agriculture and sustainable agriculture. We have gathered enough information to realize that the way we have done so far has not had favorable results in terms of environmental and human health. Although, worldwide it is difficult to introduce the model of sustainable agriculture because we stumble on many material, political, educational factors, in the future it is our only chance at a better life.

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EXAMINATION OF THE CHANGES IN THE LAST YEARS OF AZERBAIJAN'S AIR QUALITY SITUATION (AQI: AIR QUALITY INDEX)

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Abstract

The rapid economic improvement in developing countries during the last decades has been followed by growingly deteriorated air quality. Air pollution is considering one of the most critical environmental issues in the urban areas of Azerbaijan. As a result of the urbanization, emissions from oil, gas, chemistry, metal, construction material industries, and car building complex, the atmospheric air of the Absheron peninsula become the most contaminated place in Azerbaijan. The primary anthropogenic sources of air pollution in Azerbaijan are mobile sources and the oil-and-gas industry. However, the number of literature and researches was written about this problem is not adequate. In this research work, we aimed to analyze the changes in the last years of air quality in Azerbaijan. To reach our goal, we used the times series analysis method. The research is principally based on examining the air quality situation in six big cities of Azerbaijan. One of the main reasons for that was the high concentration level of PM and SO₂. We also applied Air Quality Index (AQI) method to our research, and it showed that atmospheric air in Baku, Mingachevir, and Nakhchivan was heavily contaminated. Our study revealed that air quality in the big cities of the country is poor.

Key words: Azerbaijan, air pollution, air quality, developing countries, Particulate Matter, urban areas.

INTRODUCTION

Urban air pollutants are a complex combination of numerous organic and inorganic compositions. According to most research on air pollutants' possible health effects, it has been associated with primary pollutants (Möller et al., 1994). Regarding the World Health Organization (WHO), urban air pollution is a serious public health issue. More than 2 million premature deaths can be ascribed to the consequences of urban outdoor and indoor air pollution every year. Effects of air pollution are counted by sickness and death, decreased productivity, failed educational opportunities, and other improvement opportunities for society (Mabahwi et al., 2014).

Regarding the most recent evaluation of air quality of the European Commission, high concentrations of particulate matter (PM) caused about 348,000 premature deaths in the European Union regardless of planned notable depletions in yearly PM effect from 2000 to 2020 (Morgenstern et al., 2008). Following necessary epidemiological proofs, fine

particulate matter has harmful effects on human health. Even though many research types have concentrated on respiratory health effects, there is increasing confirmation that PM is a danger factor for cardiovascular diseases (Pope et al. 2003). Moreover, regarding the current studies, people with type 2 diabetes are more susceptible to the cardiovascular effects of the airborne particle (Anderson et al., 2012).

Reliance and connection between air pollution and human health are not adequately studied in Azerbaijan. According to the examination data, 2108.5 thousand tons of wastes were discharged from stationary sources in Azerbaijan, and at that time, people who died from respiratory diseases made up 5893. Regarding the calculations, approximately 36-38% of infections are directly and indirectly associated with Azerbaijan's atmospheric air pollution (Mammadova, 2015).

The general area of Azerbaijan is 86.6 thousand km² (The State Statistics Committee of Azerbaijan Republic, Environment in Azerbaijan, 2017) and it is situated on the south-

eastern slants of the Caucasus Mountains (Frenken, 2009). According to the data from the State Statistical Committee of Azerbaijan Republic, approximately 12% of the surface of the country covered by forests, 1.7 % water, 55.1% agricultural fields (30.7% grazing and dried grass makings), and 31.2% are other lands (The State Statistics Committee of Azerbaijan Republic, Environment in Azerbaijan, 2017).

At the beginning of 2017, the population of Azerbaijan is accounted for 9.81 million people, and the density of the people for 1 km² was 113 people (The State Statistics Committee of Azerbaijan Republic, Environment in Azerbaijan, 2017). During the last five years, the median increasing rate of Azerbaijan's population is around 1.11%, and inhabitants are predicted to reach 10 million by 2020 (Rucevska et al., 2017).

The Absheron Peninsula is considering the most inhabited part of Azerbaijan, and it is the center of urbanization, infrastructure, and economic activities to both national and regional extents. The Absheron Peninsula accommodates approximately 40% of Azerbaijan's population and 70% of its industrial manufacturing. Therefore, the area is thought-out to be highly susceptible to the possible climate change persuaded threats. The peninsula economy is mainly based on oil and gas production, chemical and petrochemical industries, metallurgy, textiles, and food industry (Rucevska et al., 2017).

According to The Blacksmith Institute's research, Sumgait is included 9th place in the list of the world's worst ecological areas (Table 3). Fuller mentioned that "It is a huge, abandoned industrial wasteland" (Walsh, 2018). Regarding the recent research and data, Baku is one of the most polluted cities worldwide at the time of the Union of Soviet Socialist Republics (USSR); Baku was known for its topmost level of atmospheric contamination (Kahramanova and Namazov, 2009).

In Azerbaijan, industrial and energy sectors are considered the condemnatory creators of carbon dioxide CO₂ emissions such as burning fossil fuel in energy, oil, and gas extraction (SOCAR, BP, EXXON, LUKOIL, Turkish Petroleum, etc.) (Vidadili et al., 2017). Additionally, growth in the metallurgy sector has also been caused to

the enormous rise in greenhouse gas (GHG) emissions ("Aluminum" Production area of "Azeraluminum" LLC, "Dashkesen Ore Refining" JSC, etc.) (Azerbaijans, 2019). Following data from the State Statistical Committee of Azerbaijan Republic, the total amount of the GHG emissions were 75.5 million tons and per capita 3.7 ton in 2013 (Vidadili et al. 2017).

In Azerbaijan, artificial air pollution sources are mobile sources (mainly vehicles), oil and gas extraction and refining, thermal power plants and boiler houses, chemical industry, mining, metallurgy, and manufacturing industries construction materials. Among all of these sources, vehicles are responsible for air pollution in Azerbaijan (Tables 5, 6, 7) (Caucasus, 2013). For example, in 2005, the number of cars in Azerbaijan was approximately 50.000; however, nowadays, their numbers exceed 1.3 million (Salmanova 2017). Moreover, over the last decade, emissions from mobile sources have increased significantly. Within the previous ten years in Azerbaijan, the numbers of old vehicles (older than ten years) which use low-quality fuel and are not well maintained are enlarged dramatically (Popov, 2005).

The other reason for air pollution in Baku is urbanization, and more than half of the countries' industry established in Baku (Absheron Peninsula). Nonetheless, following the disintegration of the Soviet Union majority of the old enterprises were shutting down. Hence, the environmental impact in this area has been reduced. However, the oil-and-gas industry improved as a novel source of emissions, and in this case, the atmosphere of the Absheron peninsula is exposed to industrial pollution once more (Kahramanova and Namazov, 2009). Another issue with the urban population is indoor air quality. Thus, the number of people who utilize domestic heaters with alternative fuels without fuel combustion devices has increased significantly (Popov, 2005).

MATERIALS AND METHODS

Time series analysis can be described as the measurement of the data sequentially over time.

This method can be used in almost all application field, such as business sales figures (i.e., customer frequencies, production numbers), official statistics census data (i.e., personal expenditures), natural sciences (i.e., population size), envirometrics perception (i.e., temperature or pollution records). Time series analysis is used to visualize and this reliance on the past and then achieve future values forecast (Dettling, 2014). Time-series analyses handle statistical techniques to analyse and model, and arranged the sequence of observations. This modelling leads to the stochastic process model for the system which created the data (Madsen, 2008). In time series, data is positioned chronologically, and the order of the observations' existence is vital. If the chronological sequence of the data were neglected, much of the information included in the time series analysis would be lost (Modarres and Dehkordi, 2005).

To analyse historical changes in the weather, we have acquired statistical data from The World Bank, The State Statistical Committee of the Azerbaijan Republic, and the Ministry of Ecology and Natural Resources of the Azerbaijan Republic. Most of the data were available online; however, some data were obtained personally with authorities' special request.

Below given Air Quality Index table (Table 1) is established according to the 4/2011. (I. 14.) VM decree in Hungary. It describes ambient air quality based on the yearly concentration of air pollutants and is evaluated as excellent, good, adequate, contaminated, and heavily contaminated. The table is coloured from blue to red to differentiate the air quality even without reading the numbers easily. Initially, it was created for eight air pollutants: NO_x, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃, CO, and Benzol. Because of the lack of data in our research, we will calculate Air Quality Index only for four major air pollutants, namely NO₂, SO₂, PM₁₀, and CO. With the aid of this table, we will analyse the yearly air quality situation for the last decade in the big cities of Azerbaijan.

Table 1. Air Quality Index (Hungarian Air Quality Network)

Index	Evaluation	NO ₂ (µg/m ³)	SO ₂ (µg/m ³)	PM ₁₀ (µg/m ³)	CO (µg/m ³)
		average	average	average	average
		year	year	year	year
1	excellent	0-16	0-20	0-16	0-1200
2	good	16-32	20-40	16-32	1200-2400
3	adequate	32-40	40-50	32-40	2400-3000
4	contaminated	40-80	50-100	40-80	3000-6000
5	heavily contaminated	80<	100<	80<	6000<

RESULTS AND DISCUSSIONS

Table 2 demonstrates the quality of air in Baku city based on 4/2011. (I. 14.) VM yearly Hungarian Air Quality Index from 2008 to 2017. Air quality in given years in Baku city is summarized as heavily contaminated. The reason is that the PM concentration is exceeded the given maximum level more than two times in the last decade. The central part of Azerbaijan's industries was established in the Absheron peninsula, where Baku city locates. It is undeniable that emissions from these industries affecting the air quality. Another major reason for poor air quality is considering the increasing urban population and emissions from mobile sources.

Table 2. Air Quality Index in Baku

Baku	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NO ₂	20	20	40	40	10	20	40	40	20	30
SO ₂	14	15	15	16	18	11	11	14	19	26
PM	200	300	300	300	300	300	300	300	200	200
CO	2000	2000	2000	3000	3000	3000	3000	3000	1900	2000
AQI	heavily contaminated									

Regarding Table 3, it describes the quality of ambient air in Sumgait city from 2008 to 2017. From 2008 to 2011, the ambient air quality is considering heavily contaminated. Starting from 2012, air quality is described as good, as we did not have data for PM and other main air pollutants after 2011. The major reason for the poor air quality is emissions from oil, gas, chemistry, metal, construction material industries, and car building complexes located in Sumgait city. It has also been mentioned that Sumgait is considering one of the most polluted cities in the world.

Table 3. Air Quality Index in Sumgait

Sumgait	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SO2	20	20	20	20	26	28	25	27	26	27
PM	100	100	200	200						
AQI	heavily contaminated				good					

In Table 4 Air Quality Index is shown for Ganja city from 2008 to 2017. From 2008 to 2012, air quality is ranked as heavily contaminated because of the high level of PM. Starting from 2013 to 2017 air quality situation was graded as adequate according to the level of SO2. However, these outcomes for Ganja city cannot be considered precise for Ganja, as data was not available for PM after 2012.

Table 4. Air Quality Index in Ganja

Ganja	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NO2	20	20	20	30	30	30	20	20	20	20
SO2	37	34	34	37	46	40	38	38	37	38
PM	200	100	200	200	200					
AQI	heavily contaminated				adequate					

Table 5 describes the Air Quality Index for Mingchevir city from 2008 to 2018. Compared to the PM, other pollutants did not exceed the limit value and strongly affected the air quality. However, during all given periods, the PM level overshoots the limit value more than twice. For

this reason, ambient air quality in Mingchevir city is ranked as heavily contaminated.

Table 5. Air Quality Index in Mingchevir

Mingchevir	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NO2	20	20	20	30	30	30	30	30	20	20
SO2	11	9	10	14	20	15	15	14	14	35
PM	200	200	200	200	200	200	200	200	200	200
CO	2000	2000	2000	3000	3000	3000	3000	3000	3000	3000
AQI	heavily contaminated									

In Table 6, the air quality situation in Nakhchivan city is shown, and because of lack of data, these results are based on only two pollutants: SO2 and PM. According to the examination, the air quality situation in Nakhchivan ranked as heavily contaminated. Like the above given big industrial cities, in Nakhchivan, PM is also the main air pollutant that has a detrimental effect on air quality.

Table 6. Air Quality Index in Nakhchivan

Nakhchivan	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SO2	52	53	41	53	56	46	49	49	50	51
PM	100	100	100	100	100	100	100	100	100	100
AQI	heavily contaminated									

Table 7 shows the Air Quality Index in Sheki city from 2008 to 2017. Between all significant pollutants in Sheki city, data was only available for SO2. Therefore, we analyzed the ambient air quality according to the only SO2, ranked as good.

Table 7. Air Quality Index in Sheki

Sheki	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SO ₂	30	32	29	30	38	36	36	37	36	36
AQI	good									

CONCLUSIONS

The research work's fundamental principle was focused on examining the changes in the last years of Azerbaijan's air quality situation. To analyze the air pollution situation in the previous decades in Azerbaijan, we used the time series analysis method.

Summarization of research examination includes the average yearly concentration of PM, SO₂, CO and NO₂ in Baku, Sumgait, Sheki, Ganja, Mingchevir cities, and the Nakhchivan Autonomous Republic. The concentration of PM (Baku, Mingchevir, Ganja) and SO₂ (Nakhchivan) exceeded the given standard limit values for Azerbaijan; we applied yearly Hungarian AQI to define general the air quality situation effectively. Our outcomes represented that atmospheric air in Baku, Mingchevir, and Nakhchivan is "heavily contaminated" Because of the lack of data for some years about PM, we could not define the accurate air quality situation in Ganja and Sumgait.

From our obtained results, we can see that in the big cities of Azerbaijan, the air was polluted from 2008 to 2018, and the major reason for the pollution was PM. The current solution is recommended by our side to authorities establish new strict policies and standards to tackle the problem with PM and other air pollutants, implement cleaner methods of transportation, invest in energy-efficient power generation, replace fuel energy with renewable energy. Furthermore, we recommend individuals to plant trees use more public transport, and recycle.

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SHORT REVIEW OF CAPITALIZING ORGANIC WASTE

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Abstract

This article is an overview of the reducing the impact of wasted food by feeding the soil and composting based on information from studies made on this topic. The research includes the improvements composting has made in the agriculture, by reduces and in some cases eliminates the need for chemical fertilizers. Another thing about compost, it can help aid reforestation, wetlands restoration, and habitat revitalization efforts by improving contaminated, compacted, and marginal soils. The subject of this research is the benefits of composting in Romania and where is this possible. As a conclusion, it is mandatory to reduce the landfilled quantity of biodegradable waste generated in Romania

Key words: biodegradable, composting, environment, waste.

INTRODUCTION

Compost is more than a healing agent for the deteriorated or polluted soil, here in the moist and mouldy pile, spins the wheel of life. Nature created compost, the dead grass, left on the lawn, froze during the winter being transformed into compost due to the humidity in the soil underneath. Birds, insects and animals they all contribute with their bodies to the vast and continuous cycle of rejuvenation. The nature is sovereign.

Waste generation increases with population expansion and economic development. To eliminate the impact on the environment and the populations' health because of improper waste management, the local authorities for each county tried to implement an Integrated Waste Management System (IWMC). Recycling, waste prevention, composting and disposal programmes should give cleaner and safer cities, better resource use efficiency, resource augmentation, saving in waste management costs due to reduced levels of final waste disposal.

MATERIALS AND METHODS

In Romania, one of the counties that implemented this system successfully is Covasna. They build an Integrated Waste

Management Centre, that is basically a small factory that has a waste sorting plant, compost plant and sanitary landfill. The project that started over 10 years ago became operational in 2017.

By building the composting plant, they wanted to ensure the adequate treatment of the organic biodegradable waste separately collected from Covasna County. The composting plant has a capacity of 12.000 t/year and collects the organic waste from 89.622 people in urban area and 108.072 from the rural area. The compost station has 1.304 ha and 4 areas. The reception area is the place where the daily fresh incoming waste comes and where it is sorted. The composting area consists of a 13.040 m² concrete platform on which the main phases of composting process happen, 2 warehouses measuring 651 m² and 625 m² for storage and compost processing.

RESULTS AND DISCUSSIONS

Compost is the result of micro-biological fermentation, deodorization and maturity of different organic waste such as grass, branches and leaves from public parks, hay, livestock manure, cake feeds. The benefits of compost include reviving poor soil and plant grow, maintaining the soil moisture, reducing watering

up to 34%, helping to recycle organic waste and helping to neutralize pH soils.

The technological process has several stages. Some are simple like chopping and mechanical sorting and some are more complex involving laboratory testing.

The biological treatment has also three stages. First stages are represented by the mesophilic fermentation, characterized by temperatures between 25°-40°C. The second stage is the thermophilic stage where the aerobic degradation is intense, organic matter decomposes at temperatures up to 50°- 70°C under the action of bacteria. Due to high temperatures the material pasteurizes and the microbes die. During the last stage, maturation, temperatures stabilize at 35°-45°C, some fermentation continues, transforming the degraded material in humus.

The time for the fermentation process is 3 months in the summer season and 4-5 months in the winter season. With a comb-like machine, the windrows are reshuffled for ventilation. The frequency with which these turns are made is given by the moisture content and the type of material. If the moisture percentage is high, the turns will be more often, but if the percentage is low, under 40%, the windrows will need some addition of water.



Figure 1. Compost piles in 1st phase

Aeration is necessary in high temperature aerobic composting for rapid odour-free decomposition and also the aerobic organisms need air to survive. It's important to ensure that the material on the outside of the pile is turned

towards the centre, where it will be subject to high temperatures.

It's important to monitor the levels of different parameters to get the optimal conditions in the process of decomposition.

These parameters are:

- the environment, it needs an aerobic environment,
- the frequency of turning the piles,
- temperature should not reach values above 70°C
- humidity
- level of rotting
- water content between 40-70%
- pH value between 7-11 a little alkaline
- C:N ratio.



Figure 2. Compost tuner aerating compost piles

Once the temperature is stable at 40°C, the total volume of material is significantly reduced and the piles smell like rich forest soil, then the transformation process is over.

At this stage the material goes through a screening machine, that sorts in one side the coarse materials like straw fragments that are not decomposed, chunks of wood and on the other side the fine powders. The coarse particles will be put in another pile and go through the decomposition process once again.

Once the compost is obtained, it will be packed in bags of different sizes and ready to be sold.



Figure 3. Compost screening with rotating drum



Figure 4. Final compost packaging

CONCLUSIONS

In 2020 the Integrated Waste Management Centre from Covasna County sold at least 1000 tones of compost out of biodegradable waste. Composting, as a treatment of organic waste, has been proven to significantly reduce the volume of the landfill waste in the county. In addition, composting can also provide nutrients

that are suitable for agriculture and can be used as fertilizer to replace chemical fertilizers.

The Integrated Waste Management Centre from Covasna County is a success story. From 32 projects around the country, the one from Covasna, is one of the few fully operational. If more counties will be able to implement this integrated waste management system and make it functional, maybe Romania will come closer to the goal of recycling 50% of its waste. The success of recycling is not only in these systems, but also in the responsibility of the citizens to take part in the selective collecting of the waste. It is mandatory to reduce the landfilled quantity of biodegradable waste generated in Romania, therefore composting plants provide a viable solution to classical waste management systems, as proven in Covasna County.

In order to reach the national targets set by the Accession Treaty, we have to be aware that only us, as citizens, are responsible to separately collect biodegradable waste and treat it in a composting plant.

In our history, our grandparents living in rural areas used the same process as described in this paper for home composting, and I think we should take into consideration the provided information when we decide to throw away bio-waste to garbage bins.

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SECTION 02
WATER RESOURCES MANAGEMENT

EARTHQUAKES AND THEIR CONSEQUENCES ON BUILDINGS

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Abstract

In this paper we are going to assess the seismic behavior of the Faculty of Land Reclamation and Environmental Engineering building to future earthquakes, it carries a significant amount of uncertainty. Firstly, most of this is due to the inability to know precisely the characteristics of future earthquakes, and secondly, simplification of the assumptions used to measure the structural response. The increased sensitivity of humankind to natural disasters is not just due to a shift in the way phenomena occur, but rather to anthropogenic factors, which demand even more than before a relevant study of risk factors and the continuous engagement of experts throughout all fields of activity in the reduction of negative effects earthquakes may cause to the individuals, to the infrastructure or to the environmental conditions. The safety of buildings is one of the key efficiency standards for constructions. Expressed in a quality-like approach, these criteria must be enhanced by quantitative factors.

Key words: irregular buildings, seismic action, seismic instrumentation, structural assessment.

INTRODUCTION

In Romania there are plenty of buildings that have suffered damage from earthquakes (November 1940 and March 1977). From the experience of these two strong earthquakes, it was concluded that the irregular buildings have the most unfavorable behavior, in some cases, occurring even the collapse.

Over time, Romania has been disturbed by various earthquakes, of smaller or greater severity, with more localized or far-reaching consequences.

Over the past decade, urban growth and construction of taller buildings have increased the level of seismic hazard to cities and counties in various earthquake-prone regions.

For centuries, these seismic events have resulted in a high toll of human casualties and property damage, making Bucharest one of the most threatened among the large population centers in Europe.

The magnitude of seismic risk is significantly higher in the South and East part of the country, while the seismic risk is considerably lower in Transylvania and the Western area of Romania (Dumitru et al., 2013).

Experts concluded that the vast majority of earthquakes in Romania are of tectonic origin, triggered by the discharge of the potential energy stored in some geological structures in the Earth's crust, as well as in the upper part of the mantle (the second layer of the Earth).

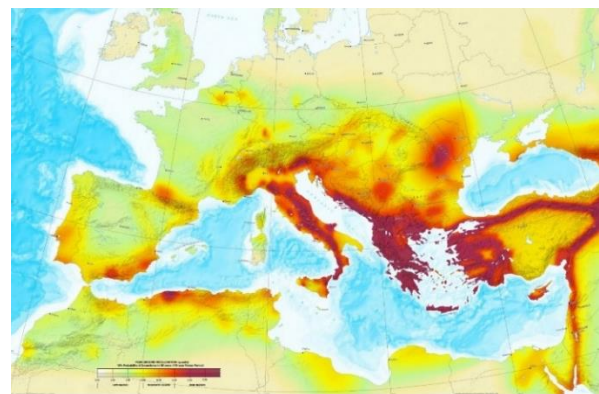


Figure 1. Romania in the seismic setting of Europe (ESC-SESAME Map)

The epicenter areas which decide the magnitude of seismicity of the country: Vrancea, Fagaras-Campulung, Banat, Dobrogea and the continental shelf of the Black Sea, Crisana, Maramures, Transylvanian Plateau and Romanian Plain (Bokelmann and Rodles, 2014).

The Vrancea area of the south-eastern Carpathians is one of the most seismically active regions in Europe and is very well recognized through its powerful intermediate depth earthquakes (Armas et al., 2015).

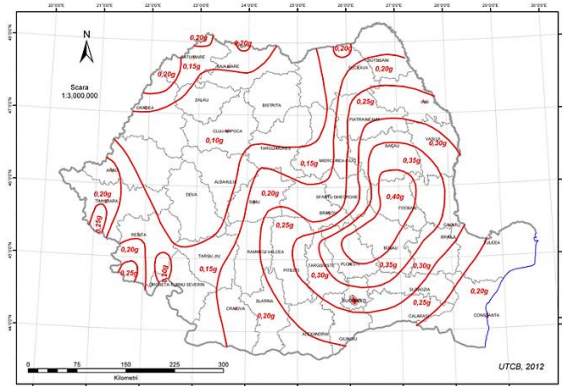


Figure 2. Seismic zoning map from P100-1/2013 (PGA)

MATERIALS AND METHODS

A key point to focus on initially is the seismic performance of structures as a core priority, as they have the greatest consequences on human lives.

Study area

Bucharest begins its development in the 14th century as a market town situated close to the bridges over the Dambovită River at the junction of existing old roads, throughout the field between the forest and the steppe. The face of the city was defined by the disasters that affected it: earthquakes (1701, 1738, 1802, 1838, 1940, 1977), Dambovită's floods, big fires (1802, 1804, 1847), and also by the invasion and influence of foreign troops.

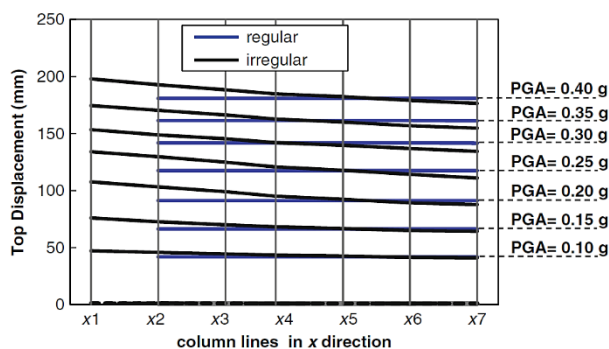


Figure 3. Top story displacement at each column line

Simplicity of a construction implies a continuous and solid enough basic structure to

maintain a straight direction, uninterrupted for the seismic loading straight to the foundation surface. Earthquake engineering should focus on creating a structure as regular and uniformly dispersed in a plan such that inertial forces are directly transferred to the foundation in the shortest possible way (Slave, 2011).

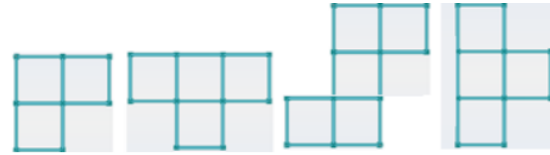


Figure 4. Examples of irregular shapes in plan

Building data

Body A of the Faculty of Land Reclamation and Environmental Engineering, University of Agronomic Sciences and Veterinary Medicine of Bucharest, is the building identified for this analysis. The structure, which was built between 1968 and 1970, has a structure on reinforced concrete frames.

The building selected for evaluation is located in Bucharest. According P100-1/2013, the area is characterized by a peak ground acceleration $a_g = 0.24g$ for design and control period of the response spectrum $T_c = 1.6\text{sec}$.

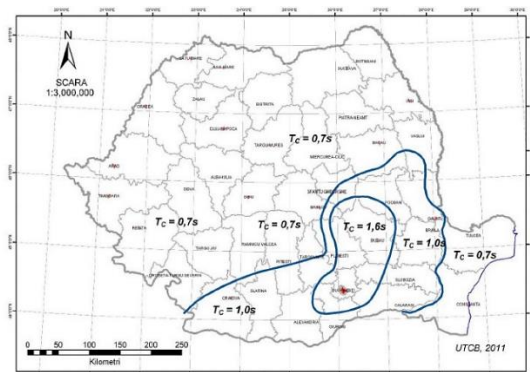


Figure 5. Normalized acceleration spectrum from P100-1/2013

The structure evaluated consists of a ground floor and 4 stories with a gross height of approximately 19 m.

Body A of the Faculty of Land Reclamation and Environmental Engineering building comes into the seismic risk class RsIII -buildings that may have non-significant structural deterioration but significant non-structural deterioration as a consequence of the earthquake design (Slave and Man, 2006).



Figure 6. Building chosen for seismic assessment

The Faculty of Land Reclamation and Environmental Engineering (F.I.F.I.M.) is formed by three buildings divided by seismic joints. Seismic joints are provided between buildings to avoid their collision under seismic action (Dragomir and Dobre, 2019).

The three buildings were designed to meet the requirements for regularity in plan and height. The structure is symmetrical in plan according to the two orthogonal directions. If the construction will generate the phenomenon of subsidence, cracks will affect the body and migrate to the roof.

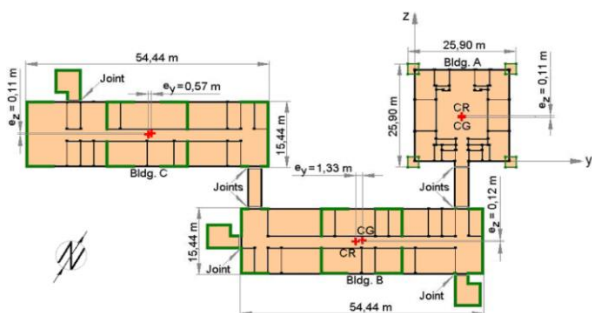


Figure 7. The positions of both centers CG and CR before the structural interventions - the case with seismic joints

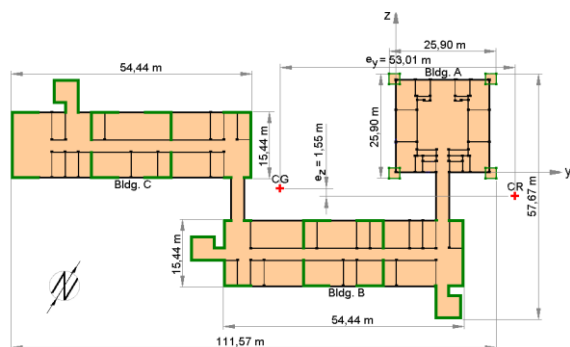


Figure 8. The positions of both centers CG and CR after the structural interventions - the case without seismic joints

Structural characteristics, materials used, foundation and foundation ground

Body A has a reinforced concrete frame structure in two directions, with pillars resting on insulated foundations, at two depth levels: the outer ones at -1.70 m and the inner ones at -0.60 m. The floors are made of reinforced concrete, and hollow brick masonry.

Bodies C and C have a two-way reinforced concrete frame structure with prefabricated reinforced concrete floors. The pillars have reinforced concrete foundations, insulated, and the walls have continuous soles made of concrete. The walls are made of brick masonry. The connecting bodies have a structure of prefabricated concrete frames. The foundation level is at -2.10, on a layer of clay with an allowable pressure of 175 kPa. Under the pillars there are provided insulated foundations with B75 simple concrete base and B150 reinforced concrete stepped type foundation, the facades are made of 30 cm thick GVP type masonry.

The building's behavior during previous earthquakes

The building withstood three major earthquakes, the first in 1977, the second in 1986, and the third in 1990, all in a seismic zone of degree VIII.

The 1977 earthquake caused isolated structural damage to the buildings on the Agronomic University Campus as well as significant damage to the structural elements.

The 1986 caused a reactivation of the 1977 effects, as well as causing new damages to some structural components.

The 1990 earthquake caused visible damage to both structural and non-structural components of almost all structures, though finishing operations have been conducted in the meantime.

Seismic instrumentation of the buildings. Case study – building F.I.F.I.M. Bucharest

All 3 corps of the building F.I.F.I.M.:

- Structural resistance made of reinforced concrete.
- Designed during the seventies, under P13-70;
- $H = 20,33$ m;

On March 4, 1977 damages were mainly made to the partition walls.

$$\begin{cases} k_1 = m \left(\frac{2\pi}{T_1} \right) \\ k_2 = m \left(\frac{2\pi}{T_2} \right) \end{cases} \Rightarrow \frac{k_2}{k_1} \times 100 = \left(\frac{T_1}{T_2} \right)^2 \times 100$$

Validation of the results achieved by modeling using structure calculation software ROBOT Millennium

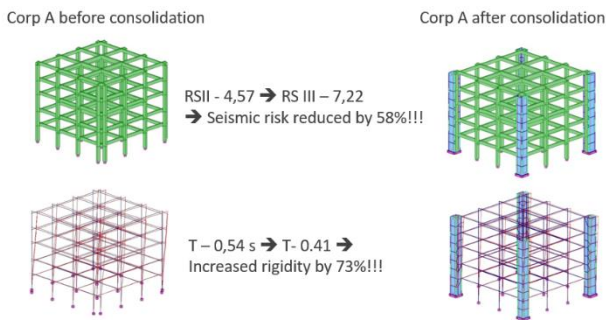


Figure 9. Spatial deformation of corp A after an earthquake, before and after consolidation

The issue of irregularity of the buildings is resolved in compliance with Eurocode 8 and Seismic Project Code P100-1: 2013, by studying the relationship between the centre of rotation (CR) and the centre of gravity (CG) (Dragomir et al., 2016).

Eccentricity can provide a global picture of the torque applied to the structure in question, as well as the structural interventions required to reduce the effects. The building's modelling and structural analysis were performed with the ROBOT Autodesk program, and the dynamic characteristics determined by temporary seismic instrumentation of the structure using GMS-18 equipment and GeoDAS software have been used as input to match the structural model.

Seismic Risk Assessment of RC buildings

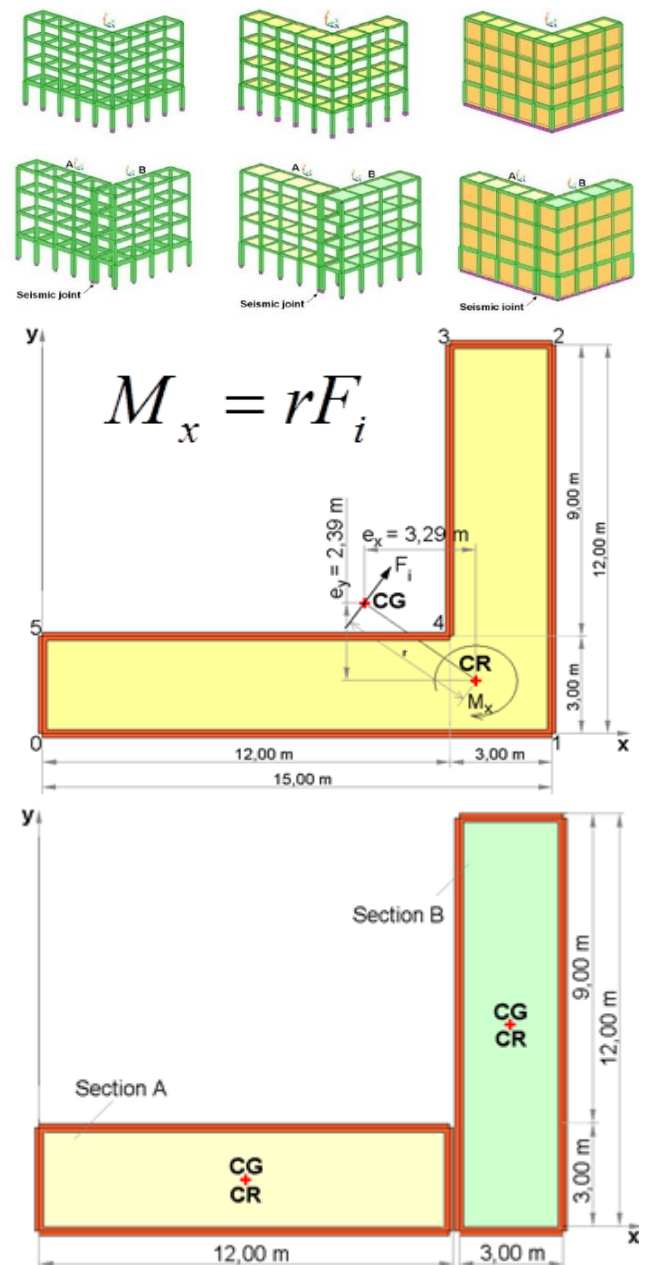


Figure 10. Space structure of L shaped-plan before and after sectioning, in different structural typologies

Monitoring the structures by seismic instrumentation

Monitoring:

- Creating maps representing the area of seismic activity
- Identifying structural characteristics
- Identifying restore and consolidation requirements
- The efficiency of previous intervention measures.

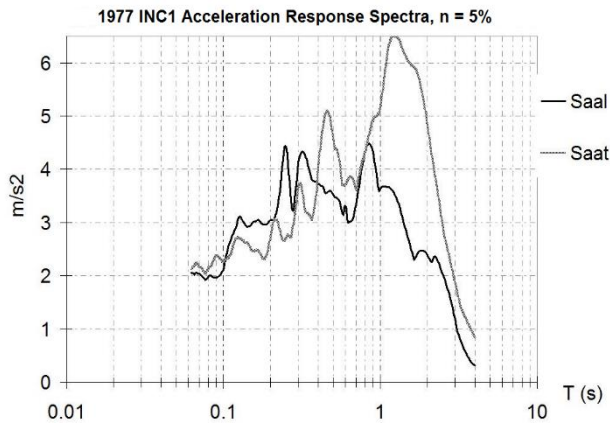


Figure 11. On March 4, 1977 – first recorded data of engineering concern to INCERC

Minimal instrumentation:

- 1 sensor in free-field
- 1 sensor to ground floor
- 1 sensor on the ceiling of the last floor

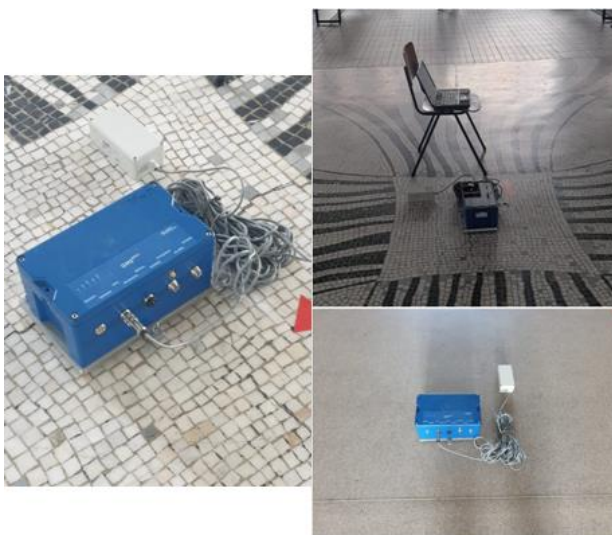


Figure 12. Seismic instrumentation used for the case study building – building F.I.F.I.M.

RESULTS AND DISCUSSIONS

The results of this study reveal that geometry plays an important role in seismic engineering, and that there are situations when remodeling a building can be effective, especially when using advanced technologies available on the European market.

According to the structural analysis, a 73% improvement in rigidity was achieved by consolidation solutions with marginal pillars (Dragomir et al., 2019).

What is indicated by the structural analysis is also confirmed by the seismic monitoring results.

Reduced oscillation periods results in increased rigidity.

Date	Execution type	Oscillation direction	
		Transversal	Longitudinal
3.12.1986	microseisms	0.62	0.57
19.11.1990	microseisms	0.53	0.43
11.10.1996	microseisms	0.50	0.44
11.10.1996	Explosion-maximum excitation	0.57	0.50
11.10.1996	Explosion-free vibration	0.53	0.44
13.02.1998	microseisms	0.42 – 0.44	0.40 – 0.42
21.12.2009	microseisms	0.35	0.42
02.03.2012	microseisms	0.38	0.42 – 0.44
05.04.2021	microseisms	0.40	0.42

Figure 13. Evolution in time (1986-2021) of specifics periods to corp A of the building

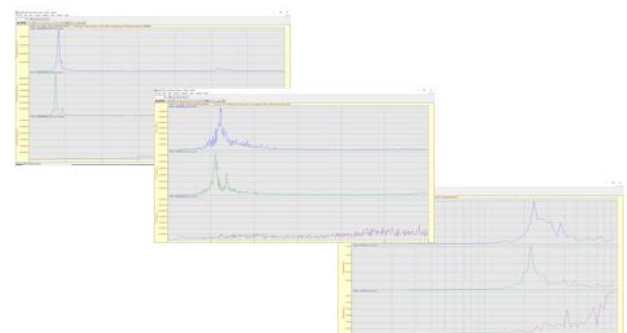
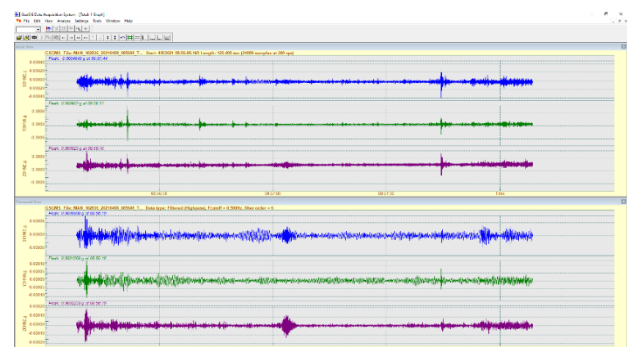
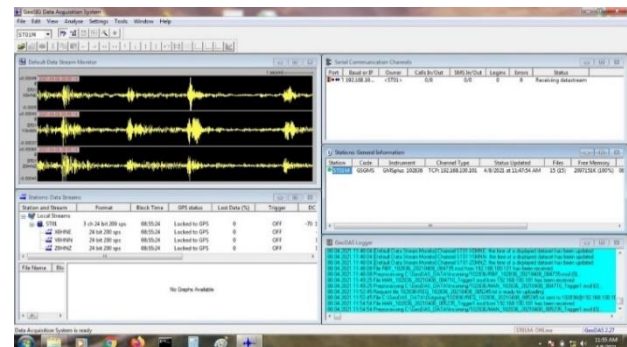


Figure 14. Own periods of body A identified by the processing and analysis of the registration from April 5, 2021

CONCLUSIONS

In-situ instrumental data contribute to a correct understanding of the importance and of the influence of various factors on the structural dynamic response, as well as their correlation with interest objectives for the building owners/beneficiary.

In this regard, the determination of the dynamic characteristics of building structures is one of the most important aspects of structural health monitoring. The results are conclusive and are discussed both on the charts and analytical results obtained.

By using the concept of performance assessment, it can predict how certain structures that have experienced earthquakes in the last century will respond to future earthquakes (Dragomir et al., 2016).

ACKNOWLEDGEMENTS

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SECTION 03

CADASTRE

MODERN POSSIBILITIES FOR GREEN SPACE MANAGEMENT THROUGH GIS TECHNOLOGY

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Abstract

This paper aims to highlight a practical way to map the Nicolae Titulescu Park in Brasov. The surface of this park (over 5 ha) was measured using the total station and GNSS technology, by mapping both utilities from this space (green space – with flowers, green space – with trees, green space – with shrubs, alleys, playground for children, recreation space), as well as the details (trees, shrubs, spaces for agricultural species, benches, traffic signs, lamps). The topographic data were rigorously compensated, by further processing in the GIS program, in which the related database was created and a series of GIS analyzes were performed such as: the ratio between major parks utilities (green space versus alleys), the ratio between the effective surface occupied by the projection of the trees and the green space surface, the control of the trees crown grooming, etc. It has thus been shown that the use of GIS is not only timely, but also extremely efficient for a modern management of green spaces.

Key words: green space, shrub, total station.

INTRODUCTION

Pollution has always been a harmful factor and has intensified with the evolution of civilization, becoming increasingly problematic for both the environment and humanity.

In order to minimize the effects of pollution, local public institutions must monitor all the time the development of vegetation lands and manage it strictly because green spaces have an important role in reducing pollution.

The aim of this paper is to verify whether GIS systems have the ability to be used in efficient management of green spaces.

Unlike previous studies conducted by the Institute of Forestry Research and Development that focused on monitoring the pollution degree of green spaces in urban areas, studies conducted for this paper are mainly based on the methods of administration and management of green spaces.

MATERIALS AND METHODS

Nicolae Titulescu Park is located in the center of Brasov and dates back to the nineteenth century,

being one of the main green spaces of the city due to its special characteristics.

For the most part, the basic shape of the park has been preserved to this day, but its size has undergone various changes due to uncontrolled urban development (Marcus, 1958).

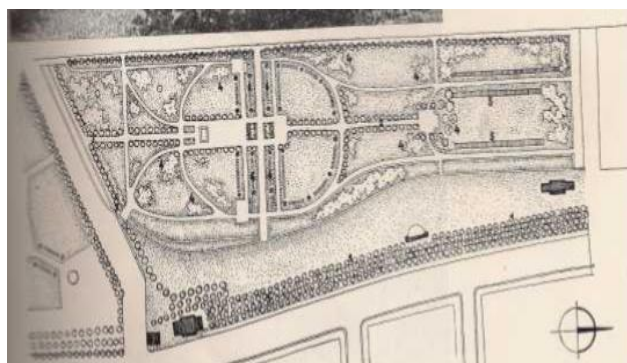


Figure 1. First shape of the park

Because the park is located in one of the most crowded and polluted areas of the city, the identified fruit species play a very important role in absorbing pollutants from the atmosphere. Over time, with the development of the area, the plants in the park have changed; at first the poplars predominated, but they were replaced by

the maple species, which are more resistant to pollution factors.

For a good organization and management of green spaces there are several methods that can be used, but the use of GIS technology is among the most efficient because unlike the others it has different possibilities for querying, locating the searched data, and also their graphical display.

The main materials on which the study was conceived are represented by old maps and plans, orthophotos and archive photographs.

The equipment used for measurements were the total station South A1 and the Trimble R4 GPS. The A1 total station uses the Android operating system, the 5-inch LCD screen displays a large amount of information and makes the measurement operations easy and clear to read (https://www.cadsolutions.ro/total-station-surveying-a1-%E2%80%93-android-_355).



Figure 2. Total station South A1

The Trimble R4 Model 3 GNSS receiver is a compact system that operates on 220 channels. The antenna, receiver and battery are embedded in the same case. Equipped with Trimble R-Track technology allows the reception of signals from GLONASS satellites that improve the GPS system solution and thus better results can be obtained in hostile conditions to satellite measurements (<https://www.giscad.ro/aparatura/iesite-din-productie/receptor-gnss-trimble-r4-model-3>).



Figure 3. Trimble R4 Model 3 GNSS

The research methods used in this paper are direct measurement method, data processing method, GIS methods and analysis.

The direct measurement method, in which the considered physical size is compared directly with the unit of measurement (https://www.ct.upt.ro/studenti/cursuri/musat/Masuratori_Geodezice.pdf), was applied in the field by making a main route closed at the point of departure.

The processing of the data collected in the field was performed automatically by the application from the GPS controller as well as by the one of the total station. However, due to the fact that the lifting network was very dense and not all station points could be determined by GPS technology, main road sections were established that were compensated using the Toposys program.

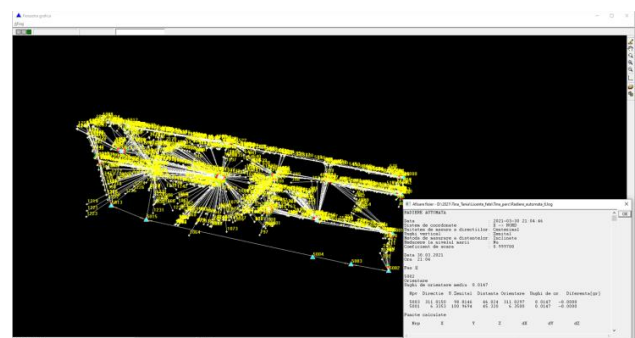


Figure 4. Radiated points in Toposys program

The aforementioned compensation was made at the office. GIS methods and analyzes were used to create the project in AutoCAD Land and finalize it in ArcGIS by organizing it in a series

of stages, phases and logical steps (Tereşneu and Vasilescu, 2012, 2013; Tereşneu et al., 2013).

RESULTS AND DISCUSSIONS

The data resulting from the measurements were processed (compensated) after which the situation plan was made in AutoCAD. This was, in fact, only an intermediate stage that was meant to group the data both by type (point, line, polygon) and by the use within the same type. (for point type data, aboriginal and shrub species were differentiated, for polygon data the various uses were differentiated etc.

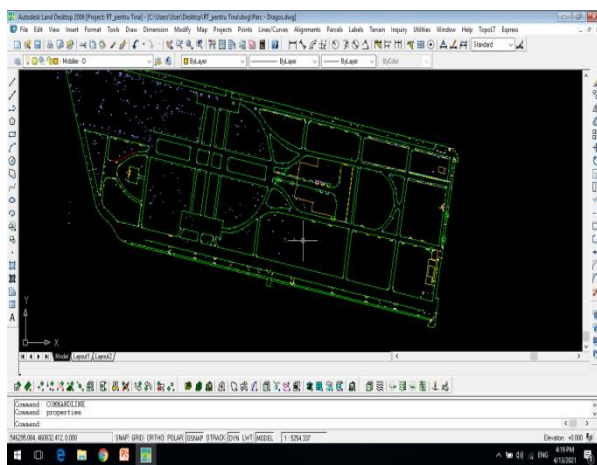


Figure 5. The situation plan in AutoCAD

After the execution of the situation plan that included the main details in the field, the data were processed in ArcGIS where the corresponding databases were created.

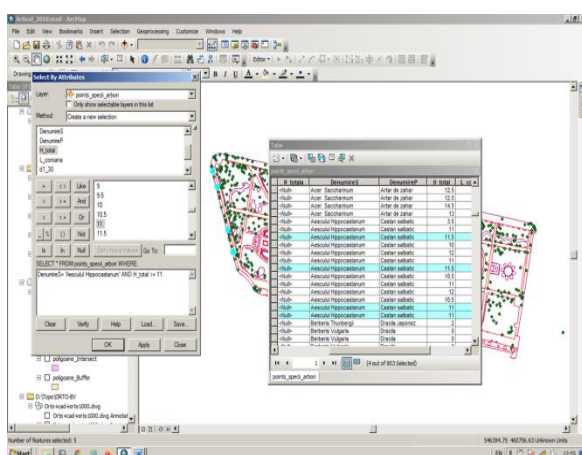


Figure 6. Completing the database in ArcGIS

For aboriginal species, the database included the following fields: the popular name and the scientific name of each tree, the total height, the length of the

crown, the diameter of the crown and the diameter at 1.30 m.

Unlike these species, in the case of shrub species, the database included the same fields, excluding the diameter at 1.30 m, which was impossible to measure.

For the flower rounds, the component species and the surface afferent to each round were registered in the database, and for the alleys we registered the length, the width and the space.

After completing the GIS project, we proceeded to the stage of performing GIS analyzes (Tereşneu et al., 2011).

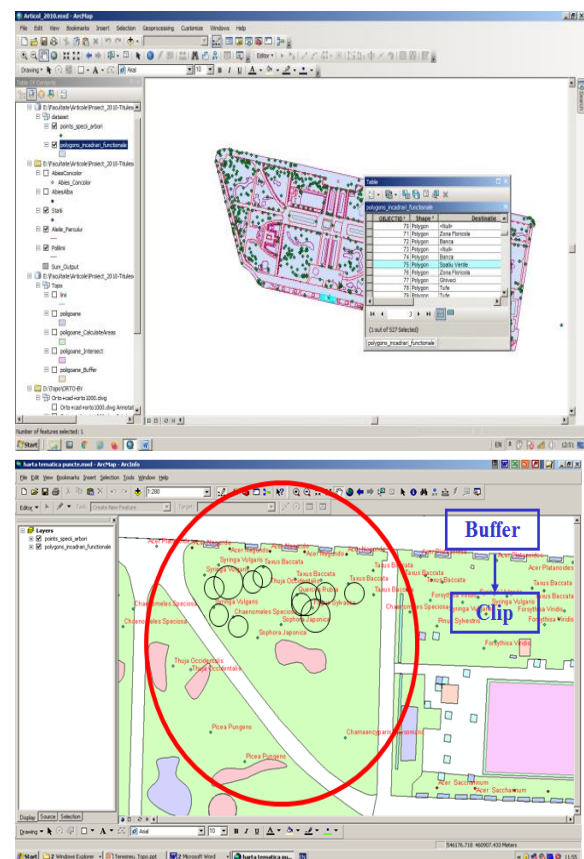


Figure 7. GIS analyzes

The management of a park requires both the existence of a correct and constantly updated database, as well as an analysis tool that will answer any query at any time; for this reason ArcGIS was used as a tool because it has all the advantages of managing a green space properly through its ability to identify problems, monitor changes, make prognosis, etc.

Table 1. Species identified in the park

No.	Species name	
1	<i>Abies alba</i>	3
2	<i>Abies concolor</i>	1
3	<i>Acer negundo</i>	19
4	<i>Acer platanoides</i>	35
5	<i>Acer pseudoplatanus</i>	6
6	<i>Acer saccharinum</i>	80
7	<i>Aesculus hippocastanum</i>	13
8	<i>Berberis thunbergii</i>	1
9	<i>Berberis vulgaris</i>	7
10	<i>Betula pendula</i>	11
11	<i>Biota orientalis</i>	9
12	<i>Buxus sempervirens</i>	14
13	<i>Carpinus betulus</i>	9
14	<i>Catalpa bignonioides</i>	4
15	<i>Chaenomeles speciosa</i>	28
16	<i>Chamaecyparis lawsoniana</i>	21
17	<i>Colutea arborescens</i>	2
18	<i>Deutzia scabra</i>	14
19	<i>Duglas albastru</i>	2
20	<i>Fagus sylvatica</i>	2
21	<i>Forsythia viridis</i>	64
22	<i>Fraxinus pennsylvanica</i>	1
23	<i>Hibiscus syriacus</i>	1
24	<i>Juniperus sabina</i>	1
25	<i>Liriodendrum tulpifera</i>	12
26	<i>Lonicera xylosteum</i>	1
27	<i>Magnolia kobus</i>	9

Table 2. Species identified in the park

No.	Species name	
28	<i>Malus sylvestris</i>	9
29	<i>Malus x purpurea</i>	7
30	<i>Morus alba</i>	5
31	<i>Philadelphus coronarius</i>	9
32	<i>Picea abies</i>	3
33	<i>Picea pungens</i>	33
34	<i>Pinus nigra</i>	16
35	<i>Pinus sylvestris</i>	5
36	<i>Pinus strobes</i>	1
37	<i>Prunus avium</i>	2
38	<i>Prunus cerasifera</i>	3
39	<i>Prunus mahaleb</i>	1
40	<i>Quercus rubra</i>	19
41	<i>Robinia pseudocacia</i>	2
42	<i>Rosa canina</i>	1
43	<i>Salix babylonica</i>	1
44	<i>Sambucus nigra</i>	1
45	<i>Sophora japonica</i>	3
46	<i>Spirea vanhouttei</i>	12
47	<i>Symphoricarpos rivularis</i>	5
48	<i>Syringe vulgaris</i>	67
49	<i>Taxus baccata</i>	49
50	<i>Thuja occidentalis</i>	17
51	<i>Thuja plicata</i>	1
52	<i>Thujopsis dolabrata</i>	1
53	<i>Tilia cordata</i>	2
54	<i>Tsuga Canadensis</i>	3

The management of a park requires both the existence of a correct and constantly updated database, as well as an analysis tool that will answer any query at any time; for this reason ArcGIS was used as a tool because it has all the advantages of managing a green space properly through its ability to identify problems, monitor changes, make prognosis, etc.

Among the countless possibilities that this modern tool can make available to the user, we can talk about

the quick visualization of the location of any species and any specimen and also about the control of grooming the crowns of trees and shrubs. This aspect was achieved by creating a VBA sequence that will automatize the indication of the optimal time for the next intervention in each species that is suitable for such an intervention (Teresneu et al., 2011).

Determining the area of various uses and determining the number of specimens of the same species are also examples of GIS applications for modern management of green spaces.

CONCLUSIONS

Following the results obtained, it was found that a modern management of green spaces cannot be designed today without the use of a GIS tool. The ArcGIS program was used, which facilitates both a very strict management of the spaces and species in such an area, as well as a proper management of the park in a way that permanently responds to the purpose for which it was created.

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MULTIMODAL TRANSPORTATION NETWORK IN BRASOV COUNTY

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Abstract

Searching for a historically rich area, we have identified the Brasov area as an important tourist attraction, therefore we have found the need to create a multimodal transport network, which would make it easy to switch between many transport networks, so as to correspond tourists' need to go to tourist attractions in the area as efficiently, safely, and relaxed as possible. The transport network is made by starting from the most popular areas from Brasov for tourists to visit, creating a beautiful route for every tourist who wants to discover a part of our country. Analyzing the current transport network, the areas where these services are in high demand, the air quality, and the opportunities for improvement, a map regarding the use of a multimodal transport system has been made. With the help of ArcGIS technology, bicycle lanes, pedestrian lanes and the best public transport solutions have been created. For starters we have georeferenced the image taken from Google Earth, which contains the area studied in ArcMap. The next task was to create a data base that corresponded to the future transport network, containing the main roads and the most important attractions. In our work we have used the following apps: ArcMap, ArcCatalog, GoogleEarthPro and also TransDatRo. In the end we obtained a map made for tourists, which aids them in their traffic, as well as a panoramic view of the most important attractions in Brasov.

Key words: Geographic Information System (GIS), multimodal transport network.

INTRODUCTION

Our daily concern is time management so that we can enjoy more free time. For this purpose, we set out to conduct a study on optimizing a route that includes several objectives. For this study we chose the city of Brasov because it's an historical center in our country. Our main purpose was to create transport routes between the main tourist points in Brasov, in order to obtain the shortest route. To achieve this goal we have created a multimodal network which includes the bus, trolley and external networks in the are. In our study we capitalized on the most important tourist attractions, namely Brasov Glade and Fortress Rupea. Brasov, the city at the foot of Tâmpa is the ideal place for a trip to your loved ones, which attracts you and invites you to discover all that is most beautiful.

MATERIALS AND METHODS

In order to carry out the study, it was necessary to follow the following steps.

The first step was to choose the area of interest in Brasov. For this I used GoogleEarthPro app where:

1. We have identified the Brasov area;

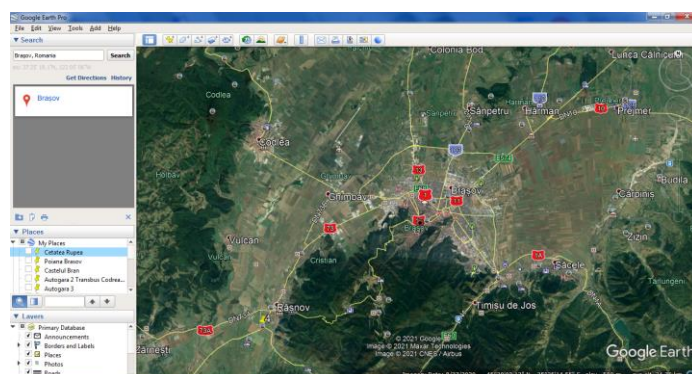


Figure 1. Area identified in Google Earth Pro

2. We have placed the check points which cover the area of interest;



Figure 2. Location of control points

3. We have obtained the coordinates of the points;

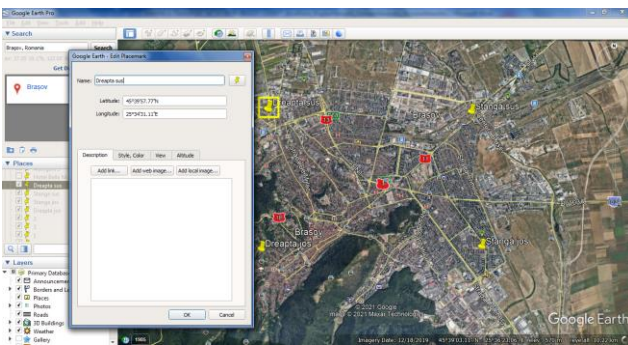


Figure 3. The coordinates of the first point

4. We saved the image to later georeferenced.

Then we used the TransDataRo 4.1. app to transform the geographical coordinates into plane coordinates.

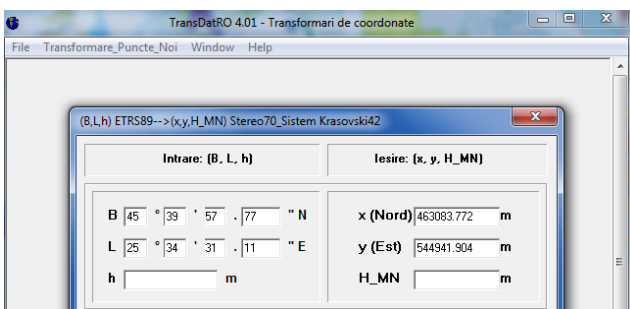


Figure 4. Transform the Geographical Coordinates into Plane Coordinates

We have created a Microsoft Excel file with the plane coordinates, useful for the georeferencing of the image.

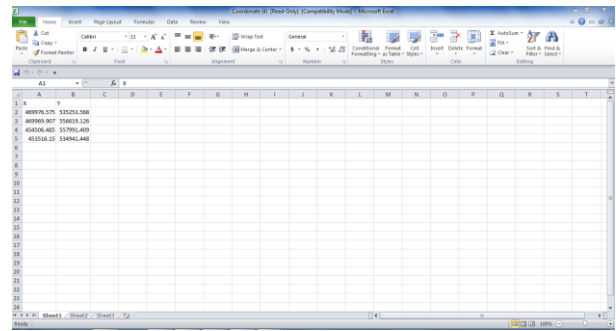


Figure 5. X and Y Coordinates in Excel

We used ArcCatalog to create a data base and data set which we later adapted to our zone.

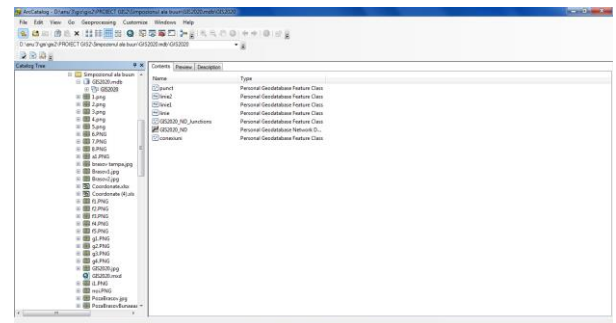


Figure 6. Picture from the ArcCatalog with the database

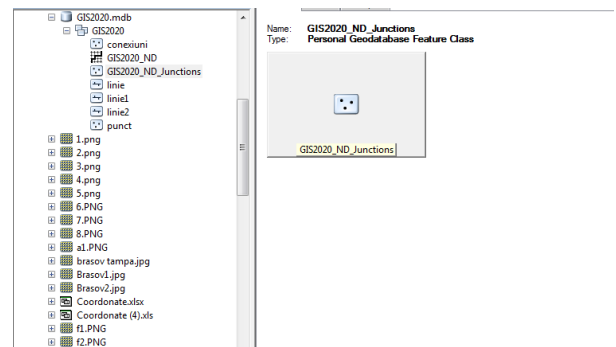


Figure 7. Creating junctions = Connecting points

In the end we used the ArcMap app where we: setup the Stereo 70 projection system; we added the image, the Excel file and data base and then we georeferenced the image.

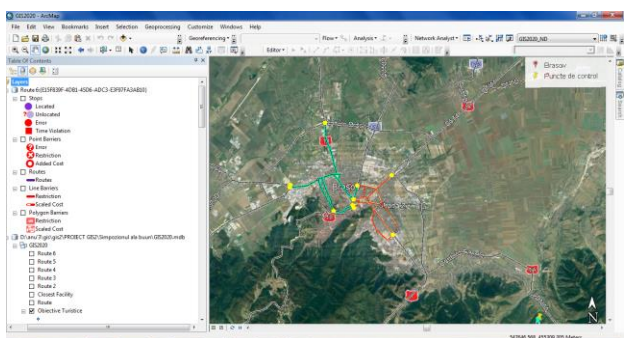


Figure 8. ArcMap picture

RESULTS AND DISCUSSIONS

The first image was save in GoogleEarth Pro which was later georeferenced in ArcMap.



Figure 9. Identify our area in GoogleEarthPro

Afterwards we vectorized the roads in our zone and we created the multimodal network.

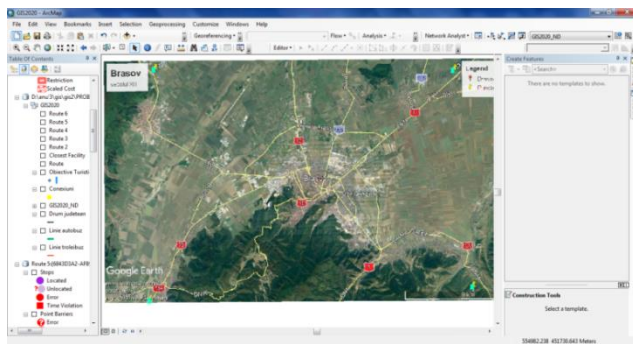


Figure 10. Georeferenced picture in ArcMap

I vectorized the county road in gray, the bus line in green and the trolleybus line in red. In the drawing you can also see the connection points with yellow, which will make the connection between the county road and the transport lines.



Figure 11. Map with all the layers

Network datasets are well suited to model transportation networks. They are created from source features, which can include simple features (lines and points) and store the

connectivity of the source features. We perform the analysis using the ArcGIS Network Analyst extension, the analysis always happens on a network dataset.

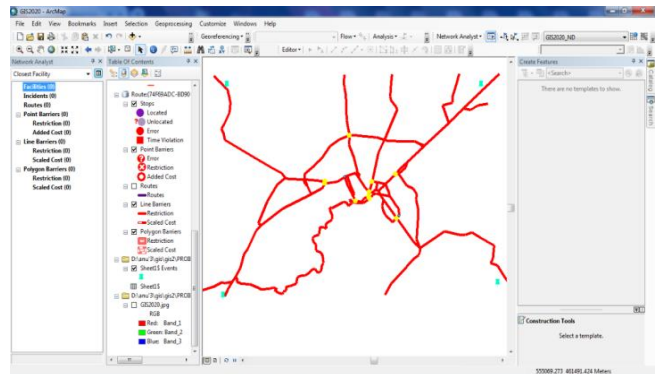


Figure 12. The Multimodal Network corresponding to our area

We used GoogleMeet to discuss and work on our project.

Due to current conditions instead of face-to-face interaction, we had to resort to different means, using the internet.

During the meetings there were discussions about the creation of the network, but also about solving the problems that arose along the way.

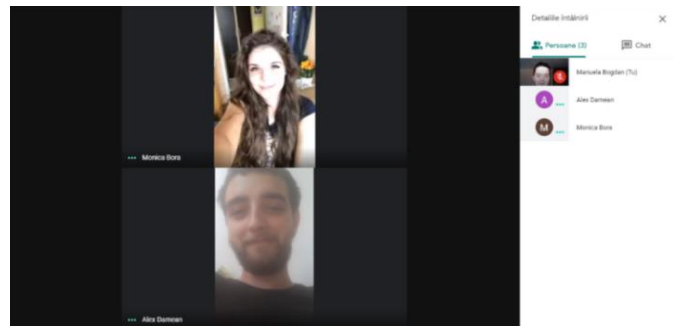


Figure 13. Our team on GoogleMeet

With the help of the teacher, I solved the small ambiguities that appeared along the way.

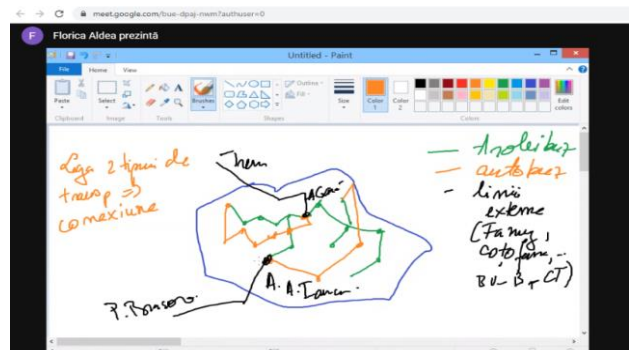


Figure 14. Collaboration sessions for the Symposium

The cladding point is represented by Codreanu Bus Station.



Figure 15. Codreanu Bus Station

Brasov Glade is the most famous winter sports resort in Romania and also an important international tourist center.



Figure 16. Brasov Glade



Figure 17. Rupea Fortress

Rupea Fortress is one of the oldest archaeological vestiges in Romania, the first signs of human settlements dating from the Paleolithic and Early Neolithic. The Rupea Fortress, as it appears to us today, covers an area of almost 11 ha with walls, towers and inner courtyards.



Figure 18. Cubix Hotel

Cubix Hotel is an elegant four-star hotel with contemporary architecture. It is the ideal place for business trips, for holidays or for organizing various events.

The objective is to determine the distance between Codreanu Bus Station and Cubix Hotel, with two stops, the first at Poiana Brasov and the second at Rupea Fortress.

Another objective of great interest is to analyze the same route if there are four restrictions as can be seen in the image below.

Also, the distance of the route was calculated with and without restrictions where a significant difference can be observed.

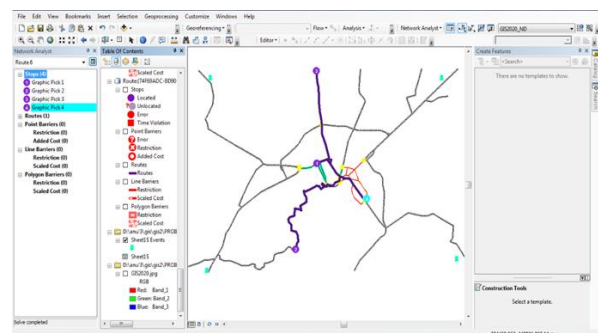


Figure 19. The route without restrictions

Figure 19 represents the georeferenced route without obstacles in which the distance was

determined, respectively 25 km from the Bus Station to the final point, Cubix Hotel.

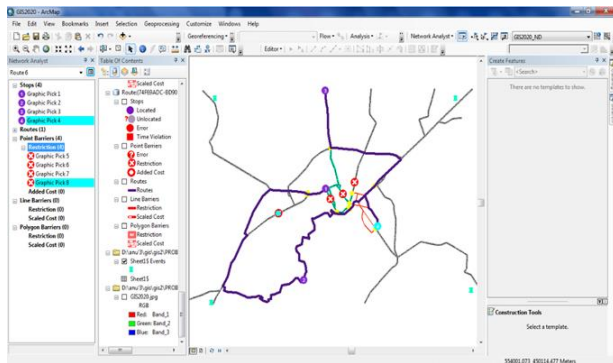


Figure 20. The route with the four restrictions

There is a clear difference between the two routes identified, the first being the fastest and the second being an alternative, respectively longer with a total distance of 34 km, starting

from Codreanu Bus Station and ending at Cubix Hotel.

To exemplify our idea, we attached images in which we simulated two routes in different conditions.

CONCLUSIONS

In light of this research we can obtain with the help of the data base and the ArcMap app the shortest route between the selected tourist attractions in our analysis.

We simulated a series of obstacles which may appear, so that the program can generate the shortest route by taking them into account.

It's worth mentioning that the multi nodal network is also the basis of GPS apps.

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THE GEOGRAPHICAL INFORMATION SYSTEM OF THE VINEYARD CADASTRE AND THE IMPACT ON THE SUSTAINABLE DEVELOPMENT PROCESS OF THE RECAȘ VINEYARD

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Abstract

The paper presents a management plan of the Recaș vineyard using software specific to Geographic Information Systems, which are based on the vineyard cadastre, information on the vineyard area, the owner, the category of use of the vineyards, and other aspects, a series of results with immediate or long-term effect on the process of sustainable development.

Creating a WEB GIS application that presents an interactive map of the Recaș vineyard using the ArcGIS online software, is a mobile and advanced solution for how to use a map in the viticultural field.

The interactive map can be used for tourism purposes, based on the exposure of the main locations and the management of all works necessary for plots in the Recaș vineyard, so good coordination will lead to the proposed results and the development of sustainable viticulture in the western part of Romania, it directly contributes to the expansion of national sustainable wine development.

Key words: ArcGIS, Geographic Information Systems, Sustainable Development, Vineyard Cadastre.

INTRODUCTION

By carrying out a management plan of the Recaș vineyard using software specific to Geographic Information Systems, based on the vineyard cadastre, information on the vineyard area, the owner, the category of use of the vineyards, as well as other aspects, a series of results can be obtained immediate or long-term effect on the sustainable development process.

The viticultural cadastre is a component of the agricultural cadastre and represents the subsystem of evidence and systematic inventory of real estate in technical, economic and legal aspects regarding the viticultural surface, the category of use of the viticultural plots and the owner.

In order to achieve the viticultural cadastre, the following stages must be completed: territorial delimitation of viticultural areas, territorial delimitation of viticultural areas intended for the production of quality wines with designation of origin and identification, registration and representation on maps and cadastral plans of scattered vineyards located outside viticultural areas.

For the application of the viticultural cadastre, the set of technical works must be carried out, which determines exactly the viticultural functional properties regarding their identification, measurement, description and representation on maps.

Also, the importance of cadastral works is paramount for the establishment of information systems of the territory, able to provide quickly, real data of management and planning of real estate in various sectors of the national economy.

The Viticultural Information System represents the unitary and obligatory system, through which the identification, registration, delimitation and representation on maps and cadastral plans of all the lands from the national viticultural patrimony and of the other real estates related to it, regardless of their destination and owners.

The purpose of the system consists in updating or drawing up plans for wine-growing centers and vineyards, the correct establishment of the agricultural income tax, their trading, leasing or concession, and the statistical processing

necessary for the elaboration of technical and economic documents.

MATERIALS AND METHODS

In order to characterize the evolution of milk production, the following indicators were used: number of cattle stock, of which dairy cows and heifers, milk yield and milk production, milk consumption per inhabitant, number of dairy farms and cow density per ha.

Sustainable viticulture as defined in the O.I.V. CST 1/2004 represents: the development of a unitary concept on grape production and processing systems, in harmony with the economic and structural sustainability of the wine-growing territory, the quality and safety of the products obtained, in the context of practicing safe viticulture, taking into account the risks related to the environment, consumer safety and to capitalize on aspects related to heritage, history, culture, ecology and landscapes of the wine-growing area.

The wine-growing area represents a national and european heritage, respectively. It must be delimited, identified, analyzed and evaluated as objectively as possible in order to be managed, capitalized and registered in the cadastre. Romania is one of the main european wine-growing countries, with a millennial tradition regarding the cultivation of vines. Romania has eight wine regions, which include numerous vineyards and wine centers.

The western region of the country has an important viticultural area with a large share in romanian viticulture. It provides favorable natural conditions for the cultivation of vines, especially varieties for high quality wines.

The geographical location and the superior infrastructure of the other viticultural areas of Romania have attracted a large number of investors, especially in recent years, who have fully contributed to the relaunch of viticulture in this area.

The wine growing area in the west of the country includes the area of some old vineyards, with a long tradition in the cultivation of vines, such as the vineyards Recaș, Petro Vaselo, Dealul Dorului and Thesaurus.

Cramele Recaș company manages an area of approximately 1150 hectares of vines located in Recaș locality, Timiș county, as well as in Miniș

locality, Arad county. The main grape varieties cultivated by the company Cramele Recaș in the Recaș vineyard as well as in the Miniș vineyard are presented in table 1.

Table 1. The main grape varieties in the vineyards of Cramele Recaș and the number of hectares allocated for each variety.

Current number	Grape varieties from Recaș vineyard and from Miniș vineyard	Area (ha)
1	Pinot Gris	71,76 ha
2	Sauvignon Blanc	106,04 ha
3	Chardonnay	60,74 ha
4	Muscat Ottonel	45,52 ha
5	Feteasca Regala	135 ha
6	Fetească Albă	3 ha
7	Riesling Italian	17 ha
8	Riesling de Rhein	36 ha
9	Mustoasă de Maderat	2 ha
10	Viognier	9,3 ha
11	Tămâioasă Românească	3 ha
12	Traminer	4 ha
13	Pinot Noir	57,95 ha
14	Cabernet Sauvignon	177 ha
15	Cabernet Franc	13,74 ha
16	Syrah	13,52 ha
17	Fetească Neagră	45,37 ha
18	Merlot	106 ha
19	Novac	1 ha
20	Negru de Drăgășani	3 ha
21	Cadarcă	3 ha

The wine heritage is an asset that is managed nationally. The information associated with the national viticultural heritage is that of cadastral and administrative records.

Thus, by creating a management plan for the Recaș vineyard using software specific to Geographic Information Systems, based on the viticultural cadastre, information on the viticultural area, the category of use of the vineyards, the owner and other aspects, a series of results can be obtained with immediate or

long-term effect on the sustainable development process.

Therefore, the restructuring of the classic vine cultivation technologies, practiced in this area, to the requirements of sustainable viticulture, requires solving interdisciplinary issues and the choice of optimal options further ensure the well-known quality of the wine products in this area.

The use of new technologies within the Receaș vineyard, such as global positioning systems (GNSS), meteorological sensors and Geographic Information Systems (GIS), contributes decisively to the development of the sustainable viticulture process in the western part of Romania (Barliba et al., 2017).

Also, the importance of cadastral works is paramount for the elaboration of the Geographic Information Systems of the viticultural territory, able to provide quickly real data of management and planning of the works undertaken within the viticultural areas.

RESULTS AND DISCUSSIONS

The Geographic Information System is the framework that allows data collection, management and analysis. With its roots in the science of geography, GIS integrates several types of data (Herban et al., 2012).

Analyze spatial locations and organize layers of information in views using maps and 3D scenes. With this unique capability, GIS reveals a deeper understanding of data, such as patterns, relationships, and situations, helping users make smarter decisions (Barliba et al., 2018).

ArcGIS is an application, very useful and fast for creating attractive maps in 2D and 3D format, data analysis and geographic knowledge generation. It provides the ability to examine relationships, test predictions, and ultimately, make better decisions (Grecea et al., 2012).

ArcGIS Online provides the tools you need to create interactive maps and applications that can be shared with specific groups or users.

The study consists in creating a GIS Web application that presents an interactive map of the Receaș vineyard, using ArcGIS Online software, the map highlights the plots on which the main varieties are grown and the plots on which the subcategories of the vine category are found, these being: land in preparation for planting, fruitful vine plantations, rootstock

plantations, vine schools, hop plants, abandoned vineyards. The map of the Receaș vineyard also includes: the Cramele Receaș tourist area, the communal road DC 66 as well as the main agricultural roads used for the specific works of viticulture.

For the plots on which the main local varieties are cultivated, the following are highlighted: the type of soil specific to each plot, the irrigable plots and the plots where the level of fertilization must be reduced or increased and the plots where there is a problem with a disease, a pest or irrigation system.

The interactive map will present several points of interest in the Receaș vineyard, which will contain information on: subcategories of the category of use of vines, the name and description of each variety of vine grown, the soil specific to each plot, whether the plot is irrigated or problem with the irrigation system, where the level of fertilization must be reduced or increased, where there is a problem with a disease or a pest, details about the geographical position of each plot, latitude and longitude, land book number, specific cadastral number each plot and a symbol that differentiates them. In order to create the WEB GIS application that presents the interactive map of the Receaș vineyard, the following steps were completed: The first stage consisted in identifying and collecting on the field the geographical coordinates of the targeted objectives using a smartphone and accessing the Bing Maps web service. This was followed by the creation of a spatial database that includes several Microsoft Excel files, each file having different attributes, depending on what it contains (Herban et al., 2012).

The figure below shows a list of databases with all Excel files (Figure 1).

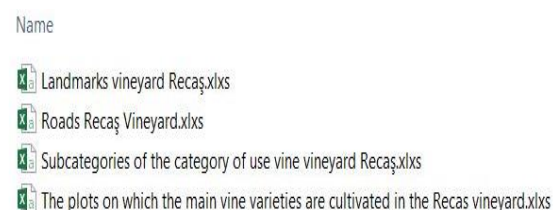


Figure 1. List of Excel files

In Figure 2 we presented the content of the GIS database for the subcategories of the vine use category from the Receaș vineyard.

	A	B	C	D	E	F
1	Name	Nr. Land Registry	Cadastral number	Latitude	Longitude	
2	Land in preparation for planting	411042	411042	45.838196	21.536447	
3	Vine plantation	415401	415401	45.833557	21.544446	
4	Planting rootstocks, grafted ropes and cuttings	411012	411012	45.836526	21.527979	
5	Vine schools	400637	400637	45.833318	21.526648	
6	Hop plantation	414981	414981	45.831395	21.534345	
7	Abandoned vineyard	415407	415407	45.833196	21.535125	
8						
9						

Figure 2. GIS database for the subcategories of the Recaș vineyard use category

In Figure 3 we presented the content of the GIS database for the plots on which the main vine varieties are cultivated in the Recaș vineyard.

Presenze per paese e categoria principali attività di vita e di politica familiare - Microsoft Excel									
File Home Insert Layout References Formulas Data Review View									
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Figure 3. GIS database for the plots on which the main vine varieties are cultivated in the Recaș vineyard

In Figure 4 we presented the content of the GIS database for the tourist objective Cramele Recaș.

	A	B	C	D	E	F	G	H
1	Name	Nr. Land Registry	Cadastral number	Latitude	Longitude	Description	Website	
2	Cramele Recaș	400210	400210	45.827361	21.525412	Cramele Recaș is a Romanian wine from http://cramelecas.ro/		
3								
4								
5								
6								
7								
8								
9								
10								

Figure 4. GIS database for the tourist objective Cramele Recaș

In Figure 5 we presented the content of the GIS database for some of the agricultural roads identified in the Recaș vineyard.

	A	B	C	D	E
1	Name	Latitude	Longitude	Nr. Land Registry	Cadastral number
2	DC 66	45.828827	21.523918	413112	413112
3	Agricultural road 1	45.829738	21.523164		
4	Agricultural road 2	45.834532	21.523039		
5	Agricultural road 3	45.834413	21.521314		
6	Agricultural road 4	45.834405	21.51905		
7	Agricultural road 5	45.836038	21.548805		
8	Agricultural road 6	45.837952	21.536779		
9	Agricultural road 7	45.827957	21.543356		
10	Agricultural road 8	45.816382	21.535547		
11	Agricultural road 9	45.817458	21.530024		
12	Agricultural road 10	45.823107	21.520148		
13	Agricultural road 11	45.827087	21.494995		
14	Agricultural road 12	45.829717	21.505871		
15	Agricultural road 13	45.832707	21.50163		
16	Agricultural road 14	45.833521	21.526658		

Figure 5. GIS database for roads identified in the Recaș vineyard

Subsequently, the Excel files with XLXS extension were converted to files with CSV extension.

- Landmarks vineyard Recaș.csv
- Landmarks vineyard Recaș.xlsx
- Roads Recaș Vineyard.csv
- Roads Recaș Vineyard.xlsx
- Subcategories of the category of use vine vineyard Recaș.csv
- Subcategories of the category of use vine vineyard Recaș.xlsx
- The plots on which the main vine varieties are cultivated in the Recaș vineyard.xlsx
- The plots on which the main vine varieties are cultivated in the Recaș vineyard.xlsx

Figure 6. List of CSV and XLXS files

The XLXS files were saved with the CSV extension, and then we stored all the CSV files in the folder where the XLXS files were (Figure 6).

The second step was to create an account and log in to the ArcGIS online platform. I accessed the creation of an interactive map and added CSV files as a theme layer (Figure 7).

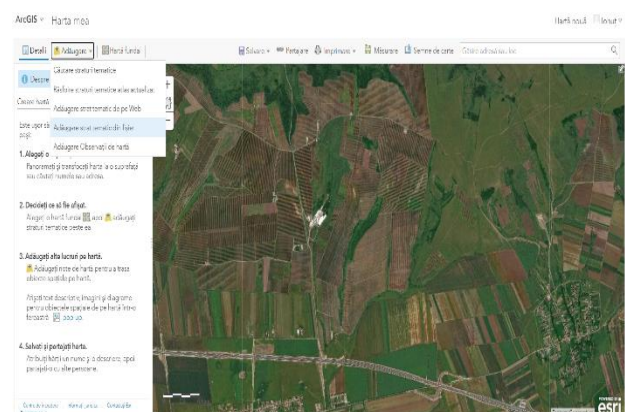


Figure 7. Inserting CSV files

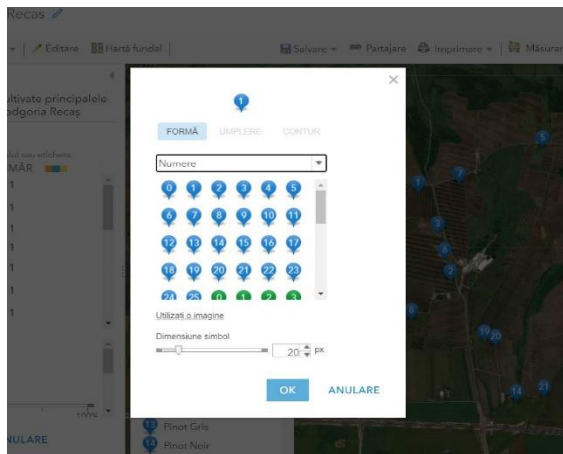


Figure 8. Highlighting points of interest on the map using different symbols

To better highlight the points of interest on the map, the ArcGIS online application allows us to enter symbols for each. For example, for the plots on which the main vine varieties are grown, we have added numerical symbols (Figure 11), and for the tourist objective Cramele Recaş we used the symbol specific to the tourist objectives.

All these aspects lead to a good mapping for the future users of the map. At the beginning I introduced the specific symbols for the points of interest that include the terrestrial communication routes, I identified the communal road DC 66, which I marked with a red car and part of the agricultural roads of the vineyard, for which I used a green car.

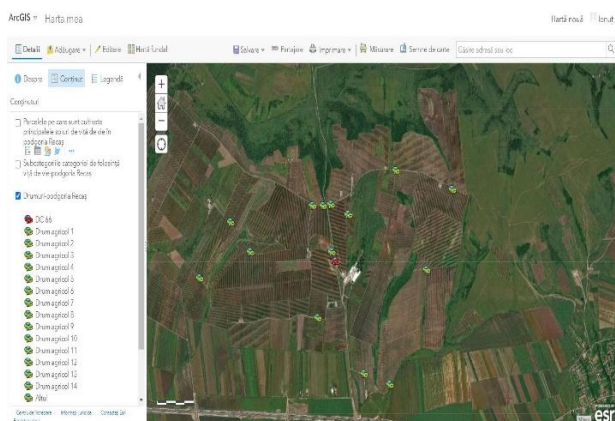


Figure 9. Examples of symbols for terrestrial communication routes identified in the Recaş vineyard

Subsequently, we also introduced the symbols for the plots on which the subcategories of the vine use category are located, for which we used a classic highlight symbol (Figure 10).

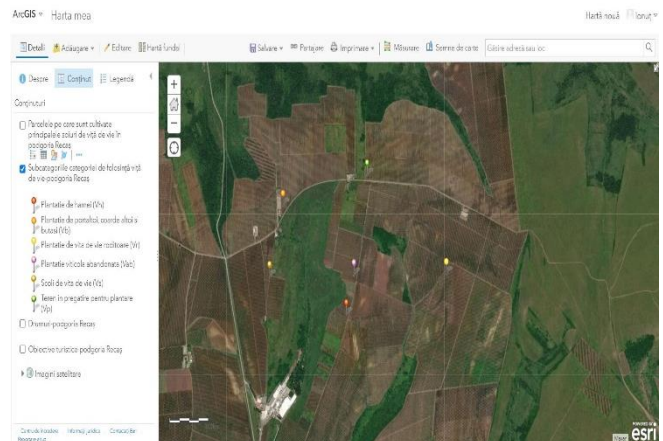


Figure 10. Examples of symbols for the plots on which the subcategories of the vineyard use category are located in the Recaş vineyard

Also, for the plots on which the main vine varieties are cultivated, we added numerical symbols (Figure 11), and for the tourist objective Cramele Recaş we used the symbol specific to the tourist objectives.

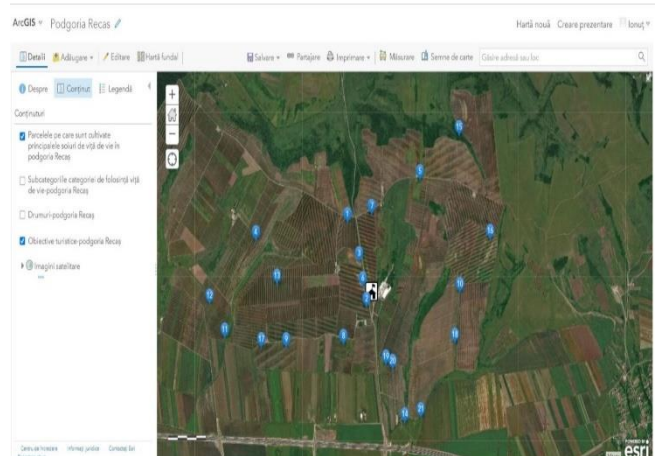


Figure 11. Examples of symbols for the plots on which the main vine varieties are cultivated in the Recaş vineyard and for the tourist objective Cramele Recaş

The figure below illustrates the interactive map of the area where the case study was conducted, where all the symbols for all identified points of interest are displayed.

The application allows us to simultaneously present all the symbols of the identified points of interest, as well as individually, the symbols of each content, for example for the plots on which are located the subcategories of the category of use of vines.

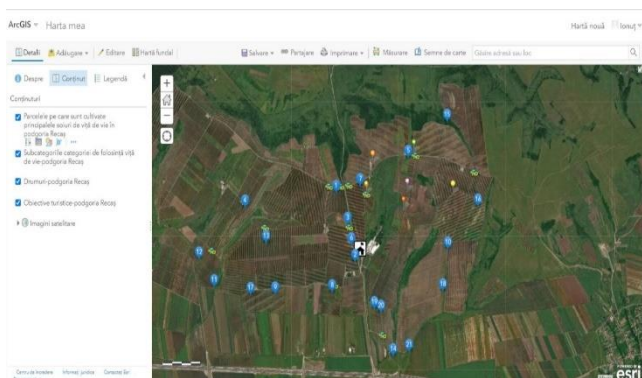


Figure 12. General map of the studied area from the Recea vineyard

The third stage shows how the information about each point of interest can be accessed, based on several attributes that contain information. By clicking on the icon, the application opens a new window in which details are presented, including the description of the point of interest, geographical coordinates, land book number, cadastral number and other elements.

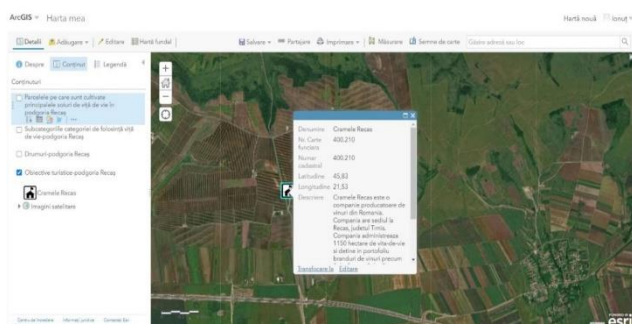


Figure 13. Information about the point of interest Cramele Recea

By clicking on the symbol specific to the point of interest Cramele Recea, a window was opened where you can see the main details about it (Figure 13).

Following the process of collecting geographical data resulted in obtaining the interactive map of the Recea vineyard, which is a modern, mobile and efficient solution for using a map in the wine field.

CONCLUSIONS

The viticultural cadastre made in the Recea vineyard, contributes decisively to the

implementation of Geographic Information Systems applications, these having an essential role in managing all the works necessary for the vineyard, so a good coordination will generate the desired results and implicitly lead to the direct development of the viticulture process sustainable in western Romania.

The realization of the WEB GIS application that presents the interactive map of the Recea vineyard, represents a mobile and advanced solution of the way of using a map in viticulture, as well as for tourist purposes, based on accessing information, for the main points of interest.

The Recea vineyard WEB GIS application can also be used to carry out precision viticulture-specific work, as it includes all aspects related to identifying and managing vineyard varieties and optimizing vine performance, in particular maximizing the yield and quality of grapes over time.

All these elements contribute decisively to the process of sustainable viticultural development of the Recea vineyard, which aims to highlight all aspects, regardless of their nature, to identify and apply the most effective solutions for the development of viticultural activities.

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MONITORING THE EVOLUTION OF DEFORESTATION IN THE NORTH-WEST ROMANIA AREA, MARAMUREȘ COUNTY, BORȘA VILLAGE

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Abstract

Considering the abusive exploitation of wood in the North-Western part of Romania, we proposed a study comparing the years 2011, 2015 and 2017, in which to obtain data on: area of grubbed-up land, quantity of wood felled, but also number of coniferous trees needed for the reforestation of the area chosen in the study.

For a more elaborate analysis of the area of interest we realized a DTM, in order to determine the slopes, the mountainsides, the exposure to the sun and some areas of a certain elevation to determine which area is most exposed to deforestation as well as the area most protected from exploitation. For this purpose, the deforested areas were classified depending on the nearest access road, namely the county road DJ 18.

The data we used to achieve our goal consists of images and coordinates taken from the Google Earth application, and then using the TransDatRo application we converted the geographical coordinates (B, L, H) into Stereo coordinates 1970 (X, Y, Z).

The data processing and analysis was made in the ArcMap application. Finally, the resulting data gives us an overview of the deforestation problem that Romania currently has, but also the negative impact it has on the soil.

Key words: Analyzes, ARCGIS, Deforestation, DTM, GIS.

INTRODUCTION

Remote sensing and GIS are complementary technologies that, when combined, enable improved monitoring, mapping, and management of forest resources.

The information that supports forest management is stored primarily in the form of forest inventory databases within a GIS environment. A forest inventory is a survey of the location, composition, and distribution of forest resources. Historically, forest management inventories were primarily for timber management and focused on capturing area and volume by species. The types of attributes attached to individual mapping units, or polygons, might include stand species composition, density, height, age, and more recently, new attributes such as leaf area index. Other remote sensing sources such as satellite digital imagery have been valuable in updating forest attributes such as disturbance, habitat, and biodiversity.

Applications of remote sensing and GIS to forestry the use of remote sensing by forest managers has steadily increased, promoted in large part by better integration of imagery with GIS technology and databases, as well as implementations of the technology that better suit the information needs of forest managers.

Detailed forest inventory, data forest inventory databases are based primarily on stand boundaries derived from the manual interpretation of aerial photographs. These stand polygons are described by a set of attributes that typically includes species composition, stand height, stand age, and crown closure.

Through this symposium work we want to highlight the evolution of illegal wood felled, near the town of Borsa, to make known the impact of deforestation on the existing flora and fauna in the area, but also the physical effort and the time necessary for a reforestation of the deforested area.

MATERIALS AND METHODS

The programs used to make this scientific work are: Google Earth, TransDatRo, ArcMap, Microsoft Office Excel.

Google Earth was used to take images with the area of interest for years 2011, 2015 and 2017. Google Earth has also been used for inserting and taking geographical coordinates (B, L, h).

Program TransDatRo was used to the transformation of geographical coordinates (B, L, H) into stereographic coordinates 1970 (X, Y, Z).

With the help of ArcMap Program we created the database, we georeferenced the images with the help of control points taken from Google Earth, after we determined surface of the studied area, the digital information was used to vectorize forest, pasture and grassland areas, for a more elaborate analysis of the area of interest we realized a DTM (digital terrain model), in order to determine the slopes, the mountainsides, the exposure to the sun and some areas of a certain elevation to determine which area is most exposed to deforestation.

To perform calculation related to: areas cover with forest, pasture and grassland, quantity of wood felled, but also number of coniferous trees needed for the reforestation, we used Microsoft Office Excel Program.

RESULTS AND DISCUSSIONS

The first stage consisted in taking the images and control points with the help of Google Earth application, the satellite images of the area of interest weresaved and later downloaded from the application at a resolution of 3840x2160 (4K UHD), for the years 2011, 2015, 2017, the control points were inserted as placemark, then the coordinates of the points were inserted into an excel file.

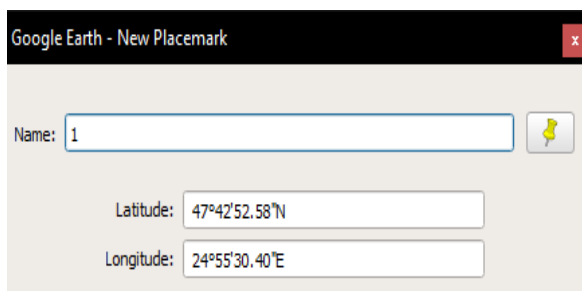


Figure 1. Taking checkpoint from Google Earth

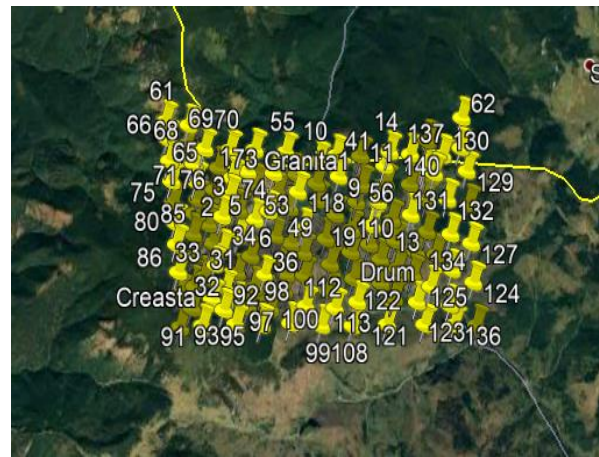


Figure 2. Insertion placemark in Google Earth

The control points from Google Earth are taken as geographical coordinates, being necessary later their transformation into stereographic coordinates 1970 with the help of the TransDatRo application.

Figure 3. Transformation of geographical coordinates into stereographic coordinates 1970

Using the ArcCatalog program we have created three databases for each year, after we establish the Stereo 70 projection system and the Black Sea altitude system. We open the ArcMap program and upload the images one by one and insert them in the corresponding database, we also attach the excel file that contains the control points.

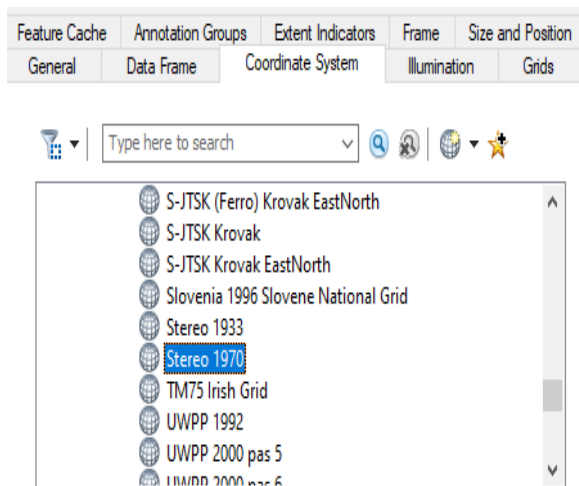


Figure 4. Selection of the projection system Stereo 1970

Next we georeferenced the satellite images using the previously transformed coordinates. Georeferencing tools are used to align the imagery to a coordinate system. When you georeference imagery, you define the image location using map coordinates allowing the imagery to be viewed, queried, and analyzed with other geographic data.

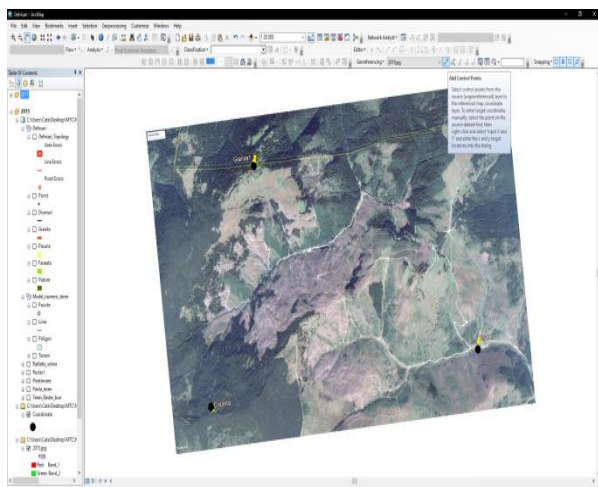


Figure 5. The georeferencing process

The vectorization of the surfaces on the georeferenced images was done using the editor tools bar. The vectorized elements were those of point, line and polygon type. The forest, pasture and grassland areas were vectorized as a polygon, the forest roads were vectorized as a line.

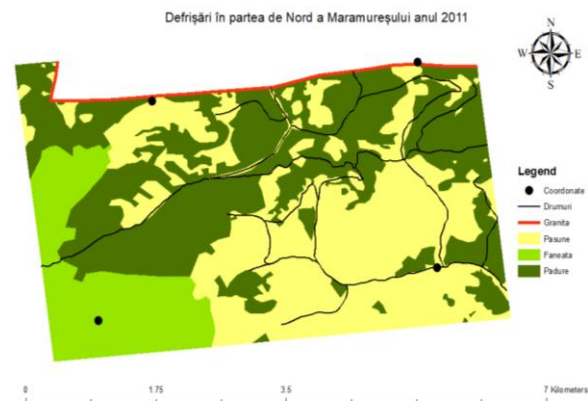


Figure 6. Vectorization of the area for 2011

Statistics of Pasune	Statistics of Padure	Statistics of Pajiste
Field SHAPE_Area	Field SHAPE_Area	Field SHAPE_Area
Statistics: Count: 35 Minimum: 1529.318046 Maximum: 2504328.378209 Sum: 8374781.367503 Mean: 239279.467643 Standard Deviation: 496881.89085	Statistics: Count: 44 Minimum: 9.656119 Maximum: 1763573.526388 Sum: 8510432.508068 Mean: 193418.920638 Standard Deviation: 326167.562161	Statistics: Count: 1 Minimum: 3077492.21634 Maximum: 3077492.21634 Sum: 3077492.21634

Figure 7. Statistics of the area for 2011

Using the attribute table of the forest layer from the created database, the statistical data related to the areas with forest, pastures and hayfields were determined in order to highlight the total area, the average area, the standard of deviations and others. With the help of this information, a study was carried out on the distribution of the total area in the 3 categories.

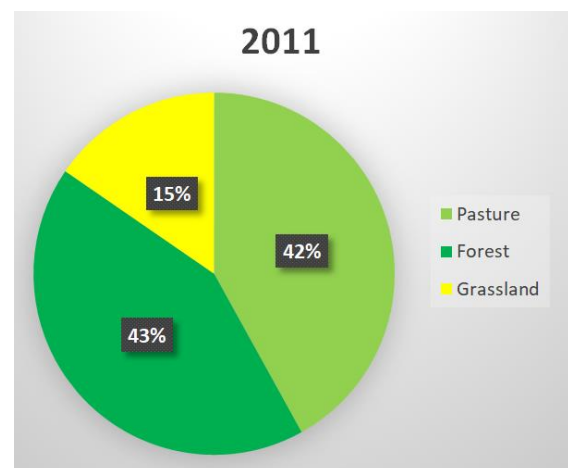


Figure 8. Pie with surface representation for year 2011

According to the graph we can see that the area covered by forest represents 43% of the area under study, the area covered with pastures

42%, and the area covered with hay represents 15%.

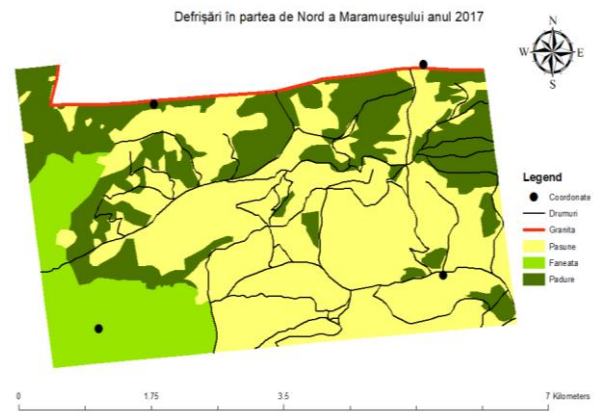
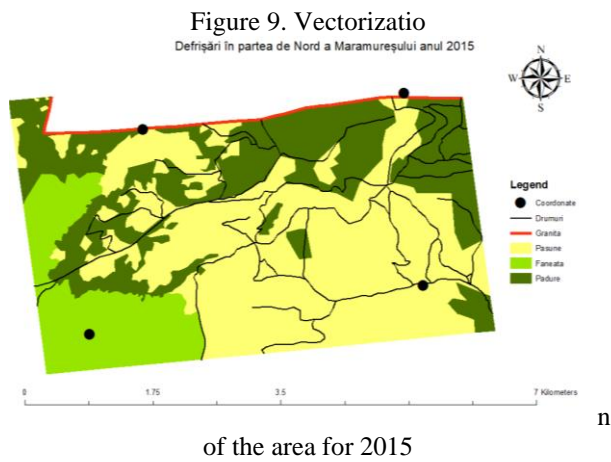


Figure 12. Vectorization of the area for 2017

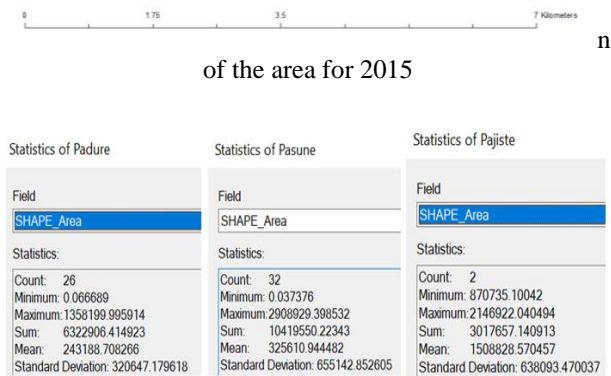


Figure 10. Statistics of the area for 2015

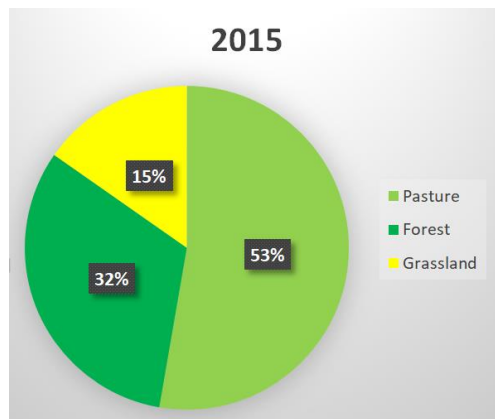


Figure 11. Pie with surface representation for year 2015

Can be seen from the graph that in 2015, the area covered by forest decreased by 10%, while the area covered by pastures increased by 11%, and the area covered with grass remained at 15%.

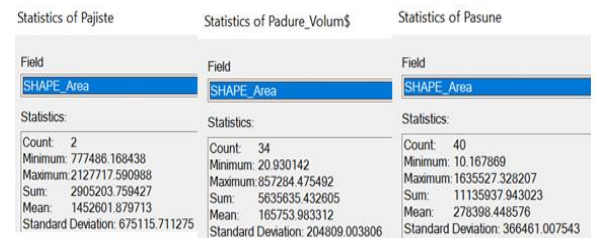


Figure 13. Statistics of the area for 2017

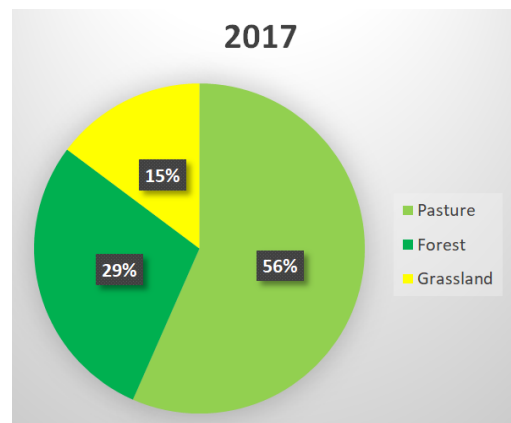


Figure 14. Pie with surface representation for year 2017

In the graph for 2017 we can see a new decrease in the area covered by forest vegetation, ie a decrease of 3% of the area covered by forest, an increase of 3% of the area covered by pastures, while the area covered by grassland remains at a constant percentage of 15%. Below we have attached the column type graph in which you can see more obviously the annual

decrease of the area covered by forest and the increase of the area covered by pastures.

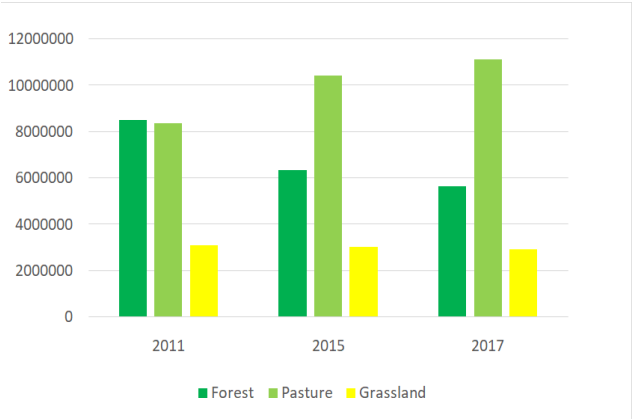


Figure 15. The evolution of the vegetation in the studied area

Next we made a classification on vectorized areas, highlighting the average volume of forest species that grow in this area.

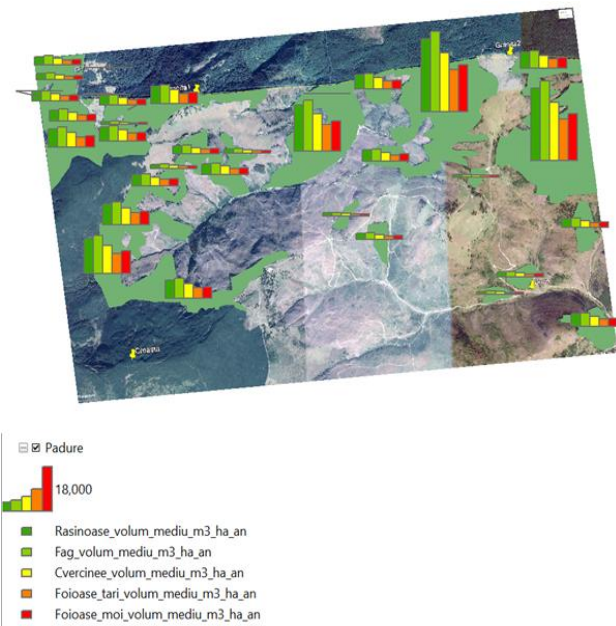


Figure 16. The average volume of tree species in the area

Depending on the vectorized forest areas we can estimate based on the data taken from the National Forest Inventory website, the annual growth depending on the tree species, from the image posted above we can see that softwoods have a higher growth compared to deciduous trees from the area.

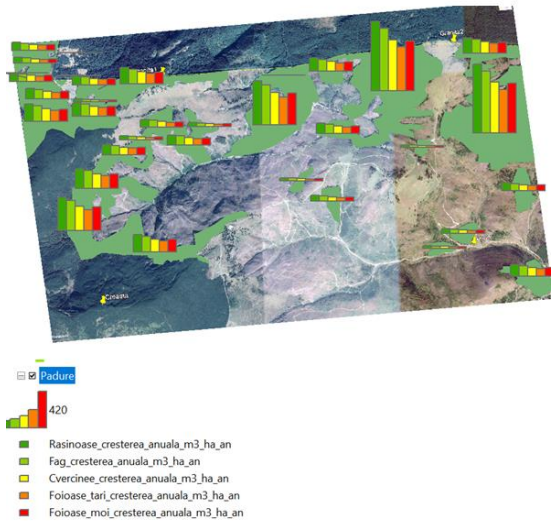


Figure 17. Annual growth of tree species in the study area

With the help of the 140 points taken from Google Earth and inserted in ArcMap, we created the DTM (digital terrain model) and the raster image.

Digital terrain models are representations of land surface point elevations. They are used as input for the generation of surface models and contours or the orthorectification process of aerial photography.

The Terrain to Raster function is used to render multipoint data managed using a terrain stored in a geodatabase. The function will be used when you add multipoint data to a mosaic dataset using the Terrain raster type.

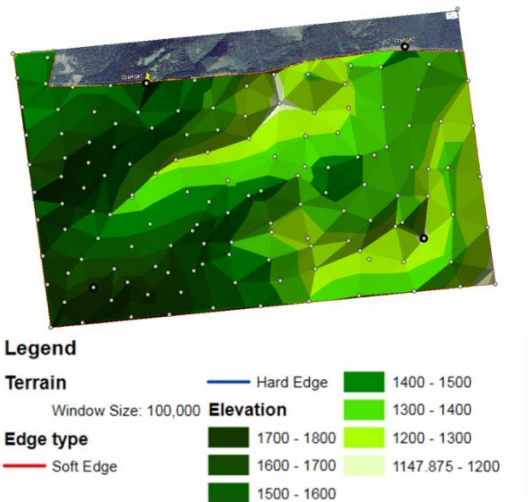


Figure 18. Digital terrain model

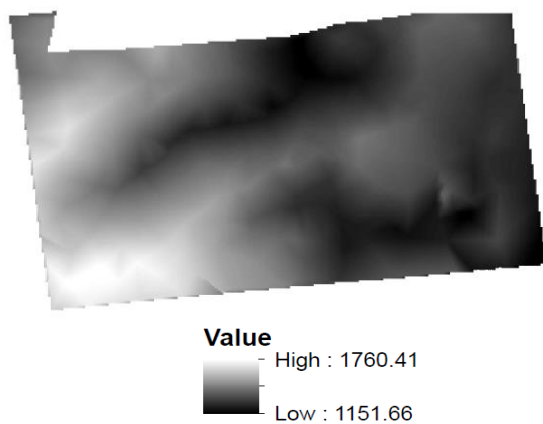


Figure 19. Raster image

In the raster image we can see with dark tones (gray, black) is represented the area with lower elevation, and with light tones (white) are represented the areas with high elevation. With the help of raster images we were able to perform various analyzes on the area studied. The main analyzes performed had as object of study: the positioning of the mountainside, the solar radiation and the slope of the land.

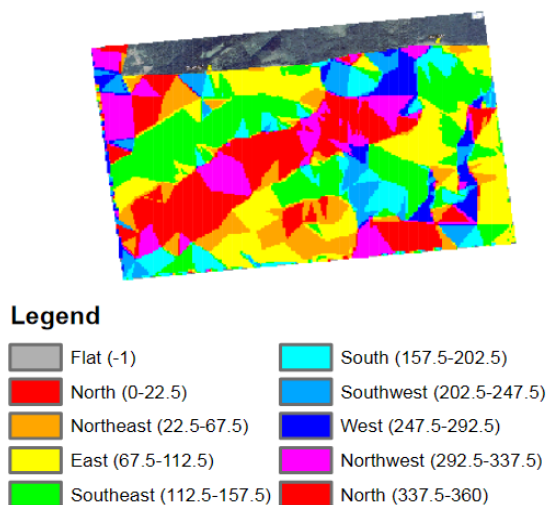


Figure 20. Mountainside positioning

Mountainside represent an area inclined to the horizontal of the place, developed between the level of peaks or ridges at the top and an almost horizontal base represented by terraces, meadows, the hearth of a depression, plain. Knowing the inclination and positioning of the mountainside helps us to assess the degree of soil erosion caused by rainfall, water runoff creating a washing effect of the slopes, this effect can be reduced by reforestation of

deforested areas, and slopes are useful in determining the river basins.

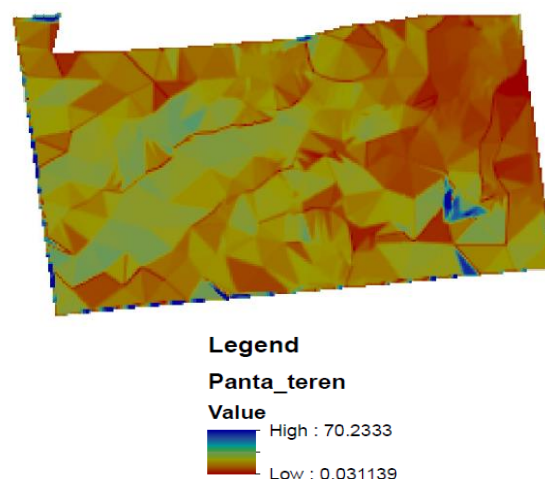


Figure 21. Terrain slope

From the image above, in which we have the representation of the slope depending on its inclination in degrees, the colors blue and green represent the areas with low slope, and the colors yellow and red represent the areas with high slope.

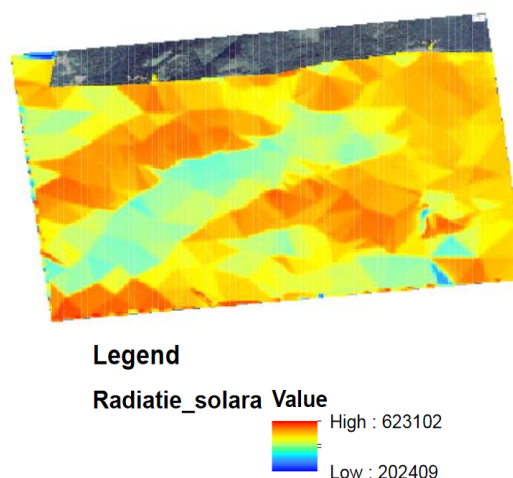


Figure 22. Solar radiation

The image with solar radiation shows that the colors red and yellow represent the areas that enjoy the most sunlight, and the areas with the colors green and blue, show us the areas where there is a deficit of light, so those areas have a higher humidity.

We made a spatial connection between the road layer from the Romania database and the forest layer from our database, thus wanting to find the distance between the studied area and the

nearest access road. As a result of the spatial connection, the nearest road is DN 18, located to 11 kilometers from our area of interest.

CONCLUSIONS

Following the calculations performed in Excel we were able to determine the total area taken into study, and later we determined the areas covered by forest, pastures and grassland. The total area is 1979,987 hectares, of which in 2011 the forest had 851,043 hectares, in 2015 there

was 632,291 hectares and in 2017 there was 563,564 hectares covered by forest.

A decrease of the area covered by forest can be observed in the period 2011-2017, when 287.480 hectares of forest being cut.

It is known that to reforest one hectare of softwoods, are needed 5000 seedlings, so for our area of 287 hectares are needed 1435000 seedlings.

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Course support

Practical work performed at GIS laboratories

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<http://roifn.ro/site/rezultate-ifn-1/>

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MĂRIȘEL MOUNTAIN AREA ANALYSIS USING GIS TECHNIQUES

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Abstract

Keeping in mind the geographical position of Mărișel Ski & Snowboard Slope from Mărișel, which is at a height of 1,150-1,250 metres, we have developed a geographic informational system in order to conduct a research on the region's slopes with the help of satellite images.

The database was processed and managed through the methods and spatial analysis technologies offered by Google Earth and ArcMap applications. The collected information was then analyzed by Digital Terrain Model, as well as by specific terrain analysis technology.

By analyzing the raster model, we have pinpointed the sunny areas of the slopes where the snow melts quickly, therefore presenting a disadvantage for the practice winter sports, and creating a need for the intervention of artificial snow machines. In order to discover the surfaces which contribute to water increase, we have ranked the area's elevation points. Another purpose of the research was to determine the slopes' exposition (Northern orientation), the direction of the drainage, as well as the drainage points in the vicinity of the pumping station.

Having experienced both the spectacular view over Beliș Fântânele Lake, and some of the area's adverse meteorological conditions, through the above mentioned process of collecting data, we would like to contribute to monitoring, developing and creating the most favourable conditions for winter sports on these slopes.

Key words: GIS, Google Earth, MNT.

INTRODUCTION

The advanced technology offered by GIS (Geographic Information System) can be used in various scientific fields, enabling the user to process, analyze, format and view spatially distributed data through a computerized process. Considering the situation we find ourselves in because of the pandemic, and it being the perfect season for winter sports, we have chosen Mărișel village in Cluj County as our area of interest. Mărișel village is the largest populated mountain plateau of the Apuseni Mountains, with the Somesul Cald River running through it. The area is most popular for its Ski & Snowboard resort, at an altitude of 1250 m-s, and 52 km-s away from the municipality of Cluj-Napoca.

The ski slope of Mărișel was opened just recently, in 2018. It has been built from scratch, as there was no previous skiing trail in the area.

As the building of the slope has been gradual, we were interested in the analysis of the relief form, thus creating a geographic information system. This system is of major importance, and it plays a crucial part in drawing thematic maps. This would eventually lead to attaining our goal, which is the following: to determine the functional units of the slopes, to analyze the processes we come across, and to study the area from the perspective of the slopes, which have a larger degree of tilting of 2-3° that connects the interflows and their adjacent drainage line.

MATERIALS AND METHODS

During our research we have made use of a satellite image from *Google Earth*, which helped us identify the area of our interest. By placing four control points, the image now has a regular geometrical shape.

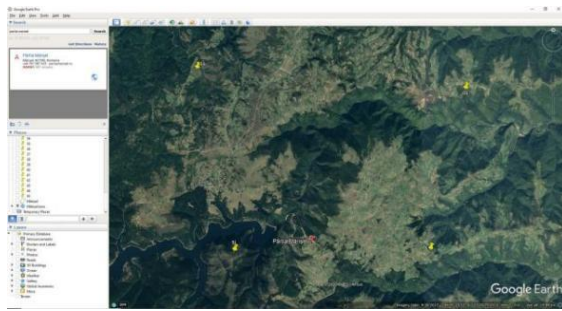


Figure 1. Satellite image from Google Earth

For processing and formatting the database, we used the methods and techniques of spatial analysis offered by the *ArcMap* app. DEM (Digital Elevation Model) facilitated the data management, together with specific surface analysis techniques.

In order to analyze a given surface, altitude needs to be taken into account as well. There is a specific database (terrain) within geographic data which enables the user to generate 3D models. This database is based on vectorial information that have the 'z' coordinate, and generate the numeric model of the given area. The result is a raster-type image, which is made of matrix pixels that display the constantly moving information within a given area, information that isn't easily divisible into vectorial elements. With the help of such raster, one is able to conduct simple and complex analyses that pertain to a particular surface.

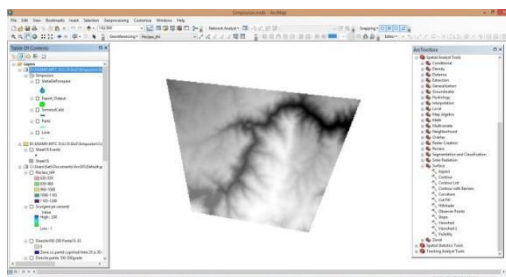


Figure 2. DTM in ArcMap

RESULTS AND DISCUSSIONS

The satellite image from *Google Earth* has the geographic coordination system in itself. With the help of *TransDatRO* application we took the geographic coordinates and transformed them into the specific coordinates of the Stereo 1970 projection system. These coordinates were then saved as *.xls* files.

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5	SJ	575123.1	350222.6						
6									

Figure 3. Control points coordinates (Stereo 1970)

The data procured from aerial photos does not have geographic reference. These images need to be connected to spatial references, that is, they need to fit into the corresponding area from the map. This is what we call georeferencing. In order to complete this phase, we have used the georeferencing tool bar of the *ArcMap* app. The connection between control points and a given image is made by clicking on the option 'Add Control Point'. Generally one has to take four points into consideration, which are the coordinates of the corners of the given image. There is a particular way of transforming the coordinates, and for a higher level of accuracy one would need the RMS (Root Mean Squares) to be as close to 0 as possible. Once the least degree of error is reached, the last task of georeferencing is done by clicking 'Update Georeferencing.'

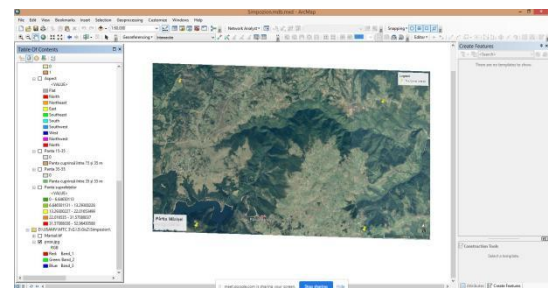


Figure 4. Georeferenced satellite image in ArcMap

In order to achieve what we have proposed for the analysis, we had to activate the following extensions from the tool bar, by clicking on 'Extensions': 3D Analyst and Spatial Analyst. From 'Spatial Analyst' we then went to 'Surface Analyst', which enabled us to generate more analyses.

In the first phase of our analysis we set out to determine the elevation of the surface, in order to be able to identify the areas that have a higher

altitude, which would eventually help us calculate the exposition.

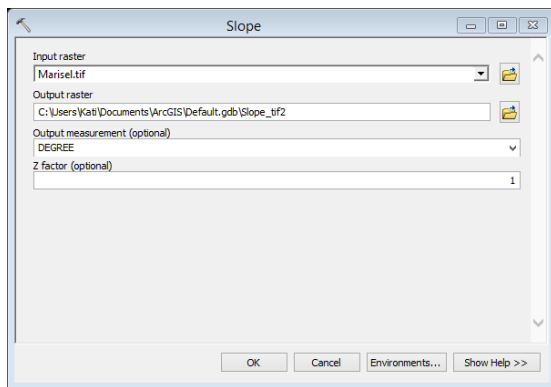


Figure 5. Determining the elevation of the surface

In order for us to obtain the expected results, we divided the pixels into five categories. For a reclassification of the elevation, we chose the option 'Classified Classes Classify' from the Symbology layer.

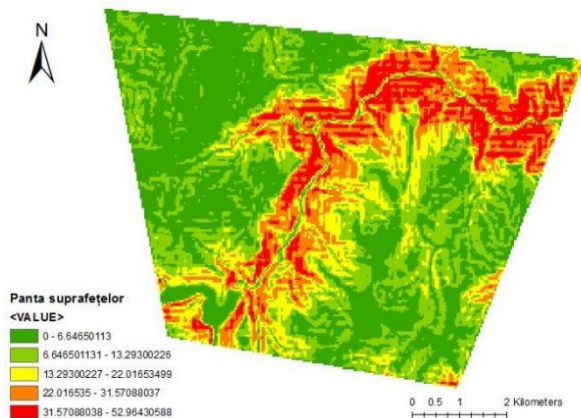


Figure 6. Area elevation according to pixels

The elevation of a given surface was determined by altitude as well. For a reclassification of hypsometry into five different categories, we have settled the difference in relief: 1288 being the highest value, and 630 the lowest. We then worked with pink and blue color palettes in 'Color Ramp'

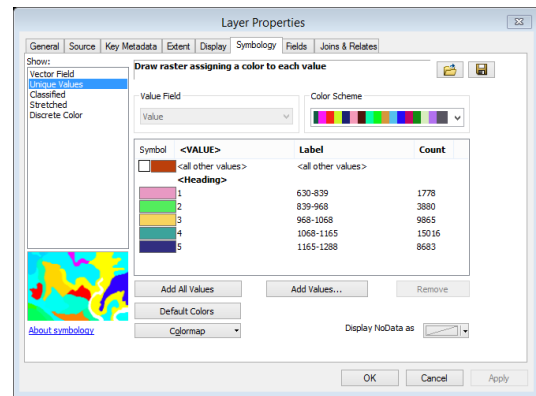


Figure 7. Determining the altitude categories

The map is finalized by going to 'Insert', then adding *caption*, *orientation* and *scale*.

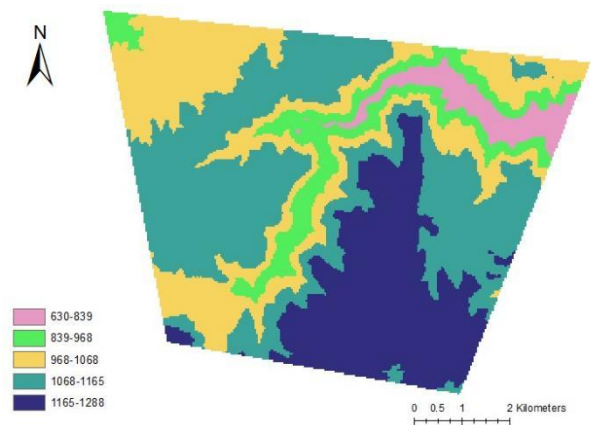


Figure 8. Area elevation according to altitude

The second phase of our research consisted of determining the slope that represents the modification rate of the elevation for each cell of the digital model. The goal was to identify the form of the slope, which turned out to be quite varying. As far as the size of the slope is concerned, we have divided the forms into three categories: abrupt, moderate and mild. As the attached map shows, we have identified that the slope has quite a tilted form, which determines the direction of the water flow and the erosion capacity of the surface.

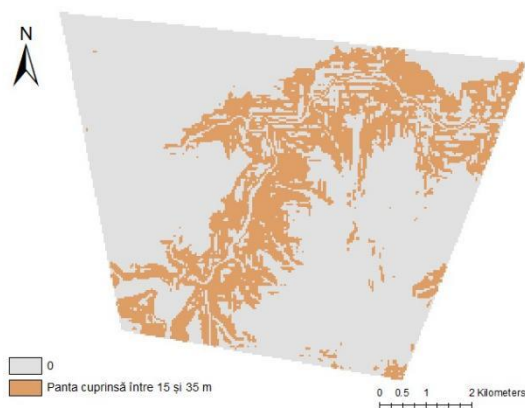


Figure 9. The slope between 15 and 35 m

In the case of the steep slopes where vegetation is reduced or entirely absent, water circulates along the crevices in the rocks, and the removal of smaller sized materials (either by disintegration or alteration) results in places where the ground collapses.

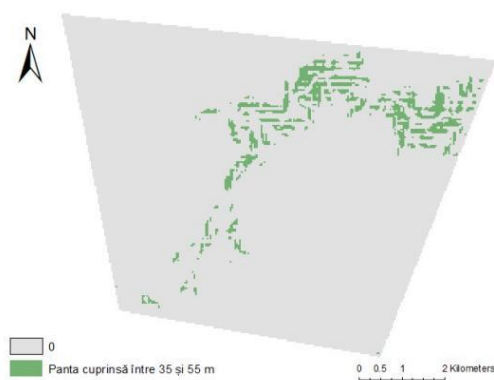


Figure 10. The slope between 35 and 55 m

Raster can be used to represent the melting process of the snow on a given surface, as well as to describe the risk raised by the melting process, which evidently hinders winter sports, and calls for the intervention of artificial snow machines.

The orientation and exposition of the slopes was made through the 'Aspect' function of the Spatial Analyst Tools. The initial result has been reclassified, given the orientation of the cardinal points, that is a 360° circle.

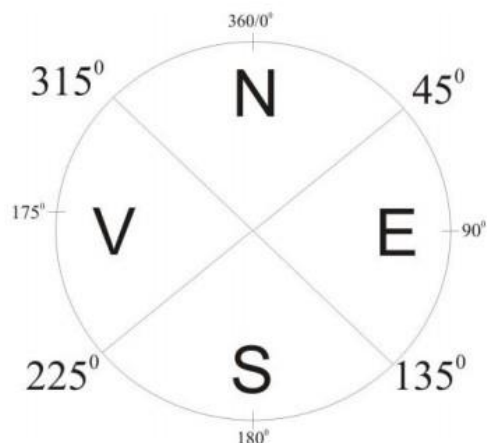


Figure 11. Cardinal points

The exposition of the slopes represents their position in relation to the cardinal points, and their exposure to the indirect solar radiation. As the map shows below, these fall into nine categories. Each color of the orientation map is connected to the respective characteristic of the slopes, as far as orientation is concerned, in the following manner: light blue represents the southern slopes with the highest temperatures; red represents the northern slopes with the lowest temperatures; green represents the eastern slopes; and blue represents the western slopes.

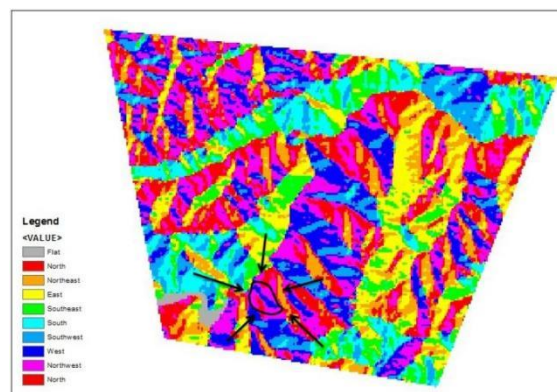


Figure 12. Sunny areas depending on the exposition

For a more detailed analysis, we have set the value of the northern slopes to 1, and 0 for all

the other directions which don't fall into our area of interest.

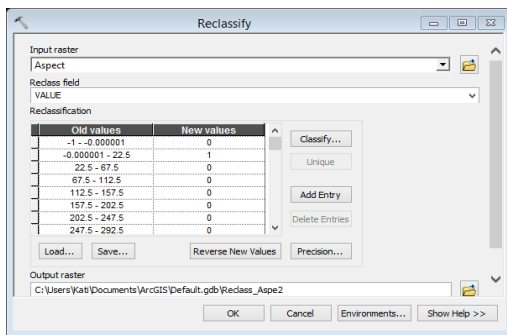


Figure 13. Determining the exposition towards the North

The results are found in the figure attached below, marked with green. In this area the melting process of the snow is relatively low, which is advantageous for ski slopes.

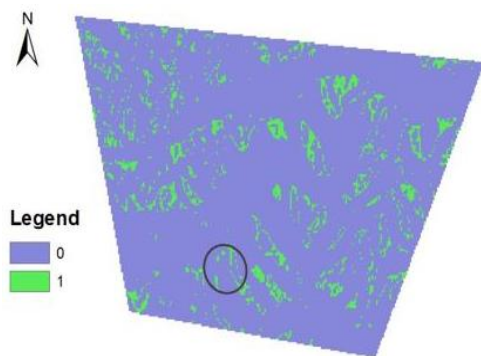


Figure 14. Northern orientation of the slopes

There has been another object of interest as well, namely to determine the sunny areas. For this we have used the same tools as for the previous analysis, and we have looked at the southern, south-eastern and south-western orientation of the slopes, resulting in value 1.

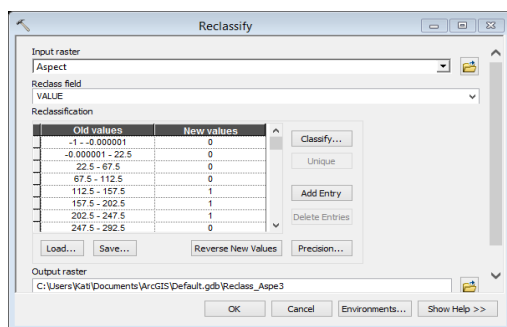


Figure 15. Determining the exposition towards the South, South-East, South-West

The southern and the south-eastern slopes are the ones with the highest solar radiation, which makes them the warmest and driest. These

slopes are also the most suitable for certain geomorphologic processes, as the melting process of the snow is a lot more sudden, allowing more time for these processes to take place.

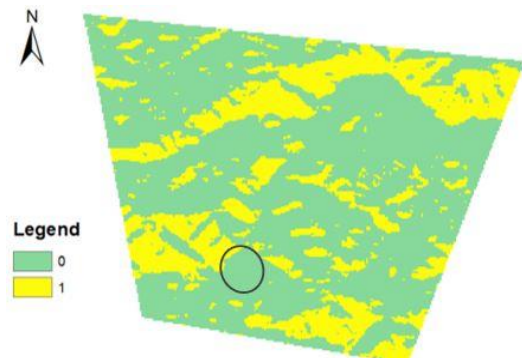


Figure 16. Southern, South-Eastern, South-Western orientation of the slopes

The previous maps have been interpolated using the Spatial Analyst Tools - Map Algebra - Raster Calculator.

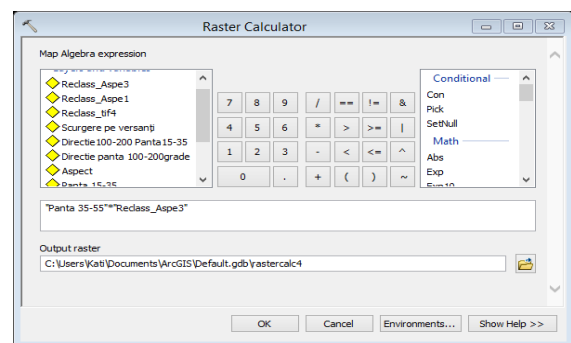


Figure 17. Interpolation of the maps

The interpolation of the maps is relevant for the orientation of the slopes which are steeper, more fragmented and their relief is more intense. This helped us determine those areas where crashes and torrential valleys are more likely to appear.



Figure 18. Sunny areas with steeper slopes

The slopes ensure the flow of water, affected by gravity, vegetation and the soil type of the cumulating system. In this case, we have the Someșul Cald River, which flows into Beliș-Fântânele Lake.

The satellite image below conveys the information gained through vectorization, and it follows the drainage route of the Someșul Cald river, as well as the perimeters of the lake.

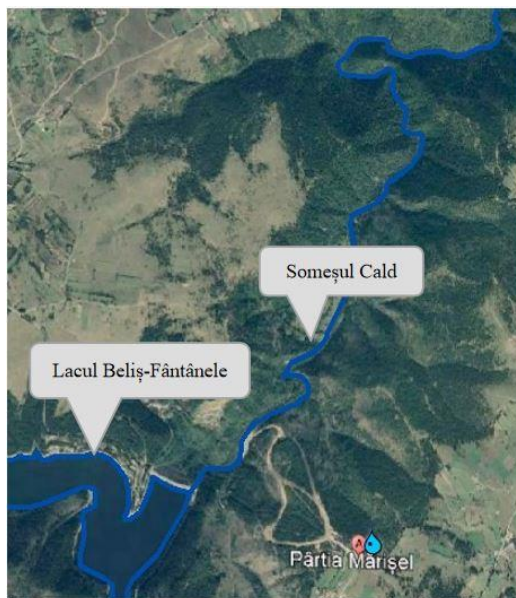


Figure 19. Drainage routes

CONCLUSIONS

As a result of the processed data, we have found the mountain area of our study to be suitable for winter sports, due to its geographic location and exposition.

The results of our analysis of the mountain slopes have a great importance, as they have an effect on the speed at which the water flows along the slopes. At the same time, they ensure

the necessary debit for artificial snow machines, which are indispensable for a ski slope in the case of unfavorable weather conditions.

The applicability of GIS techniques plays a crucial role in the analysis of suitability, research of collisions, developing a certain area (mountain, hill, geographical depression, etc.), as well as in the analysis of the possible extension of a constructed site (resorts, locations, etc.).

The very same methodology can be applied to any location, in order to achieve the same degree of complexity in results. The present research is only an example of mountain areas.

Having reached our results, and with the spectacular view over Beliș-Fântânele Lake, we wish to contribute to the monitoring and development of winter sports, in the best possible conditions.



Figure 20. View over Beliș-Fântânele Lake

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SECTION 04
FUNDAMENTAL SCIENCES

APPLYING TAYLOR SERIES IN ONE VARIABLE TO FUNCTION LIMITS

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Abstract

It is common belief that the first person in history who ever used infinite series approximations to trigonometric functions was the Indian mathematician Madhava (1340–1425 bC), the founder of the Kerala astronomy school, who deduced some approximation formulas for trigonometric functions by geometric arguments.

In the West, the intuitive idea of more general Taylor series was given by the Scottish mathematician James Gregory, but they were formally introduced by the English mathematician Brook Taylor in 1715. Taylor series centered at 0 are also called Maclaurin series, in the honour of the Scottish mathematician Colin Maclaurin, who extensively used this special case in his works in the 18th century. The partial sums of a Taylor series are called Taylor polynomials. The Taylor series are very powerful methods used to function approximations (numerical approximations, integrals, differential equations, asymptotic calculus). In this article we use the asymptotic expressions of Taylor series in order to calculate function limits.

Key words: function approximation, function limits, Maclaurin series, Taylor polynomial, Taylor series.

INTRODUCTION

First, we present without proof some classical derivability theorems.

Theorem 1 (Fermat's theorem, Boboc, 1998).

Let $f: (a, b) \rightarrow \mathbb{R}$ be a derivable function. If $x_0 \in (a, b)$ is an extremely local point of f , then $f'(x_0) = 0$.

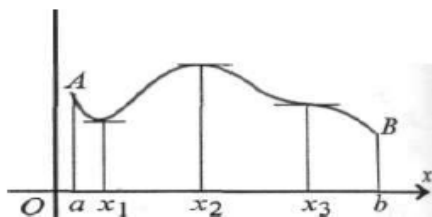


Figure 1. The geometrical interpretation of Fermat's theorem

The point x_1 is a minimum and the x_2 is a maximum on (a, b) . The graph tangents at the abscissa points x_1 and x_2 are horizontal.

Theorem 2 (Rolle's theorem, Colojoară, 1983).

Let $f: [a, b] \rightarrow \mathbb{R}$ a continuous function,

derivable on (a, b) . If $f(a) = f(b)$, then there exists $c \in (a, b)$ such that $f'(c) = 0$.

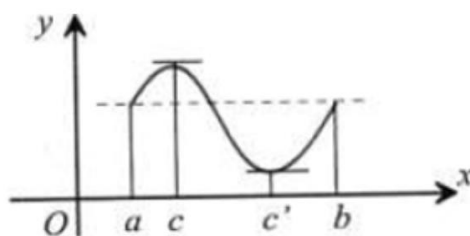


Figure 2. The geometrical interpretation of Rolle's theorem

Remark 1. This point c is not necessarily unique, as shown in the picture above.

Theorem 3 (Lagrange's mean value theorem).

Let $f: [a, b] \rightarrow \mathbb{R}$ a continuous function, derivable on (a, b) . Then there exists $c \in (a, b)$ such that $\frac{f(a)-f(b)}{a-b} = f'(c)$.

If we denote $A(a, f(a))$ and $B(b, f(b))$, then $\frac{f(a)-f(b)}{a-b}$ represents the slope of the line AB and $f'(c)$ represents the slope of the tangent to the graph in point $C(c, f(c))$. Then, the conclusion of Lagrange's theorem is expressed geometrically by the existence of a point (at

least) where the tangent to the graph is parallel to the line joining the ends of the graph.

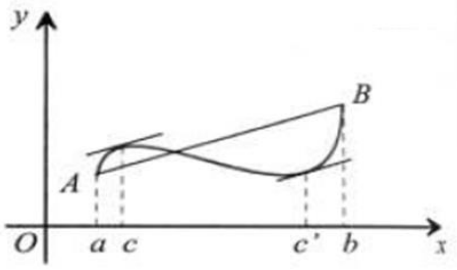


Figure 3. The geometrical interpretation of Lagrange's theorem

Theorem 4 (Cauchy's mean value theorem). Let $f: [a, b] \rightarrow \mathbb{R}$ a continuous function, derivable on (a, b) , with $g'(x) \neq 0$, for all $x \in (a, b)$. Then there is $c \in (a, b)$ such that

$$\frac{f(a)-f(b)}{g(a)-g(b)} = \frac{f'(c)}{g'(c)}.$$

TAYLOR SERIES

Definition. Let $I \subset \mathbb{R}$ be an interval, $f \in C^n(I)$ (n times derivable on I , with the n -th derivative continuous) and $x_0 \in I$, fixed. It is called the *Taylor polynomial of degree n , attached to the function f at the point x_0* , the polynomial:

$$\begin{aligned} T_{n,f,x_0} &= T_{n,f,x_0}(x) = \sum_{k=0}^n \frac{f^{(k)}(x_0)}{k!} (x - x_0)^k \\ &= f(x_0) + f'(x_0)(x - x_0) \\ &\quad + \frac{f''(x_0)}{2!} (x - x_0)^2 + \dots \\ &\quad + \frac{f^{(n)}(x_0)}{n!} (x - x_0)^n \end{aligned}$$

Remark 2. For simplicity, we will denote $T_{n,f,x_0}(x)$ by $T_n(x)$ or T_n .

Definition 1. With the previous notations, $R_n(x) = f(x) - T_n(x)$ is called the *remainder of order n* associated to the function f at the point x_0 .

Remark 3. We have $f(x) = T_n(x) + R_n(x)$ and, if $\lim_{n \rightarrow \infty} R_n(x) = 0$, then

$$\begin{aligned} f(x) &= \lim_{n \rightarrow \infty} T_n(x) = \sum_{n \geq 0} \frac{f^{(n)}(x_0)}{n!} (x - x_0)^n \\ &= f(x_0) + f'(x_0)(x - x_0) + \frac{f''(x_0)}{2!} (x - x_0)^2 + \\ &\quad + \dots + \frac{f^{(n)}(x_0)}{n!} (x - x_0)^n + \dots \end{aligned}$$

(the development in *Taylor series* centered at $x = x_0$).

Theorem 5 (Taylor's theorem with Lagrange's remainder, Nicolescu et al., 1971).

Let $I \subset \mathbb{R}$ be an interval, $f \in C^{n+1}(I)$ and $x_0 \in I$. Then, there exists $c_x \in (x, x_0)$ such that:

$$f(x) = T_n(x) + \frac{f^{(n+1)}(c_x)}{(n+1)!} (x - x_0)^{n+1}$$

Remark 4. In fact $c_x \in (x, x_0)$ or $c_x \in (x_0, x)$, in a convenient order.

Proof. By mathematical induction. For $n = 0$, the statement becomes: $f(x) = f(x_0) + f'(c_x)(x - x_0)$, for some $c_x \in (x, x_0)$, which is true from Lagrange's theorem.

$n - 1 \rightarrow n$: Suppose the statement is true for $n - 1 \in \mathbb{N}$. Thus, for any function $g \in C^n(I)$, there exists $d_x \in (x, x_0)$ such that:

$$g(x) = T_{n-1}(x) + \frac{g^{(n)}(d_x)}{n!} (x - x_0)^n$$

We denote $U(x) = f(x) - T_n(x)$ and $V(x) = (x - x_0)^{n+1}$. We obtain:

$$\begin{aligned} \frac{f(x) - T_n(x)}{(x - x_0)^{n+1}} &= \frac{U(x)}{V(x)} = \frac{U(x) - U(x_0)}{V(x) - V(x_0)} = \frac{U'(d_x)}{V'(d_x)} \\ &= \frac{f'(d_x) - T_{n-1}(d_x)}{(n+1)(d_x - x_0)^n} = \frac{f^{(n+1)}(c_x)}{(n+1)!} (x - x_0)^{n+1} \end{aligned}$$

where $d_x \in (x, x_0)$ and $c_x \in (d_x, x_0) \subset (x, x_0)$ (we have applied the theorem of Cauchy for the functions $U(x)$ and $V(x)$ the induction hypothesis for $g = f' \in C^n(I)$).

Remark 5. Taylor's theorem is the generalization to the order n of Lagrange's theorem.

Definition 2. A Taylor series development at $x_0 = 0$ is called *Maclaurin series*:

$$\begin{aligned} f(x) &= \sum_{n \geq 0} \frac{f^{(n)}(0)}{n!} x^n \\ &= f(0) + f'(0)x + \frac{f''(0)}{2!} x^2 + \dots + \frac{f^{(n)}(0)}{n!} x^n + \dots \end{aligned}$$

The list of Maclaurin series for some common functions:

The Exponential function:

$$e^x = \sum_{n \geq 0} \frac{x^n}{n!}$$

$$= 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \dots, \quad x \in \mathbb{R}$$

The Logarithmic function:

$$\ln(1+x) = \sum_{n \geq 1} (-1)^{n+1} \frac{x^n}{n}$$

$$= x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots, \quad x \in (-1, 1]$$

The Binomial function:

$$(1+x)^\alpha = \sum_{n \geq 0} C_n^\alpha x^n$$

$$= 1 + \alpha x + \frac{\alpha(\alpha-1)}{2} x^2 + \dots, \quad x \in (-1, 1).$$

where $C_n^\alpha = \frac{\alpha(\alpha-1)\dots(\alpha-n+1)}{n!}$.

Particularly, for $\alpha = \frac{1}{2}$ we obtain:

$$\sqrt{1+x} = (1+x)^{\frac{1}{2}}$$

$$= 1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^2 - \dots, \quad x \in (-1, 1).$$

The Trigonometric functions:

$$\sin x = \sum_{n \geq 0} (-1)^n \frac{x^{2n+1}}{(2n+1)!}$$

$$= x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots, \quad x \in \mathbb{R}.$$

$$\cos x = \sum_{n \geq 0} (-1)^n \frac{x^{2n}}{(2n)!}$$

$$= 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots, \quad x \in \mathbb{R}.$$

$$\operatorname{tg} x = \sum_{n \geq 1} \frac{B_{2n} \cdot (-4)^n (1-4^n) x^{2n-1}}{(2n)!}$$

$$= x + \frac{x^3}{3} + \frac{2x^5}{15} + \dots, \quad x \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right).$$

where B_n , $n \in \mathbb{N}$, are the Bernoulli numbers, defined by the equality

$$\frac{x}{e^x - 1} = \sum_{n \geq 0} \frac{B_n}{n!} x^n$$

$$B_{2n+1} = 0, \quad n \geq 1,$$

$$B_0 = 1, B_1 = -\frac{1}{2}, B_2 = \frac{1}{6}, B_4 = -\frac{1}{30}, B_6 = \frac{1}{42} \dots$$

$$\operatorname{arctg} x = \sum_{n \geq 0} (-1)^n \frac{x^{2n+1}}{2n+1}$$

$$= x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \dots, \quad x \in [-1, 1].$$

The Hyperbolic functions:

$$\operatorname{sh} x = \frac{e^x - e^{-x}}{2} = \sum_{n \geq 0} \frac{x^{2n+1}}{(2n+1)!}$$

$$= x + \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \dots, \quad x \in \mathbb{R}.$$

$$\operatorname{ch} x = \frac{e^x + e^{-x}}{2} = \sum_{n \geq 0} \frac{x^{2n}}{(2n)!}$$

$$= 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \dots, \quad x \in \mathbb{R}.$$

Remark 6. $\operatorname{ch}^2 x - \operatorname{sh}^2 x = 1$.

ELEMENTS OF ASYMPTOTIC CALCULUS

Definition 3. Let $f, g: I \rightarrow \mathbb{R}$. We say that $g(x) = o(f(x))$ at $x = x_0$ if there exists $h: I \rightarrow \mathbb{R}$, such that $g(x) = f(x)h(x)$ and $\lim_{x \rightarrow x_0} h(x) = 0$.

Remark 7. If $f(x) \neq 0$ on a neighborhood of x_0 (excluding x_0), then

$$g(x) = o(f(x)) \Leftrightarrow \lim_{x \rightarrow x_0} h(x) = 0.$$

Properties:

$$1) o(f(x)) = o(1) \Leftrightarrow \lim_{x \rightarrow x_0} f(x) = 0;$$

$$2) o(f(x)) + o(f(x)) = o(f(x));$$

- 3) $g(x) \cdot o(f(x)) = o(f(x)g(x));$
 4) $o(f(x)) \cdot o(g(x)) = o(f(x)g(x));$
 5) $\alpha \cdot o(f(x)) = o(f(x)), \forall \alpha \in \mathbb{R}^*.$

APPLICATIONS TO THE CALCULATION OF LIMITS

- 1) Prove that $\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1.$

Solution. We use the Maclaurin development for the function $\sin x$ at $x_0 = 0$:

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots = x + o(x)$$

$$\text{Thus, } \frac{\sin x}{x} = \frac{x+o(x)}{x} = 1 + o(1) \xrightarrow{x \rightarrow 0} 1.$$

- 2) Compute $\lim_{x \rightarrow 0} \frac{tg(x)-x}{x^3}.$

Solution. We use the Maclaurin development for $\cos x$ at 0:

$$\begin{aligned} tg x &= x + \frac{x^3}{3} + \frac{2}{15}x^5 + \dots \\ &= x + \frac{x^3}{3} + o(x^3) \end{aligned}$$

So, we have

$$\frac{tg(x)-x}{x^3} = \frac{\frac{x^3}{3}+o(x^3)}{x^3} = \frac{1}{3} + o(1) \xrightarrow{x \rightarrow 0} \frac{1}{3}.$$

- 3) Compute $\lim_{x \rightarrow 0} \frac{1-\cos x}{x^2}.$

Solution. We use the Maclaurin development for $\cos x$ at 0:

$$\begin{aligned} \cos x &= 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots \\ &= 1 - \frac{x^2}{2} + o(x^2) \end{aligned}$$

Thus, we obtain

$$\frac{1-\cos x}{x^2} = \frac{\frac{x^2}{2}-o(x^2)}{x^2} = \frac{1}{2} - o(1) \xrightarrow{x \rightarrow 0} \frac{1}{2}.$$

- 4) Compute $\lim_{x \rightarrow 0} \frac{\ln(1+x)}{x}.$

Solution. We consider the Maclaurin development for $\ln(1+x)$ at the point 0:

$$\begin{aligned} \ln(1+x) &= x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots \\ &= x + o(x) \end{aligned}$$

Therefore, we have

$$\frac{\ln(1+x)}{x} = \frac{x+o(x)}{x} = 1 + o(1) \xrightarrow{x \rightarrow 0} 1.$$

- 5) Compute $\lim_{x \rightarrow 0} \frac{\sin x - \arctg x}{x^3}.$

Solution. We use the Maclaurin development for the $\sin x$ and $\arctg x$ at 0:

$$\begin{aligned} \sin x &= x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots \\ &= x - \frac{x^3}{6} + o(x^3) \\ \arctg x &= x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \dots \\ &= x - \frac{x^3}{3} + o(x^3) \end{aligned}$$

Therefore,

$$\begin{aligned} \frac{\sin x - \arctg x}{x^3} &= \frac{\frac{x^3}{3} - \frac{x^3}{6} + o(x^3) - o(x^3)}{x^3} = \\ &= \frac{\frac{x^3}{6} + o(x^3)}{x^3} = \frac{1}{6} + o(1) \xrightarrow{x \rightarrow 0} \frac{1}{6}. \end{aligned}$$

- 6) Show that $\lim_{x \rightarrow 0} \frac{(1+x)^\alpha - 1}{x} = \alpha$, where $\alpha \in \mathbb{R}.$

Solution. We use the Maclaurin development for the power series $(1+x)^\alpha$ at 0:

$$\begin{aligned} (1+x)^\alpha &= 1 + \alpha x + \frac{\alpha(\alpha-1)}{2}x^2 + \dots \\ &= 1 + \alpha x + o(x) \end{aligned}$$

So, for $x \rightarrow 0$, we have

$$\begin{aligned} \frac{(1+x)^\alpha - 1}{x} &= \frac{\alpha x + o(x)}{x} = \\ &= \alpha + o(1) \xrightarrow{x \rightarrow 0} \alpha. \end{aligned}$$

- 7) Compute $\lim_{x \rightarrow 0} \left[\frac{1}{x^2} - \frac{e^x}{(e^x-1)^2} \right].$

Solution. We have that

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \dots,$$

so

$$\begin{aligned} &(e^x - 1)^2 = \\ &= \left(x + \frac{x^2}{2} + \frac{x^3}{6} + \dots \right) \left(x + \frac{x^2}{2} + \frac{x^3}{6} + \dots \right) \\ &= x^2 + x^3 + \frac{7}{12}x^4 + o(x^4) \end{aligned}$$

$$= \frac{-2+o(1)}{1+o(1)} \xrightarrow{x \rightarrow 0} -2.$$

Thus, we obtain:

$$\begin{aligned} \frac{1}{x^2} - \frac{e^x}{(e^x - 1)^2} &= \frac{(e^x - 1)^2 - x^2 e^x}{x^2 (e^x - 1)^2} = \\ &= \frac{\frac{1}{12}x^4 + o(x^4)}{x^4 + o(x^4)} = \frac{\frac{1}{12} + o(1)}{1 + o(1)} \xrightarrow{x \rightarrow 0} \frac{1}{12} \end{aligned}$$

8) Calculate $\lim_{x \rightarrow 0} \frac{sh(x^4) - x^4}{(x - \sin x)^4}$.

Solution. We know that

$$sh(x) = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} \dots,$$

which implies that

$$\begin{aligned} sh(x^4) - x^4 &= \frac{x^{12}}{3!} + \frac{x^{20}}{5!} + \frac{x^{28}}{7!} + \dots \\ &= \frac{x^{12}}{6} + o(x^{12}) \end{aligned}$$

For the denominator, one has:

$$\begin{aligned} (x - \sin x)^4 &= \left[\frac{x^3}{6} + o(x^3) \right]^4 \\ &= x^{12} \left[\frac{1}{6} + o(1) \right]^4 = \frac{x^{12}}{6^4} + o(x^{12}) \end{aligned}$$

Therefore, we obtain:

$$\begin{aligned} \frac{sh(x^4) - x^4}{(x - \sin x)^4} &= \frac{\frac{x^{12}}{6} + o(x^{12})}{\frac{x^{12}}{6^4} + o(x^{12})} = \\ &= \frac{\frac{1}{6} + o(1)}{\frac{1}{6^4} + o(1)} \xrightarrow{x \rightarrow 0} 6^3 = 216. \end{aligned}$$

9) Compute $\lim_{x \rightarrow 0} \frac{\sqrt{1+4x} - 1 - \sin(2x)}{\ln(1+x^2)}$.

Solution. We have the following Taylor developments at 0:

$$\begin{aligned} \sqrt{1+4x} &= (1+4x)^{\frac{1}{2}} \\ &= 1 + 2x - 2x^2 + 4x^3 + \dots \\ &= 1 + 2x - 2x^2 + o(x^2) \end{aligned}$$

$$\begin{aligned} \sin(2x) &= 2x - \frac{4}{3}x^3 + \dots \\ &= 2x + o(x^2) \end{aligned}$$

$$\begin{aligned} \ln(1+x^2) &= x^2 - \frac{x^4}{2} + \frac{x^6}{3} \dots \\ &= x^2 + o(x^2) \end{aligned}$$

We obtain:

$$\frac{\sqrt{1+4x} - 1 - \sin(2x)}{\ln(1+x^2)} = \frac{-2x^2 + o(x^2)}{x^2 + o(x^2)}$$

10) Find the parameters $a, b \in \mathbb{R}$ for which $\lim_{x \rightarrow \infty} (a\sqrt{x^2 + ax} - b\sqrt{x^2 + bx} - 2x) = 1$.

Solution. We replace $x \rightarrow \infty$ with $\frac{1}{y}$, where $y \rightarrow 0, y > 0$. The initial limit transposes into the following limit where $x \rightarrow 0, x > 0$:

$$\frac{1}{y} (a\sqrt{1+ay} + b\sqrt{1+by} - 2) \xrightarrow[y > 0]{y \rightarrow 0} 1.$$

For the sake of simplicity, we denote again y by x . Thereby:

$$\frac{1}{x} (a\sqrt{1+ax} + b\sqrt{1+bx} - 2) \xrightarrow[x > 0]{x \rightarrow 0} 1.$$

Using the Taylor developments at 0:

$$\begin{aligned} \sqrt{1+ax} &= (1+ax)^{\frac{1}{2}} \\ &= 1 + \frac{a}{2}x - \frac{a^2}{8}x^2 + \dots \\ &= 1 + \frac{a}{2}x - \frac{a^2}{8}x^2 + o(x^2) \end{aligned}$$

$$\begin{aligned} \sqrt{1+bx} &= (1+bx)^{\frac{1}{2}} \\ &= 1 + \frac{b}{2}x - \frac{b^2}{8}x^2 + \dots \\ &= 1 + \frac{b}{2}x - \frac{b^2}{8}x^2 + o(x^2) \end{aligned}$$

we must obtain:

$$\begin{aligned} &\frac{1}{x} (a\sqrt{1+ax} + b\sqrt{1+bx} - 2) \\ &= \frac{a+b-2}{x} + \frac{a^2+b^2}{2} + o(x) \xrightarrow[x > 0]{x \rightarrow 0} 1 \end{aligned}$$

This is possible if and only if $\begin{cases} a+b-2=0 \\ a^2+b^2=2 \end{cases}$, which represents a system of equations with the solutions $a=b=1$.

CONCLUSION

Taylor series are a very powerful method to solve difficult function limits.

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SRINIVASA RAMANUJAN – THE MAN WHO (WAS?) REVEALED INFINITY

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Srinivasa Ramanujan (1887-1920)

Abstract

The Indian mathematician Srinivasa Ramanujan (22 December 1887 – 26 April 1920) was one of the most enigmatic figures in the history of science. He was born in a poor family and had no formal education in mathematics, being mostly self-taught, but he made important contributions to mathematical analysis, number theory, infinite series, and continued fractions, including the solutions to some open mathematical problems. Some of his work even has applications in nowadays top science domains, such as cosmology and string theory. Back then, paper was very expensive and Ramanujan did most of his calculations with chalk on the ground floor of a local temple and then recorded them in his notebooks, mostly without the proofs, just like in the book “A Synopsis of Elementary Results in Pure and Applied Mathematics” by G. S. Carr, which influenced him deeply. He said that his formulas were revealed to him in his dreams by some Indian gods, especially by the goddess Namagiri. In his short life he found more than 3900 results (mostly identities and equations), many of them completely novel and very unconventional, which opened new directions in science and were inspiring for later scientists.

Key words: *continued fractions, infinite series, mathematical analysis, number theory, Srinivasa Ramanujan.*

INTRODUCTION

EARLY LIFE

In 2020 the scientific world commemorated the centenary of the great Indian mathematician Srinivasa Ramanujan's passing away. Ramanujan was born on 22 December 1887 in Erode, Tamil Nadu, at the residence of his maternal grandparents. They lived in Sarangapani Street in a traditional home in the town of Kumbakonam. In December 1889, Ramanujan had smallpox and recovered. He moved with his mother to her parents' house in Kanchipuram, near Chennai. Since Ramanujan's father was at work most of the day, his mother took care of him as a child. From her, he learned about tradition and puranas (Hindu religious texts that are part of the Vedas). He has been taught to be a religious person and he was praying every day. Just before the age of 10, in November 1897, he passed his primary examinations in English, Tamil, geography and arithmetic. With his scores, he stood first in the district. That year, Ramanujan entered Town Higher Secondary School where he encountered formal mathematics for the first time. By the age of 11, he had exhausted the mathematical knowledge of two college students who were lodgers at his home. He was later lent a book on advanced trigonometry written by S. L. Loney. He completely mastered this book by the age of 13 and discovered sophisticated theorems on his own. By 14, he was receiving merit certificates and academic awards which continued throughout his school career and also assisted the school in the logistics of assigning its 1200 students (each with their own needs) to its 35-odd teachers. He completed mathematical exams in half the allotted time, and showed a familiarity with geometry and infinite series. Ramanujan was shown how to solve cubic equations in 1902 and he went on to find his own method. In 1903 when he was 16, Ramanujan obtained from a friend a library-loaned copy of the book "A Synopsis of Elementary Results in Pure and Applied Mathematics" by G. S. Carr, which contained a collection of 5000 theorems. Ramanujan reportedly studied the contents of the book in detail. The book is generally acknowledged as a key element in awakening the genius of Ramanujan. The next year, he had independently developed and studied the

Bernoulli numbers and had calculated Euler's constant up to 15 decimals. When he graduated from Town Higher Secondary School in 1904, Ramanujan was awarded the "K. Ranganatha Rao" prize for mathematics by the school's headmaster, Krishnaswami Iyer, who introduced Ramanujan as an outstanding student who deserved scores higher than the maximum possible marks. He received a scholarship to study at Government Arts College, Kumbakonam. However, Ramanujan was so intent on studying mathematics that he could not focus on any other subjects and failed most of them, losing his scholarship in the process. He later enrolled at Pachaiyappa's College in Madras. He again excelled in mathematics but performed poorly in other subjects such as physiology. Ramanujan failed his Fine Arts degree exam in December 1906 and again a year later. Without a degree, he left college and continued to pursue independent research in mathematics. At this point in his life, he lived in extreme poverty and was suffering from starvation.

ADULTHOOD IN INDIA

On 14 July 1909, Ramanujan was married to a nineyear old bride, Janaki Ammal. After the marriage, Ramanujan developed a hydrocele testis. His family did not have the money for the operation, but in January 1910, a doctor volunteered to do the surgery for free. After his successful surgery, Ramanujan searched for a job. He stayed at friends' houses while he went door to door around the city of Chennai looking for a clerical position. To make some money, he tutored some students at Presidency College who were preparing for their exam.

MATHEMATICAL ACHIEVEMENTS

In mathematics, there is a distinction between having an insight and having a proof. Ramanujan's talent suggested a group of formulae that could then be investigated in depth later. It is said that Ramanujan's discoveries are unusually rich. As a by-product, new directions of research were opened up. Examples of the most interesting of these formulae include the infinite series for π , one of which is given below. One of his remarkable capabilities was the rapid solution for problems. He was sharing a room with P. C. Mahalanobis who had a problem,

"Imagine that you are on a street with houses marked 1 through n . There is a house in between (x) such that the sum of the house numbers to left of it equals the sum of the house numbers to its right. If n is between 50 and 500, what are n and x ?" This is a bivariate problem with multiple solutions. Ramanujan thought about it and gave the answer with a twist: He gave a continued fraction. The unusual part was that it was the solution to the whole class of problems. Mahalanobis was astounded and asked how he did it. "It is simple. The minute I heard the problem, I knew that the answer was a continued fraction. Which continued fraction, I asked myself. Then the answer came to my mind," Ramanujan replied. In 1918, Hardy and Ramanujan studied the partition function $p(n)$ extensively and gave a nonconvergent asymptotic series that permits exact computation of the number of partitions of an integer. He discovered mock theta functions in the last year of his life. For many years these functions were a mystery, but they are now known to be the holomorphic parts of harmonic weak Maass forms.

RAMANUJAN, HARDY AND LITTLEWOOD



G.H. Hardy (left) and J.E. Littlewood (right)

Since 1904, Ramanujan started to produce sophisticated mathematical results. After his introduction in 1910 to V. Ramaswamy Aiyer,

the founder of the Indian Mathematical Society, he began to publish his results in the Society's Journal.

In 1913, Ramanujan wrote a letter to three prominent English mathematicians from Cambridge University. The first two, H. F. Baker and E. W. Hobson returned the paper without any comment. On 2 February 1913, England's leading mathematician Professor G.H. Hardy, from Trinity College, Cambridge University, opened an untidy envelope with many Indian postage stamps to find on crumpled pages an unsolicited letter, dated 16 January 1913, from an unknown Hindu clerk, which began:

"Dear Sir, I beg to introduce myself to you as a clerk in the Accounts Department of the Port Trust Office at Madras on a salary of only £20 per annum. I am now about 23 years of age. I have had no University education but I have undergone the ordinary school course. After leaving school I have been employing the spare time at my disposal to work at Mathematics. I have not trodden through the conventional regular course followed in an University course, but I am striking out a new path for myself. I have made special investigations of divergent series in general, and the results I get are termed by the local mathematicians as "startling".

There followed eleven pages of mathematical formula, wild and fantastic theorems on prime numbers, infinite series, integrals, and continued fractions (for those who seek a copy of these pages, note that pages 8 and 10 are lost). Hardy's first reaction was one of irritation at the large number of theorems stated without proof: perhaps the author was a crank, or the letter an elaborate fraud; or perhaps this was a well-crafted practical joke by a colleague. However, Hardy was intrigued, and at the end of his typical and routine Cambridge day his second reaction was to meet with his colleague J.E. Littlewood and to work as best they could through the theorems. Some were already theorems such as

the integral formula (Berndt, 1997).

$$\int_0^a e^{-x^2} dx = \frac{\sqrt{\pi}}{2} - \frac{e^{-a^2}}{2a + \frac{1}{a + \frac{2}{2a + \frac{3}{a + \frac{4}{2a + \dots}}}}}$$

Others were new, but rather interesting than important results, such as

$$\int_0^\infty \frac{\cos \pi x}{\Gamma^2(\alpha + x)\Gamma^2(\alpha - x)} dx = \frac{1}{4\Gamma(2\alpha - 1)\Gamma^2(\alpha)} \quad \text{where } \alpha > \frac{1}{2}$$

And yet others were nothing like anything that they had seen before. For example

$$\frac{1}{1 + \frac{e^{-2\pi}}{1 + \frac{e^{-4\pi}}{1 + \dots}}} = \left(\sqrt{\frac{5 + \sqrt{5}}{2}} - \frac{\sqrt{5} + 1}{2} \right) e^{\frac{2}{5}\pi}$$

Hardy said that some of the formulas had “defeated” him “completely”.

“I had never seen anything in the least like them before. A single look at them is enough to show that they could only be written down by a mathematician of the highest class. They must be true because, if they were not true, no one would have had the imagination to invent them”. Hardy and Littlewood showed Ramanujan’s results to some of their colleagues, and it quickly became obvious that Ramanujan was a mathematician of exceptional ability. They decided to invite him to Britain in order to receive formal training and an advanced degree from Cambridge. However, Ramanujan was initially unwilling to leave his family or to cross the sea for religious reasons; so, as a short-term measure, his mathematical friends in India applied, successfully, for a temporary research scholarship on his behalf at the University of Madras, which allowed him to concentrate on his mathematical research full time while supporting his family financially. But there was still the matter of persuading him to make the long sea journey to England. After a year of wrangling, these obstacles were gradually surpassed and, with his family’s consent, he

finally agreed to go, setting sail for England on 17 March 1914.

On his arrival in Cambridge the following month, he immediately began to work with Hardy and Littlewood. Not surprisingly, however, they soon found that their mathematical methodologies were profoundly different. Hardy and Littlewood, being strict analysts, were insistent on absolute rigour and formal proofs, while Ramanujan was content to rely on intuition and inductive experimentation. Indeed, as Littlewood later wrote

“He was not interested in rigour ... [and] the clear-cut idea of what is meant by a proof ... he perhaps did not possess at all.”

Also, talking about Ramanujan’s intuition, he noted that “every positive integer was one of [Ramanujan’s] personal friends.”

Hardy thus decided to remedy the gaps in Ramanujan’s formal training by sending him to take some courses, without destroying his enthusiasm and wild intuition. This proved to be a real challenge.

Adapting to life in Britain was difficult for Ramanujan. The cold and wet climate affected him, and he had problems getting vegetarian food, especially after the beginning of the First World War in August 1914. He cooked his own simple meals in his room in Trinity College, and thus did not eat with the rest of the college community as would usually have been expected. The war also resulted in many of Cambridge’s best mathematicians, including Littlewood, being called away for military service, further adding to Ramanujan’s sense of isolation.

Despite all the problems, Ramanujan’s mathematical output was rapid. He quickly began to publish papers in British journals, including a 60-page paper in the Proceedings of the London Mathematical Society in 1915 on “highly composite numbers, for which he was awarded the degree of Bachelor of Science by Research (renamed PhD in 1920) by the University of Cambridge.

During his stay in England, Ramanujan published alone or in collaboration 21 articles. He was elected member of the London Mathematical Society in December 1917, followed by fellowships of the Royal Society in May 1918 and Trinity College in October 1918.

Ramanujan's health had never been strong, but by May 1917 he was seriously ill, being diagnosed with tuberculosis and severe vitamin deficiency, although recent investigations have suggested that he may have been suffering from hepatic amoebiasis, a complication arising from previous attacks of dysentery. By November 1918, his health had improved enough for Hardy to write about a return to his home land:

"He will return to India with a scientific standing and reputation such as no Indian has enjoyed before, and I am confident that India will regard him as the treasure he is. His natural simplicity and modesty have never been affected in the least by success – indeed all that is wanted is to get him to realise that he really is a success".

On 27 February 1919, he embarked for India, arriving in Kumbakonam two weeks later, but his health deteriorated again despite medical treatment. He died on 26 April 1920 at the age of 32.

RAMANUJAN'S NOTEBOOKS

Ramanujan recorded the bulk of his results in four notebooks of loose - leaf paper. These results were mostly written up without any proofs. This is probably the origin of the misperception that Ramanujan was unable to prove his results and simply thought up the final result directly. This style of working may have been for several reasons. Since paper was very expensive, Ramanujan would do most of his work and perhaps his proofs on slate, and then transfer just the results to paper. Using a slate was common for mathematics students in the Madras Presidency at the time. His first notebook has 351 pages with 16 somewhat organized chapters and some unorganized material. The second notebook has 256 pages in 21 chapters and 100 unorganised pages, with the third notebook containing 33 unorganised pages. The results in his notebooks inspired numerous papers by later mathematicians trying to prove what he had found. Hardy himself created papers exploring material from Ramanujan's work as did G. N. Watson. A fourth notebook with 87 unorganised pages, the so called "lost notebook", was rediscovered in 1976 by George Andrews. Notebooks 1, 2 and 3 were published as a two volume set in 1957 by the Tata Institute of Fundamental Research (TIFR), Mumbai, India. This was a photocopy edition of the

original manuscripts, in his own handwriting. In December 2011, as part of Ramanujan's 125th birth centenary celebrations, TIFR republished the notebooks in a coloured two volume collector's edition. These were produced from scanned and microfilmed images of the original manuscripts by expert archivists of Roja Muthiah Research Library, Chennai.

RECOGNITION

Ramanujan's home state of Tamil Nadu celebrates 22 December (Ramanujan's birthday) as 'State IT Day', memorializing both the man and his achievements, as a native of Tamil Nadu. A stamp picturing Ramanujan was released by the Government of India in 1962 – the 75th anniversary of Ramanujan's birth – commemorating his achievements in the field of number theory and a new design was issued on December 26, 2011, by the India Post. Since the Centennial year of Ramanujan, every year 22 Dec, is celebrated as Ramanujan Day by the Government Arts College, Kumbakonam where he had studied and later dropped out. Ramanujan's work and life are celebrated on 22 December at The Indian Institute of Technology (IIT), Madras in Chennai. A prize for young mathematicians from developing countries has been created in the name of Ramanujan by the International Centre for Theoretical Physics (ICTP), in cooperation with the International Mathematical Union, who nominate members of the prize committee. The Shanmugha Arts, Science, Technology & Research Academy (SASTRA), based in the state of Tamil Nadu in South India, has instituted the SASTRA Ramanujan Prize of \$10,000 to be given annually to a mathematician not exceeding the age of 32 for outstanding contributions in an area of mathematics influenced by Ramanujan. The age limit refers to the years Ramanujan lived, having nevertheless still achieved many accomplishments. This prize has been awarded annually since 2005, at an international conference conducted by SASTRA in Kumbakonam, Ramanujan's hometown, around Ramanujan's birthday, 22 December. On the 125th anniversary of his birth, India declared the birthday of Ramanujan, December 22, as 'National Mathematics Day' (Karthikeyan,

2018).

RAMANUJAN'S MATHEMATICAL LEGACY

During his short life, Ramanujan independently obtained nearly 3,900 results (mostly identities and equations). Many were completely novel; his original and highly unconventional results, such as the Ramanujan prime, the Ramanujan theta function, partition formulae and mock theta functions, have opened entire new areas of work and inspired a vast amount of further research. Nearly all his claims have now been proven correct (Berndt, 1997; Merroty, 2020).

Sum of consecutive integers

$$1 + 2 + 3 + \dots = -\frac{1}{12}$$

This claim is obviously false if one considers the classical convergence of sequences and series in real analysis. It can be “proved” by considering that this serie and others similar converge in a different way. However, the result has a deep meaning. The most important function in number theory is the *Riemann Zeta function*

$$\zeta(s) = \sum_{n \geq 1} \frac{1}{n^s}$$

Note that, formally,

$$\zeta(-1) = \sum_{n \geq 1} \frac{1}{n^{-1}} = 1 + 2 + 3 + \dots$$

$\zeta(s)$ converges for $s > 1$, but it can be extended analitically to all complex numbers, and the value of its extension at $s = -1$ is indeed $-\frac{1}{12}$.

Partition formula (Hardy-Ramanujan-Rademacher asymptotic formula)

This formula helped in establishing the fame of Ramanujan in the world of mathematics. He along with Hardy discovered and proved an asymptotic formula for the well known partition function which helps to approximate the function for large enough numbers. This function also has a lot of applications both within number theory and outside.

The *partition number* $p(n)$ represents the number of ways in which a positive integer n can be written as a sum of positive descending integers. So, for instance, the integer $n = 5$ can be written in five different ways, namely: 5,

4 + 1, 3 + 2, 3 + 1 + 1, 2 + 2 + 1, 2 + 1 + 1 + 1, 1 + 1 + 1 + 1 + 1. Thus, $p(5) = 7$. Other examples: $p(15) = 176$, $p(34) = 12310$ and

$$p(200) = 3\,972\,999\,029\,388\,004.$$

In 1918 Hardy and Ramanujan proved the asymptotic formula

$$p(n) \sim \frac{1}{4n\sqrt{3}} e^{\pi\sqrt{\frac{2n}{3}}}.$$

A complete asymptotic expansion was given in 1937 by Rademacher.

Ramanujan congruences

Ramanujan independently discovered three congruences related to the partition function. These are perhaps the most beautiful results given by him. In his paper (Ramanujan, 1921), the first two congruences were proved and the third was extracted from his notebooks and proved by Hardy after Ramanujan's death.

$$\begin{aligned} p(5n + 4) &\equiv 0 \pmod{5} \\ p(7n + 5) &\equiv 0 \pmod{7} \\ p(11n + 6) &\equiv 0 \pmod{11} \end{aligned}$$

Ramanujan master theorem

This theorem is one of the most applied results of Ramanujan. This is used to evaluate the Mellin transforms of several complex valued functions. This has been generalised and now this is used in Quantum mechanics through Feynmann diagrams.

The result states that if a function $f: \mathbb{R} \rightarrow \mathbb{C}$ admits an expansion of the form

$$f(x) = \sum_{n=0}^{\infty} \frac{\varphi(n)}{n!} (-x)^n$$

then the *Mellin transform* of $f(x)$ is given by

$$\int_0^{\infty} x^{s-1} f(x) dx = \Gamma(s) \varphi(-s)$$

where $\Gamma(s) = \int_0^{\infty} x^{s-1} e^{-x} dx$, $s \in \mathbb{C}$, $\text{Re}(s) > 0$, is the *Gamma function*.

Theta functions and their results

Ramanujan greatly studied a group of functions which he named as the theta functions. These functions have been found to have a large number of properties which are applicable in advanced physics and mathematics. For example, these functions are used in the working

of nuclear reactors. The Ramanujan theta function is used to determine the critical dimensions in Bosonic string theory, superstring theory and M - theory.

The *Ramanujan theta function* is defined in (Ramanujan, 1916) as

$$f(a, b) = \sum_{n=-\infty}^{\infty} a^{\frac{n(n+1)}{2}} b^{\frac{n(n-1)}{2}},$$

for $|ab| < 1$

The *Jacobi triple product*

$$\prod_{n=1}^{\infty} (1 - x^{2n})(1 + x^{2m+1}y^2) \left(1 + \frac{x^{2m-1}}{y^2}\right) = \sum_{n=-\infty}^{\infty} x^{n^2} y^{2n}$$

can be written in the following way

$$f(a, b) = (-a, ab)_{\infty} (-b, ab)_{\infty} (ab, ab)_{\infty}$$

where $(a, q)_{\infty}$ denotes the q - *Pochhammer symbol*

$$(a, q)_{\infty} = \prod_{k=0}^{n-1} (1 - aq^k)$$

Mock theta functions

Another class of functions discovered and studied by him. These are even more advanced and applicable than theta functions. Ramanujan described them in his last letter to Hardy. These functions are extremely useful in Quantum field theory and string theory. These functions are used for predicting the entropy of black holes.

Ramanujan's approximation for π

The most efficient approximation for π till date. Modern computers use this formula to approximate π up to trillions of decimal places. In 1910, Ramanujan found several rapidly converging series of π , including

$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{n=0}^{\infty} \frac{(4n)! (1103 + 26390n)}{(n!)^4 \cdot 396^{4n}}$$

which computes 8 new decimals of π with each term.

Ramanujan's results on highly composite numbers

Ramanujan got his BSc degree after writing his paper entitled "Highly composite numbers" (HCN). A *highly composite number* (or anti-prime number) is a positive integer with more divisors than any of the numbers smaller than it. Such examples are: 1, 2, 4, 6, 12 etc. He discovered these numbers and studied them and as a result discovered highly original results of the subject.

Generalization of Bertrand's postulate

Bertrand's postulate states that for any $n \geq 3$ there exists at least a prime number p , such that

$$n < p < 2n$$

In other words, if we denote for $x \in \mathbb{R}$ the prime counting function

$$\pi(x) = \text{card} \{p \leq x ; p \text{ prime}\}$$

then Bertrand's postulate can be reformulated:

$$\pi(2n) > \pi(n), \quad \forall n \geq 3$$

One of the three mathematicians who proved the Bertrand's postulate was Ramanujan. His short proof involved advanced properties of the gamma function and in this proof, he generalized the result which is the best generalization till date. Later on, his methods of generalization were used by several mathematicians like Sondow who first defined and studied the Ramanujan primes.

Ramanujan derives the postulate from the following stronger inequality:

$$\pi(x) - \pi\left(\frac{x}{2}\right) > \frac{1}{\log x} \left(\frac{x}{6} - 3\sqrt{x}\right), \quad \forall x > 300$$

A conjecture of Ramanujan's related to Fermat's Last Theorem

In his paper "On certain arithmetical functions" (Ramanujan, 1916), Ramanujan defined the so-called *delta-function*, whose coefficients are called $\tau(n)$ (the *Ramanujan tau function*).

He proved many congruences for these numbers, such as:

$$\tau(p) \equiv 1 + p^{11}(\text{mod } 691), \quad \text{for primes } p$$

This congruence (and others like it that Ramanujan proved) inspired Jean-Pierre Serre (1954 Fields Medalist) to conjecture that there is a theory of Galois representations that "explains" these congruences and more generally all modular forms. $\Delta(z)$ is the first example of a modular form to be studied in this way. Deligne (in his Fields Medal-winning work in 1973) proved Serre's conjecture. That Ramanujan conjecture is an assertion on the size of the tau-function, which has as generating function the discriminant modular form $\Delta(q)$, a typical cusp form in the theory of modular forms. The proof of Fermat's Last Theorem proceeds by first reinterpreting elliptic curves and modular forms in terms of these Galois representations. Without this theory there would be no proof of Fermat's Last Theorem.

Hardy – Ramanujan number 1729

"I remember once going to see him when he was ill at Putney. I had ridden in taxi cab number 1729 and remarked that the number seemed to me rather a dull one, and that I hoped it was not an unfavourable omen. "No", he replied, "it is a very interesting number; it is the smallest number expressible as the sum of two cubes in two different ways." (Hardy)

The two ways are

$$1729 = 1^3 + 12^3 = 9^3 + 10^3$$

Generalisations are now called "taxicab numbers".

CONCLUSIONS

Ramanujan's mathematical achievements and life have inspired generations of mathematicians and scientists from India and from all over the world. Despite his extremely short life, he remains one of the most productive mathematicians throughout history.

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THE SURVIVAL ABILITIES OF *DEINOCOCCUS RADIODURANS* BACTERIUM

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Abstract

The aim of this review is to highlight the survival abilities of the Deinococcus radiodurans bacterium after it suffers degradation caused by exposure to high levels of ionizing radiation. Ionizing radiation is a type of energy either in wavelength or particle form, able to produce ions by removal of electrons and breaking of chemical bonds and with harmful potential leading to DNA strand breaks and cell death. Deinococcus radiodurans has built up a strong resilience to factors like dehydration and oxidative stress, the imbalance between reactive oxygen species and antioxidants. It relies on a complex defence system comprising of several mechanisms such as: catalase and superoxide dismutase, enzymes capable of breaking down the harmful free radicals; nonenzymatic antioxidants like manganese and carotenoids complexes, among which deinoxanthin is a pigment produced solely by this particular bacterium and transcriptional regulatory proteins - PpRM, IrrE, DdrA-.

This ability to withstand the oxidative stress of the ionizing radiation led to the discovery of a wide range of practical applications such as usage in the medical field, in environmental protection like cleaning toxic and radioactive waste and even prospective use in areas with high levels of radiation like the surface of planet Mars.

Key words: *Deinococcus radiodurans, ionizing radiation, oxidative stress, survival abilities.*

INTRODUCTION

Deinococcus radiodurans is a non-sporulating, non-pathogenic bacterium, with a characteristic pink orange colour and a well-known resistance to ionizing radiation (IR), dehydration and oxidising molecules (Murray, 1986; Murray, 1992; Munteanu et al., 2015). Its optimum growth temperature is 30°C, but it can continue to show increased growth up to 37°C. The development stops at a minimum of 4°C and a maximum temperature of 45°C (Battista, 1997). *Deinococcus radiodurans* was first isolated in 1956 by Arthur (Andy) Anderson and his colleagues at the Oregon Experimental Agricultural Station in Corvallis, Oregon, USA after signs of contamination appeared in a meat can which had been previously subjected to radiation treatment.

IR represents high-energy radiation that produces ions by breaking molecular bonds and by displacement of electrons from atoms, a fact which generates alterations in living cells with both beneficial and harmful effects. Examples

include gamma rays and X-rays on the upper end of the electromagnetic spectrum and subatomic particles, like alpha and beta particles. IR can produce reactive oxygen species (ROS) through water radiolysis. These can be classified in 3 groups: hydroxyl radical (OH), hydrogen peroxide (H₂O₂), and superoxide (O₂•-) (Ghosal, 2005). As a main cause of oxidative stress, ROS can either be the results of the metabolic processes or can be produced by exposure to physical or chemical agents like IR, dehydration, ultraviolet radiations, hydrogen peroxide and mitomycin (Ghosal et al., 2005; Potts, 1994; Jurkiewicz and Buettner, 1994; Imlay, 2003; Lown et al., 1978). The free oxygen radicals can cause degradation of DNA, RNA and proteins (Zeng and Ma, 2017).

IR-based sterilization techniques represent a key component in a wide range of sectors of activity, since most bacteria do not survive a 500 Gy irradiation (Daly, 2011; Thornley, 1963). While most bacteria can sustain between 1 and 5 IR-induced double-strand DNA breaks on the haploid genome, *Deinococcus radiodurans* can

survive up to almost 200 such ruptures (Daly and Minton, 1995; Lin et al., 1999).

Additionally, *Deinococcus radiodurans* presents a high resistance to dehydration, exhibiting the ability to survive up to 6 years in a desiccator with a 10% viability (Murray, 1992). Studies showed a connection between the IR resistance and the dehydration resistance, proving that during dehydration, *Deinococcus radiodurans* suffers double-strand DNA breaks (Mattimore and Battista, 1995). Thus, it seems feasible to consider that the special ability to resist IR is an effect of its adaptability to withstand dehydration (Battista, 1997).

This paper gives a brief overview of the possible survival mechanisms, as well as the potential applications of this unique feature that *Deinococcus radiodurans* possesses.

MATERIALS AND METHODS

The present paper represents a scientific literature review from the public domain. The relevant websites consulted were Science direct, Google Scholar, PubMed and Mendeley. In this study, only the research articles from the last few years were consulted. For this review more than 150 papers were accessed, the most relevant to the subject being selected.

RESULTS AND DISCUSSIONS

1. HYPOTHESES ON SURVIVAL MECHANISMS

DNA Protection

Given the critical functions of DNA, one could consider that a robust repair system would play a major role in the IR resistance of *Deinococcus radiodurans* (Qi et al., 2020). However, the ability of *Deinococcus radiodurans* to survive in IR, compared to sensitive organisms, cannot be explained either by unusual methods of DNA protection or by a special protein dedicated to repairing DNA, neither by the large number of genomes or by their alignment and structure (Daly et al., 2009). No specific protein has been identified that would confer *Deinococcus radiodurans* a special ability to survive compared to IR-sensitive bacteria like *Shewanella oneidensis* and *Escherichia coli* and there is no evidence of increased activity of

DNA repair proteins such as RecA and PolA in *Deinococcus radiodurans* (Daly et al., 2009; Krisko and Radman, 2010; Slade and Radman, 2011).

It seems that a major factor in the radiation protection of the bacterium is represented by a high capability to neutralize reactive oxygen species generated after irradiation (Daly et al., 2007).

The genome of the bacterium *Deinococcus radiodurans* is not special in terms of resistance to IR. Numerous studies have shown that it is as sensitive to IR as other species (Gerard et al., 2001). Instead, its proteins are better protected against oxidative stress caused by ROS compared to radiation-sensitive species (Daly et al., 2007).

Protein Protection

Walter Dale (1940; 1942; 1943) together with his team were the first to study the effects of IR on vitro purified enzymes in the year 1940. They observed that the enzymes deactivate at a dose smaller than 20 Gy. In addition to this, Dale proved that by adding substrates or other smaller organic compounds like sugars, amino acids or nucleotides to these purified enzymes, their capacity to resist IR grows significantly.

In 2007, Daly and his team emphasized that the level of protein oxidation was different in IR resistant bacteria in comparison to IR sensitive ones. Not only that, their survival was correlated with this level of oxidation.

Following those studies, Daly et al. (2010) pointed out that the oxidation of proteins in radiated cells is not a consequence of the cell's death, but rather it could be the reason behind it. In a study made in 2020 by Gao et al. concerning the level of *Deinococcus radiodurans* protein overexpression after oxidative stress, it was observed that ribosomal proteins were overexpressed by up to 242(rpsL), 232(rpsR) and 193(rpsT) times than normal. This suggests that a large number of proteins must be resynthesized to replace the essential proteins affected by IR. These discoveries are consistent with other studies highlighting the fact that transcription and translation were induced as a response to cell irradiation, a necessity for the rapid synthesis of proteins and thus, for the replacement of the affected protein. This, in turn, leads to the repair of the cells'

macromolecules (lipids, DNA, etc) (Lipton et al., 2002; Liu et al., 2003; Zhang et al., 2005). Studies were done that suggest the fact that the whole protein complex of the *Deinococcus radiodurans* bacterium is well protected by the antioxidant system after IR exposure (Agapov and Kulbachinskiy, 2015; Munteanu et al., 2015).

Cellular Wall

Also following the study made by Gao et al. (2020), the transmission electron microscopy results showed that the integrity of the cellular wall suffered because of the oxidative stress caused by exposure of the *Deinococcus radiodurans* bacteria to a concentration of 80 mM H₂O₂ for 30 minutes.

Other studies indicated that exposure to thermal stress affects the cellular wall in *E. coli* as well as in *Deinococcus radiodurans* (Ji, 2010; Carbonneau et al., 1989; Xue et al., 2019). Following these results, it has been proven that external stress destroys the cellular wall first, after which it affects the physiological activities of the bacteria (Gao et al., 2020).

Antioxidants

Deinococcus radiodurans contains several mechanisms which offer its strong resistance, including sRNA (small RNA), neutralization enzymes of ROS (like the catalase and superoxide dismutase), a system formed from nonenzymatic antioxidants like manganese and carotenoids complexes and also transcriptional regulators like PprM, IrrE, DdrA (Chen et al., 2019).

In 1990, Chou alongside Tan emphasized that resistance against radiation and the oxidative stress of *Deinococcus radiodurans* is due to a high level of catalase (CAT) activity and superoxide dismutase (SOD).

A study compared the activity of SOD and CAT between *Deinococcus radiodurans* and *E. coli*. The result was that SOD presented an activity 6 times bigger and CAT 30 times bigger in *Deinococcus radiodurans* (Wang and Schellhorn, 1995).

In *Deinococcus radiodurans*, three catalases were highlighted: DR1998 (KatE1), DRA0259 (KatE2) and DRA0146. The first two (DR1998 and DRA0259) are expressed continuously in normal conditions (Lipton et al., 2002; Jeong et

al., 2016). In *Deinococcus radiodurans*, KetE1 is the most important catalase, having the largest activity of 68.800 U/mg and demonstrating increased efficiency neutralizing the hydrogen peroxide compared to KatE2 and DRA0146 (Jeong et al., 2016; Kobayashi et al., 2006). In the study Gao et al. (2020) made, after exposure to hydrogen peroxide, it was shown that DR1998 was overexpressed by 2.29 times in oxidative stress conditions, suggesting that it would be resistant against oxidative stress in the bacteria. Alongside KetE1, other proteins such as Dps, DdrI and IrrE were also overexpressed. The same study indicated that the rate of survival of *Deinococcus radiodurans* decreased in proportion to the time of exposure. As a result of exposing, it for 30 minutes to the treatment, the rate of survival of the bacteria dropped at 68% compared to the control group.

Depending on the structure of the protein and the metal that can be bound, SOD is cataloged in 3 groups: CuZnSOD (can be bound both to copper and zinc), FeSOD / MnSOD (binds either to iron or manganese) and NiSOD (binds to nickel) (Perry et al., 2010). *Deinococcus radiodurans* contains 2 periplasmic CuZnSOD (DR1546 and DRA0202) and 1 cytoplasmic MnSOD (DR1279). This MnSOD neutralizes superoxides more efficiently compared to the ones from the *E. coli* bacteria because of protonation and the faster release of H₂O₂ (Abreu et al., 2008). Some studies discovered that MnSOD from *E. coli* and *Deinococcus radiodurans* presents some characteristics which allow latching onto the DNA. This latching could protect the DNA from the effects of oxidative stress and radiation (Dennis et al., 2006; Smolik et al., 2014).

Owing to the fact that superoxides are not capable of traversing the cellular membrane, since they are negatively charged, it is assumed that CuZnSOD (DR1546 and DRA0202) neutralises the superoxides situated at the edge of the cell, thus protecting the bacterium from oxidative stress (Qi et al., 2020).

Regarding the role of carotenoids, deinoxanthin is a carotenoid which exists only in *Deinococcus* (Tian et al., 2009).

A study investigated the sensitivity of a mutant strain, without pigment, of the *Deinococcus radiodurans* bacterium to treatment with H₂O₂ at a concentration of 50 mM. It was observed

that the mutant bacteria's sensitivity to hydrogen peroxide was 100 times bigger (Carbonneau et al., 1989). Deinoxanthin held a higher rate of hydrogen peroxide elimination compared to xanthophylls and in vitro carotenes (Tian et al., 2009).

The following genes, CrtI (DR0861), CrtB (DR0862) and CrtO (DR0093), were discovered as the main genes that influence the biosynthesis of deinoxanthin's pigment. By eliminating them, the bacteria displayed a higher sensitivity to oxidative stress and became colorless (Zhang et al., 2007). Another study done by Gao et al. (2020) also managed to highlight the fact that CrtI (DR0861) and CrtE (DR1395) were overexpressed by 2.91 and respectively 1.79 times after *Deinococcus radiodurans* bacteria's exposure to H₂O₂ treatment, suggesting that these play a role in the high resistance to oxidative stress.

PprM protein is a protein that responds to oxidative stress (Jeong et al., 2016). It's elimination in *Deinococcus radiodurans* leads to a higher sensitivity of the bacteria to UV (Jeong et al., 2016). This protein seems to also be responsible for catalase KatE1 regulation in *Deinococcus radiodurans* (Jeong et al., 2016).

In a study made by Zeng and Ma (2017), a mutant variant of *Deinococcus radiodurans*, without the gene responsible for PprM protein's synthesis, was created. This variant was less colored than the wild one. In the experiment, the mutant variant had a smaller light absorption rate compared to the wild strain. This proves that the elimination of the gene responsible for PprM leads to a reduction in the biosynthesis of the deinoxanthin's pigment in *Deinococcus radiodurans*. It was also observed that in the mutant variant the genes responsible for the biosynthesis of the deinoxanthin's pigment CrtI (DR0861), CrtB (DR0862) and CrtO (DR0093), were under-expressed. CrtI (DR0861) had a 0.5 times lower transcription and both CrtB (DR0862) and CrtO (DR0093) 0.4 times lower, compared to the wild variant. Besides these, a gene with a connection in the concentration ratio Mn / Fe, DPS-2 (DRB0092) was also under-expressed, decreasing 0.5 times (Zeng and Ma, 2017; Reon et al., 2012). Exposure to dehydration emphasized the fact that the mutant variant had a lower rate of survival compared to the wild one (Zeng and Ma, 2017). Fluorescence

detection showed that the mutant variant suffered ROS accumulation 2 times more than the wild strain (Zeng and Ma, 2017). After exposure to 2.000 Gy radiation, this difference of accumulated ROS increased by 4 times compared to the wild variant (Zeng and Ma, 2017). All these results suggest that PprM may influence the antioxidant abilities of *Deinococcus radiodurans* through the synthesis adjustment of deinoxanthin's carotenoid and through metal ions ratio concentration adjustment (Zeng and Ma, 2017).

IrrE protein, sometimes named PprI, was found only in the *Deinococcaceae* and *Thermaceae* bacteria. It is considered that it regulates a lot of the bacteria's reactions to stress like dehydration, IR and oxidative stress (Hua et al., 2003; Bauermeister et al., 2009; Lu et al., 2008). Gao et al. (2020) observed a rise of up to 3.77 times in the overexpression of PprI as a response to oxidative stress. The mutant variant, without PprI, showed a decrease in catalase activities as a response to IR treatment while also displaying an increase in sensitivity to these radiations (Hua et al., 2003). The overexpression in *E. coli* bacteria of the IrrE highlighted a rise in catalase activity and a higher tolerance to salt, osmosis and radiation (Gao et al., 2003; Pan et al., 2009; Zhao et al., 2015; Ma et al., 2011).

DdrI is one of the four receptor proteins of the AMP (Adenosine monophosphate) cycle synthesized by *Deinococcus radiodurans*. Under oxidative stress conditions, it was observed that this protein was overexpressed by up to 6.75 (Gao et al., 2020). A mutant variant, having their DdrI protein removed, exhibited a higher susceptibility to oxidative stress and to thermal shock. This suggests that this protein plays a role in the defensive mechanism against those external factors (Yang et al., 2016; Meyer et al., 2018). Beside this, the mutant variant had a much lower catalase activity both in normal conditions and in oxidative stress conditions (Yang et al., 2016). It was demonstrated that DdrI regulates the transcription of 8 genes: DR1998, DR0349, DR1974, DR1506, DR2531, DR1819, DRA0346 and DR1447 (Yang et al., 2016).

2. APPLICATIONS

The Cleansing Of Uranium

A study used a genetically modified variant of *Deinococcus radiodurans* bacteria (named DR1-bf + in the study) which had the ability to create biofilm, to later be used in the extraction of UO_2^{2+} from uranyl nitrate aqueous solution (Shukla and Rao, 2017; Manobala et al., 2019). DR1-bf + bacteria, cultivated and raised in a medium enriched with 20 mM Ca^{2+} , exhibited superior abilities of eliminating uranyl ions, having a rate of elimination of 75+-2% from 1000 mg/L uranium in the first 30 minutes of treatment (Manobala et al., 2019). It was also shown that this rate is directly proportional with the biofilm's age (Manobala et al., 2019).

Applications Outside Terrestrial Space

In a 2020 study, a team from the University of Vienna demonstrated that *Deinococcus radiodurans* survived for a long period of time in Earth's lower orbit as long as the electromagnetic radiation to which it was exposed never passed below 200 nm. The radiation spectrum on Mars exceeds the 190 nm threshold, CO_2 working as a shield under this limit (Ott et al., 2020). The dehydrated cells managed to survive for one year (Ott et al., 2020).

Other Applications

In 2000, Brim et al. genetically modified a *Deinococcus radiodurans* bacterium to treat a mixture of toxic waste which contained ionic mercury.

In 2014, Misra et al. managed to precipitate uranium from radioactive areas, using a genetically modified strain of *Deinococcus radiodurans*.

In 2019, Li et al. biosynthesized gold and silver nanoparticles using *Deinococcus radiodurans*, with practical applications in the medical, industrial and environmental domains.

In 2020, Weng et al. combined the proteins from *Deinococcus radiodurans* with gold and silver nanoparticles, this mixture later being used to degrade the toxic colorant "Malachite Green".

CONCLUSIONS

This article intended to provide some information regarding the mechanisms that offer *Deinococcus radiodurans* bacterium such a strong resistance to IR and other elements such as dehydration, oxidative stress, thermic shock, mechanisms that by far do not represent the whole arsenal of *Deinococcus radiodurans*. While *Deinococcus radiodurans* does not have a specific protein to help restore or protect genetic information or lipids in its cellular wall, it uses a combination of multiple defence mechanisms to build its resilience. These abilities with practical uses in the medical fields and environmental protection offer *Deinococcus radiodurans* a vast potential, a fact highlighted by its extensive research in recent years.

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