Universitatea „Dunărea de Jos” din Galați
Școala doctorală de Inginerie industrială

PHD THESIS

Modern forest ecosystems monitoring methods for health level assessing

Summary

Eng. Valentin HAHUIE

Scientific leader,
Prof. Dr. Ing. Lucian GEORGESCU

Series I4: Industrial Engineering Nr. 46

GALAȚI
2017

Universitatea „Dunărea de Jos” din Galați

Școala doctorală de Inginerie industrială

TEZĂ DE DOCTORAT

Metode moderne de monitorizare a ecosistemelor forestiere, pentru evaluarea nivelului de sănătate

Rezumat

Ing. Valentin HAHUIE

Conducător științific,	Prof. dr. ing. **Lucian Puiu GEORGESCU**
Președinte	Prof. univ. dr. ing. **Eugen RUSU**
Referenți științifici	CSI dr. ing. **Nicolae Ovidiu BADEA** - Institutul Național de Cercetare Dezvoltare în Silvicultură „Marin Drăcea"
	CSI dr. ing. **Ionel POPA** - Institutul Național de Cercetare Dezvoltare în Silvicultură „Marin Drăcea"
	Conf. dr. ing. **Florin CLINOVSCHI** - Facultatea de Silvicultură - Universitatea „Stefan cel Mare" Suceava

Seria I4: Inginerie industriala Nr. 46

GALAȚI

2017

Seriile tezelor de doctorat sustinute public în UDJG începând cu 1 octombrie 2013 sunt:

Domeniul **ȘTIINȚE INGINEREȘTI**

Seria I 1**: Biotehnologii**
Seria I 2: **Calculatoare și tehnologia informației**
Seria I 3**: Inginerie electrică**
Seria I 4**: Inginerie industrială**
Seria I 5**: Ingineria materialelor**
Seria I 6**: Inginerie mecanică**
Seria I 7: **Ingineria produselor alimentare**
Seria I 8**. Ingineria sistemelor**

Domeniul **ȘTIINȚE ECONOMICE**

Seria E 1: **Economie**
Seria E 2: **Management**

Domeniul **ȘTIINȚE UMANISTE**

Seria U 1: **Filologie-Engleză**
Seria U 2: **Filologie-Română**
Seria U 3**: Istorie**

We are proud and glad to personally thank the representatives of the institutions and representative bodies that helped us to document, start, manage and complete this interesting thesis.

This work is intended to be the fruit of a sustained effort of years of study and experimentation, as well as successive attempts and resolutions of specific issues.

Thank you Professor Lucian Puiu Georgescu, PhD, coordinator and mentor teacher, for the time granted and devoted to this thesis. We know that in this thesis we have not been able to fully integrate all the studies we would have wanted to expose, but this work can be a cornerstone in future applications.

Last but not least, we would like to thank Professor Habil. Gabriel Murariu for the substantial collaboration in the processing and publication of data and results, from the present research paper, in well-known publications.

Research is at the beginning and the results obtained are presented and published in a number of 7 articles in BDI journals such as The Annals of "Lower Danube" University of Galati - Fascicle II. Two other articles are being published ISI- in the International Journal of Conservation Science (IJCS) (http://www.ijcs.uaic.ro/current.html) as well as 1 ISI Proceedings article already published (**http://doi.org/10.1063/1.4972387**).

There have also been a number of 12 participations at international conferences on environmental and interdisciplinary issues (TIM 15-16 Physics Conference) and international prestigious conferences (ICEEM) 6 - 9 September 2017 - Alma Mater Studiorum Università di Bologna, Italy) and continental organizations (International UAB - B.EN.A., Conference on Environmental Engineering and Sustainable Development - Alba Iulia, Romania, May 25-27th, 2017).

All of these results demonstrate a sustained effort to successfully complete PhD studies.

Listă lucrări personale

A. *Articole ISI si ISI proceedings*

1. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni, Catalina Iticescu, Adrian Gabriel Murariu, *Study on the influence of atmospheric parameters on the accuracy of the geodetic measurements*, **AIP Conference Proceedings 1796, 040009 (2017); http://doi.org/10.1063/1.4972387 (http://aip.scitation.org/doi/abs/10.1063/1.4972387)**

2. Gabriel Murariu, **Valentin Hahuie,** Adrian Gabriel Murariu, Lucian Georgescu, and Catalina Iticescu, *Growth rate modeling for white poplar in the south eastern part of Romania: an important issue of forest conservation* , The International Journal of Conservation Science (IJCS), Volume 8, Issue 2, pp. 303-316, 2017, (http://www.ijcs.uaic.ro/current.html)

3. Gabriel Murariu, **Valentin Hahuie,** Lucian Georgescu, Adrian Gabriel Murariu, Catalina Iticescu, Mihaela Calin, *Assessment of The Efficiency Exploitation for White Poplar Species Using an Optimized Management System. Case Study - Independenta Forest*, **in second review** to Annals of Forest Research

B. *Articole trimise spre revizie:*

1. Gabriel Murariu, Adrian Murariu, **Valentin Hahuie**, Lucian Georgescu, Alina Mihaela Calin, Ionica Soare, *Forest Composition Monitoring Method Using Satellite And UAV Aerial Images. Case Study - Bălăbăneşti Forest*, The International Conference on Environmental Engineering and Management (ICEEM), 6 – 9 September 2017 at the Alma Mater Studiorum Università di Bologna, Italy.
2. Gabriel Murariu, Adrian Murariu, **Valentin Hahuie**, Lucian Georgescu, Alina Mihaela Calin, Ionica Soare, *Growth Rate Assessment and the Evaluation of the Logging Efficiency. Case Study - Independenta - Hanu Conachi Forest*, The International Conference on Environmental Engineering and Management (ICEEM), 6 – 9 September 2017 at the Alma Mater Studiorum Università di Bologna, Italy
3. Gabriel Murariu, **Valentin Hahuie**, Adrian Murariu, Lucian Georgescu, Catalina Iticescu, Mihaela Alina Calin, Ionica Soare, Oniga Mihaela, *Assessment of Forests Composition Using Combined Techniques with Satellite Images and Specific High Definition Aerial UAV Pictures. Case Study - Buciumeni Forest*, International U.A.B. – B.EN.A. Conference Environmental Engineering And Sustainable Development, Alba Iulia, Romania, May 25-27th, 2017
4. Gabriel Murariu, **Valentin Hahuie**, Adrian Murariu, Lucian Georgescu, Catalina Iticescu, Mihaela Alina Calin, Ionica Soare, Oniga Mihaela, *Assessment of the Efficiency Exploitation for White Poplar Species Using an Optimized Management System. Case Study - Independenta Forest*, International U.A.B. – B.EN.A. Conference Environmental Engineering And Sustainable Development, Alba Iulia, Romania, May 25-27th, 2017

C. *Articole in reviste indexate BDI*

1. **Hahuie Valentin**, Emilian Dănilă, Adriana Dănilă, Lucian Georgescu, *Using multifractal geometry to change the structure of forest in Galati area*, Annals of "Dunarea de Jos" University of Galati, Mathematics, Physics, Theoretical Mechanics Fascicle II, Year VI (XXXVII) 2014, Special Issue, 26-32
2. **Valentin Hahuie**, Emilian Danila, Adriana Danila, Lucian Puiu Georgescu, *Using Multifractal Geometry to Change the Structure ff The Forest In The Galati Area*, Proceedings of the Third Scientific Conference of the Doctoral Schools from "Dunarea de Jos" University of Galati (CCSD-UDJG 2015), Galati 4-5 June 2015, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VII (XXXVIII) 2015, No. 1, pag. 26-33 (http:/ /www.phys.ugal.ro/ Annals_Fascicle_2/ Year2015/Vol1.htm)
3. Gabriel Murariu, **Valentin Hahuie,** Adrian Murariu, Catalina Iticescu, Lucian Georgescu, Ciprian Vlad, Proceedings of the Fourth Scientific Conference of Doctoral Schools from "Dunărea de Jos" University of Galati (CCSD-UDJG 2016), Galati, June 2-3, 2016, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016, No. 1, pag. 118-127 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryII.htm)
4. Gabriel Murariu, **Valentin Hahuie,** Adrian Murariu, Catalina Iticescu, Lucian Georgescu, Ciprian Vlad, Investigation on satellitar and UAV cadastral results. Case study - Balabanesti forest areas, Proceedings of the Fourth Scientific Conference of Doctoral Schools from "Dunărea de Jos" University of Galati (CCSD-UDJG 2016), Galati, June 2-3, 2016, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016,, No. 1, pag. 128-138 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryII.htm)
5. Bogdan Burlacu, Lucian Georgescu, Catalina Iticescu, Gabriel Murariu, Adrian Gabriel Murariu, Radu Manolache, **Valentin Hahuie,** Proceedings of the Fourth Scientific Conference of Doctoral Schools from "Dunărea de Jos" University of Galati (CCSD-UDJG 2016), Galati, June 2-3, 2016, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016, No. 1, pag. 71-80 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryII.htm)
6. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Catalina Iticescu, The fractal analysis results for forest area evolution monitoring – Study case Balabanesti Forest, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016, No. 2, pag. 256-259 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryVolume2.htm)
7. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Catalina Iticescu, The fractal analysis results for forest area evolution monitoring – Study case Valeni Forest, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016, No. 2, pag. 253-255 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryVolume2.htm)
8. Mihaela Cudalbeanu, **Valentin Hahuie**, Lucian Georgescu, Catalina Iticescu, Gabriel Murariu, The annual dynamics that characterizes the physico-chemical parameters for water quality in the Grindu Area, Annals of "Dunarea De Jos" University ff Galati, Mathematics, Physics, Theoretical Mechanics, FASCICLE II, YEAR VIII (XXXVIX) 2016, No. 2, pag. 200-203 (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2016/SummaryVolume2.htm)
9. **Valentin Hahuie**, Emilian Dănilă, Adriana Dănilă, Lucian Georgescu, *Changing the structure of forest land in the region of Galati by means of multifractal geometry*, Annals of "Dunarea De Jos" University of Galati, Mathematics, Physics, Theoretical Mechanics, Fascicle II, YEAR VI (XXXVII) 2014, 74-79
10. **Valentin Hahuie**, Emilian Dănilă, Adriana Dănilă, Lucian Georgescu, Dănuţ Lefter, *Desertification - causes, solutions to reduce the phenomenon and the benefits of afforestation*,

Annals of “Dunarea de Jos” University of Galati Mathematics, Physics, Theoretical Mechanics, Fascicle II, Year VI (XXXVII) 2014, Special Issue, 1-16, (http://www.phys.ugal.ro/Annals_Fascicle_2/Year2014/Summary.htm)

11. Dănuţ LEFTER, Lucian P. GEORGESCU, Daniela L. BURUIANĂ, Ina I. HUMENIUC, **Valentin Hahuie**, Catalina M. TOPA, *Monitoring and Prediction of Soil Pollution in Galati Area*, Annals of “Dunarea de Jos” University of Galati Mathematics, Physics, Theoretical Mechanics, Fascicle II, Year VI (XXXVII) 2014, Special Issue, 1-16

D. *Articole in proceedings ale conferintelor*

1. G. Murariu, **V. Hahuie,** L. P. Georgescu, A.G. Murariu, *Evaluation of the Evolution And Composition of Forested Areas. Preliminary Results. Study Case- Balabanesti Forest*, IBWAP Conference (http://www.ibwap.ro/2016/articles/program)

E. *Lucrari prezentate la conferinte internationale*

1. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, *Improving Orthophotoplans And Patterns Construct of Land by Using Aerial Photographs Captured Using. Case Study - Forest Garboavele*, Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE West University of Timisoara, 26th – 28th of May 2016 (http://www.timconference.uvt.ro/upload/TIM15-16_Conference%20Schedule.pdf)

2. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, *Investigation On Satellitar And UAV Cadastral Results. Case Study - Galati County Forest Areas* , Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE, West University of Timisoara, 26th – 28th of May 2016 (http://www.timconference.uvt.ro/upload/TIM15-16_Conference%20Schedule.pdf)

3. Gabriel Murariu, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, *Study on the Influence of Atmosheric Parameters on the Accuracy Of The Geodetic Measurements* Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE, West University of Timișoara, 26th – 28th of May 2016 (http://www.timconference.uvt.ro/upload/TIM15-16_Conference%20Schedule.pdf)

F. *Cărți / Îndrumare cu caracter didactic / profesional*

1. Lucian P. Georgescu, Cătălina Iticescu, **Valentin Hahuie**, *Reconstrucție si revitalizare ecologică*, Editura Europlus, Galați, 2015, ISBN 978-606-628-129-4, 210 pagini.

THE THESIS CONTENT

INTRODUCTION

Monitoring the environment and especially preventing its degradation is at present a major desideratum. Soil degradation, diminishing forest areas, global warming phenomena, etc., generate effects that are difficult to assess in the future. In this respect, any effort to monitor the environment and identify environmental changes is impetuous.

The emergence and development of the human being was the "event" that introduced strong influences on the natural environment. If plants and animals adapt to the environment, man imposes his will by adapting the environment to his needs. Through the continuous improvement of science and technology, the anthropic factor has produced important changes in the functional structure of the environment, starting with deforestation, which currently affects the entire world and up to radioactive pollution due to excessive and defective atomic energy use. Environmental degradation means the destruction of ecological balance and the occurrence of an inverse reaction from nature to man, the new conditions of the modified environment being less favorable to the life of all living things.

Galati County enters the area of the Danubian Counties, being relatively close to the Black Sea, at the confluence of three major river waters - Danube, Siret, Prut. The natural conditions of climate, relief, precipitation regime, vegetation and lithological substratum, coupled with inadequate agrotechnics of land management, make Galaţi County among the counties with the largest areas of degraded land in the country. The need for immediate ecological actions is dictated by the emergence of severe forms of degradation, namely: increased erosion of surface and deep erosion, numerous ravines, pits, gullies and streams, forms of degradation leading to: decrease of soil fertility, drought activation, Agricultural production, reduction of arable land, worsening of water regime, clogging of accumulation lakes, soil pollution, impoverishment of agricultural land, and finally the degradation of roads and human settlements. The lands in Galaţi County are also characterized by extremely limiting ecological factors: strong water loss in the soil during the vegetation period, long uneven waves with high degree of kneading, sunstroke, excessive evapo-sweating, sun exposure, high slope, lack of soil Mostly humus. The characteristic forms of these landscapes, combined with climatic elements (wind, wind, temperature and petrographic subsoil shaped like loess and sands), continuously favor surface and depth erosion.

On the other hand, a great emphasis was put on the development, implementation and use of new and modern methods and methods for monitoring and evaluation of forest ecosystems in the county.

From this point of view, the developed and applied means and processes have emphasized the use of contemporary air monitoring methods using ortho-photograms and satellite imagery. Such an approach fully complies with modern research requirements in the field. There are exposed procedures for efficient use of satellite photographers and those taken from our own UAVs, but, on the other hand, new methods of study are proposed and explained.

In this spirit, the present paper analyzes in a critical perspective the modern methods used in the monitoring of vegetation on large areas and it could say that these methods are not at all effective and offer no immediate response to concrete problems raised by society. We can proudly say that we have come up with an alternative solution that has been tested in this work on 4 forest bodies for the deficiencies observed.

The success and effectiveness of the designed, implemented and implemented methods in this study is not entirely assured, as it is necessary to verify and implement in other parts of the country other relief forms with other structures and compositions of the wooded areas. However, the methods and procedures developed in this paper correspond to those used at national and world level, the only impediment being the resolution of the photographers taken over.

From this point of view, this paper can be considered as a beginning in the development of new researches in this direction, as evidenced by the large number of papers presented and published on this topic.

The choice of the 4 forest bodies within Galaţi County, namely the Bălăbăneşti, Buciumeni, Vălenii Vaslui, Independenta forests, was made on the basis of an objective reason: it was wanted that models developed by us could be verified in the field by actual measurements and Then the reason to select close bodies was essential.

This selection also brought some procedural and methodological advantages by the fact that from the selection of some forest areas in the area of Galaţi county, the relief forms encountered were almost similar. This aspect, combined with the fact that these forms of relief were devoid of uneven areas, has certainly been an advantage in terms of the applicability of our methods. In the research that will continue, we will test the effectiveness of the analysis methods in some wooded areas located in the valleys or on the mountainside.

Another major advantage that we exploited was the fact that the used satellite photos were non-referenced, taken and processed according to the same standard. This was essential in our analysis, especially during the processing of image elements. Thus, the resolution was rigorously respected, the sampling period was the same, and especially the fact that the photographs were referenced with a precision of up to 4 meters, obviously constituted an advantage that allowed the development of an efficient method of highlighting the dynamics and The development of a forest ecosystem.

Regarding the set of methods presented in the present paper, we can state that these methods, used, studied, tested and validated with good precision, fall into the field of modern methods used worldwide in similar cases.

On the other hand, more and more emphasis is now being placed on the use of software to help with the processing of information taken over by various surveillance means: satellites, airplanes, unmanned aerial vehicles. This important aspect was also a starting point in the writing of this thesis. In this respect, it can be said that the emphasis on the use of monitoring and evaluation methods using remote sensing is high on a global level, which was a starting point for the drafting of this thesis.

The main purpose of this paper is to test and prove the possibility of combining relatively complementary surveillance and monitoring techniques - the first technique based on the reception of satellite images in the visible resolution with acceptable resolution to provide the basis of a first analysis and two methods based on Taking high-precision aerial photographs using UAV devices. In this way, this paper is part of the current general context of combining different monitoring techniques to achieve superior performance. This goal is easily detached from the works published in the literature. Another objective pursued in this paper was to test and demonstrate the possibility of obtaining a reliable monitoring system with minimal cost. In this sense, the design, testing and verification of a methodology that combines LANDSAT-type photos - comprising only three spectral bands (red band, green and blue respectively) - photos that can be obtained at a minimal price and The use of high-resolution aerial photographs taken by UAVs from carefully selected points to confirm and correct the model built on satellite imagery.

CHAPTER 1.

The current state of development of monitoring and assessment systems for forest areas

1.1 History of monitoring systems

In the development of human civilization, from the earliest times, one can identify a series of moments and essential periods that have been marked by the connection between man and forest (Balenović I. et al., 2011, Balenović I. et al., 2012 Balenović I. Et al., 2013, Murariu et al., 2015). Since ancient times, when forests have been a shelter for humans and ending today, when forests contribute to mitigating the effects of climate variability, they purify, filter and oxygenate the air while also providing raw materials, and so man is always in close contact with them (Balenović I. et al., 2011-2013, Murariu et al., 2015).

Fig. 1.1. - UAV used in monitoring protected areas - Dunărea de Jos University - Galati

1.1.a History of classic monitoring systems

From ancient times, man has always been interested in the supervision and care of forests (Anttila P., 1998, Anttila P., 2005). Many beneficial effects have been recorded over time, with the stabilization of soil against landslides and ending with the means used by humans to fight against desertification (Anttila P., 1998, Anttila P., 2005). These requirements and methods were encountered both during the Middle Ages when forests were the source of food and shelter, but also in the modern historical period, when the wooded areas were considered as sources of income for religious orders, landowners and communities (Balenović I. et al. 2011-2013, Murariu et al., 2015).

1.1.b History of modern monitoring systems

In the contemporary age, especially in the last 50 years, surveillance techniques have multiplied (Alberti G., et al., 2013). If at first people traveled through difficult forest trails to inspect all areas of interest, after 1945, aerial surveillance methods were developed using selfpropelled means such as airplanes and airships (Michailoff I., 1943, Meyer P., Et al., 1996, Korpela I., 2004, Magnusson M., et al., 2005, Mingireanu et al 2011, Benko M., 1993, Balenović I., 2011).

Since the 1960s surveillance methods have diversified by introducing satellite and combined observations (avio-satellite) (Morgan JL, et al., 2010, Lemmens M., 2011, L. Barrett, et al., 2015, Murariu et al. , 2016a). This practical moment marks the birth of organizations and services specialized in the global observation of vegetation parameters and the level of forest development in an automated way (http://www.nnvl.noaa.gov/).

1.2 Contemporary applications of monitoring systems

In the last, 30 years ago, our country was affiliated to a European soil monitoring system. Forest monitoring is a systematic transnational and national network where, starting with 1987, annual assessments of the state of forest health are made. (Badea O., et al., 2010, Mihai D., et al., 2000). The main role is to know the dynamics and spatial distribution of injured forests in Europe, to build a database on the state of the tree crowns, the soil and their nutrient content. The overall objectives of the monitoring are to track the effects of air pollution and other biotic and abiotic harmful factors at the level of the entire forestry fund and to provide a unitary and operational information support at national and European level regarding the spatial and temporal variation of forest environmental conditions. The ultimate goal is to inventory the forest fund and assess the health of forests.

This paper supports the above-mentioned method by creating a time-based surveillance and monitoring model, using initially measurements and data from the ground and subsequently in the coming years, identifying expeditiously an important part of the criteria pursued using digital data, aerial photographs and satellite imagery.

1.5 National applications and local uses of satellite and airborne systems

At national level, there are a number of specialists who have carried out research activities in the field of monitoring and evaluation of the economic and tourist potential of the forested areas in Romania (Badea O., et al., 2010, Borz S. et al., 2013, Popa I. et al., 2007, Drăgoi M. et al., 2011, Mihai D., et al., 2000).

The research carried out was a reference point for this work. On the other hand, using the methods presented further in this thesis, the results obtained are comparable to those at national and world level.

CHAPTER 2.
MATERIALS AND METHODS

2.1. Introduction

The investigations described in this paper were conducted on the territory of Galaţi County (Murariu et al., 2015, Hahuie et al., 2015a, Hahuie et al., 2016).

Galati County is the main economic and industrial center in the central-eastern part of Romania (Murariu et al., 2015, Hahuie et al., 2015a, Hahuie et al., 2016).

Fig. 2.1 Representing map of Romania with the position of Galati County (www.google.ro).

2.2. Studied forest areas

There are a number of 23 protected areas in Galati County. In this study there were systematically approached a number of 4 forest areas from 3 production units (UP) from the territory of Galaţi county (Fig. 2.2).

In Griviţa Forestry it was chosen the Bălăbăneşti Forest (Fig 2.3) due to the composition of this forest body. In the case of Bălăbăneşti Forest (position 1 - Fig. 2.3) we were able to conceive, check and then generalize in other cases the nonlinear models and the method proposed in this paper.

In the north-west, at the border with Vrancea county, it was chosen the Buciumeni forest (position 2 - Fig. 2.2) because in this case we were able to check the linear models of study (models to be presented further).

Fig. 2.2 Map of forest areas in Galaţi County

In the western part of Galaţi county we chose the forest outside the Independenta commune (position 3 - Fig. 2.3). Within this forest body, we conducted a large-scale statistical study to validate nonlinear and color distribution models - models to be presented further.

Table 2.2 Galaţi County - forest bodies studied

No. crt.	Area of interest	composition	Consistency (Coverage degree of crown	Density (Number of trees / ha)
0	1	2	3	4
1	Bălăbăneşti (GL,VS)	50Sc 20Go 13Te 5St 3Fr 3Ca 6DT DM	0.83	650-1300
2	Buciumeni (GL,VN)	33Te 18Sc 13St 12Ca 8Fa 16DT DM	0.8	500-1100
3	Piscu-Independenta (GL)	29Sa 26Pla 17Plea 9Sc 6Pi 11DTDM	0.76	700-900 Sa si 350 Pl.ea
4	Văleni (VS)	45Go 25St 15Te 5Sc 5Fa 5DT DM	0.85	700

Legend:
GL = Galati County
VN = County of Vrancea
VS = Vaslui County
Composition - proportion of percentage species
Consistency = degree of crown cover on the ground
Production class = quality of exploitable timber
Density = number of trees (strains) at ha
Species:
Sc = acacia
St = oak (all species)
St.b. = oak brumariu
St.p. = pedunculate oak
Go = gorun
Fa = beech
Sa = willow
Pl = poplar (all species)
Plane = Euramerican poplar (hybrid clones)
Pl.nn = black poplar
Pl.a. = White poplar
Te = tei
Fr = ash
Ca = hornbeam
Pi = pin
DT = other hardwood hardwoods
DM = other hardwoods with softwood

The natural conditions of climate, relief, precipitation regime, vegetation and lithological substratum, coupled with inappropriate agro-technical management of the land fund, make Galati county among the counties with the largest degraded land areas in the country. This area is also very poor in forests, and the increase in the phenomenon of drought and aridity in the last two decades leads to a strong ecological degradation of the area.

Fig. 2.3 Map of studied forest areas in Galaţi County

2.3 Methods of data acquisition

The main methods used for data acquisition were mainly those based on field studies, by direct observations from the studied areas (Figure 2.4), but also by the use of photograms and aerial observation means (Fig 2.5a and Fig.2.5b) .

Fig.2.4 – Photo from field monitoring campaign - Independenta forest (original photo)

2.3.1 Direct monitoring methods

Direct monitoring and observation methods have been used throughout the three years of study. Observations and measurements were made quarterly, noting compositional elements, harvest volume, coverage, etc.. Also, the average age, density per hectare, volume was monitored and the harvesting of studied forest bodies was recorded.

Territorial, research and analysis have been carried out both in the forest areas in Galaţi County, within the management of the Galaţi, Griviţa, Hanu Conachi and Tecuci forest farms, as well as in areas outside the forestry forest owned by the administrative units Territorial areas where erosion and land degradation phenomena occur and where ecological reconstruction and reconstruction work is required (Hahuie et al, 2014).

Fig. 2.5.a – Fixed-wing UAVs equipped by the Faculty of Science and Environment of the Dunarea de Jos University in Galati

2.3.2 Aerial monitoring and observation methods

Aerial monitoring and observation methods are a set of modern procedures, widely used worldwide in research on fauna and flora.

In this context, the girl's work falls within the international framework through the modernity of the methods and procedures used. Thus, for the observations performed on larger areas, aerial photographs taken by flying wing UAVs from the Faculty of Science and Environment of the Duanrea de Jos University in Galati (Fig. 2.5.a) were used, but also with the help of the Multi-rotor UAV device equipped with the Faculty of Sciences and the Environment (Figure 2.5.b).

The winged wings used have 2.8 m (Fig 2.5.a) and 4.2 m respectively. The 2,8 m flying wing has electric traction and is equipped with engines powered by 10-cell batteries. The payload capacity is about 1kg and has been used in several monitoring campaigns, equipped with digital photographic equipment and position recording equipment, respectively.

The flight cap was between 200 m and maximum 2000 meters (according to the regulations in force) and in the case of forest studies, the flight cap was programmed at 150 m, being in the autopilot mode (PicsHawk 3.2 compatible autopilot With Mission Planner type programming).

The flight time was up to 15 minutes, being influenced by the amount of payload loaded on board. Flight scheduling is done on site using the software used and the launch is done using a specially designed catapult.

Fig. 2.5.b – Multi-rotor UAVs equipped by the Science and Environment Faculty, Dunărea de Jos University of Galați

The second type of equipment used to capture high-resolution images for restricted areas was the DJI Phantom 3 (Fig.2.5.b).

2.4. Mathematical models

Generally, a photo is a collection of colored cells. Normally, each pixel - the cell contains a number between 0 - of the black color and 255 - of the white color if it is part of a black and white photograph. In this case, a black-and-white photograph can be considered as a whole and positive array of arrays ranging from 0 to 255 The number m represents the number of lines and the number n - the number of columns.

2.4.1 Modele matematice utilizate

In our work we propose a combination of the two dedicated photogrammetry modes in order to obtain improved results with minimal resources.

In principle, airborne or satellite aerial images offer several advantages - take-off speed and high-coverage coverage. At the same time, there are a number of disadvantages such as high costs and high processing times. On the other hand, in the case of photographers taken from the UAV, the advantages include: low processing times, reduced costs, etc. A big disadvantage is the relatively small surface covered on a flight (about 10 hectares in a 12-minute flight).

In this respect, the processes and algorithms built and tested in the Department of Chemistry, Physics and Environment consists in approaching on three directions the study of the photograms associated with the areas in the forests:

- - an approach based on the study of the spectrum of reflection using linguistic and non-linear models
- - a purely geometric approach, studying the properties of satellite and aerial photograms, considering the hypothesis that a forest can be assimilated to a fractal
- - a chromatic approach, using color analysis and layout techniques

2.4.1.1 Linear mathematical models used in studying the reflection spectrum

In literature many references are made to the analysis and use of the reflection spectrum. Light, as an energy transport vector, interacts with different surfaces and experiences a reflection phenomenon. The color and intensity of reflected light can provide valuable information.

It is known that for vegetation, the spectrum used is the infra red - visible. With its help, it is possible to assess the state of vegetation development on a certain surface.

The most commonly used index in studying the reflection spectrum is the NDVI index (Fig 2.6).

$$NDVI = \frac{NIR - R}{NIR + R} \tag{1}$$

where NIR - the intensity of infrared light, R - the intensity of red light,

The NDVI index translates into the ratio of the energy difference in Near Infra Red to Red and their sum.

At this point, we can see that this index does not respond effectively to our requirements for assessing the state of health and vegetation of a forest.

The color-based analysis is based on dynamic RGB reflection spectra for satellite or aerial photogra- phy of the same area.

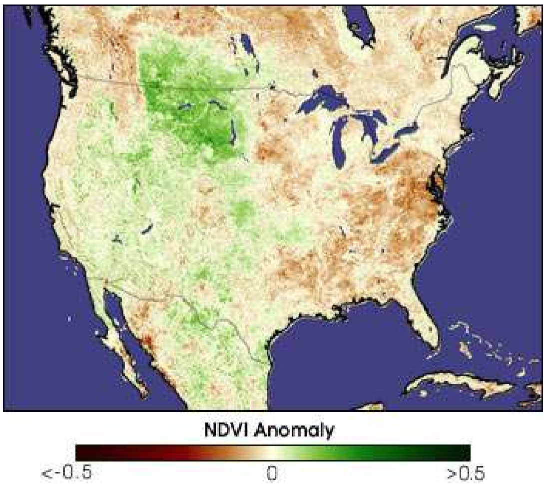


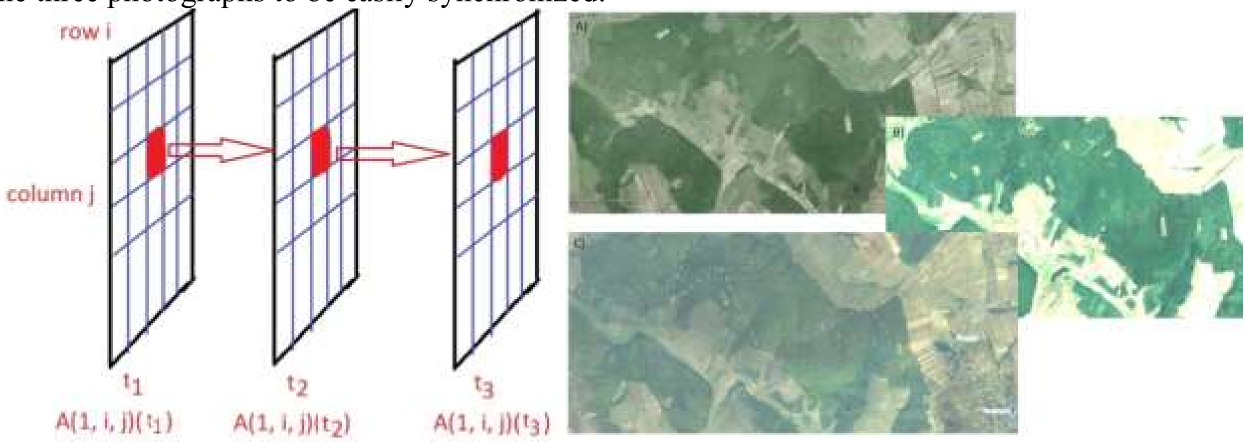
Fig. 2.6.a - NDVI index calculated for the US

Fig. 2.6.b - NDVI index calculated for the Balabanesti forest

Fig. 2.6.c - Satellite image for the Balabanesti forest

For the beginning, we studied the possibility of defining a linear model to efficiently process these color spectra, and the results were encouraging.

We describe the algorithm as follows: For a first-order linear pattern, a set of at least 3 complete aerial photographers for the same area is considered. In this case, the three photograms must contain at least one landmark - for example a geodetic strand, common in the three photographs to be easily synchronized.



(a) (b)

Fig. 2.7 - Schematic representation of the calculation method for the evaluation of each cell based on historical data.

In this way, our system built by us will make the comparison of the spectra from the first two photograms, chronologically placed, and bee based on a MATLAB program and described in Appendix 1, will then make a prediction over the spectrum for the most recent photogram.

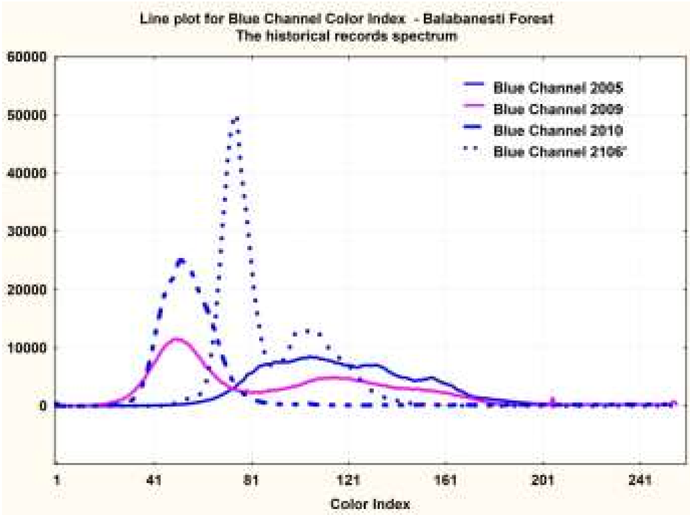


Fig. 2.8 - Successive spectral series for the same forest over a 10-year period

For each color, we will note $A_1[k,i,j] = A_1[k,i,j](t_1)$ the value of each pixel for the color channel k (k can be R, G or B) for the time t_1.

Analogously we will note $A_2[k,i,j] = A_2[k,i,j](t_2)$ the value of each pixel for the color channel k of the moment t_2. In this case, for a later moment t_3, in the case of a linear variation, we can write relationships of the form::

$$A[k,i,j](t_3) = at_3 + b \tag{2}$$

Where, based on the first data, we can determine that

$$a = \frac{A[k,i,j](t_2) - A[k,i,j](t_1)}{t_2 - t_1} \tag{3}$$

respectively

$$b = \frac{-t_1 A[k,i,j](t_2) + t_2 A[k,i,j](t_1)}{t_2 - t_1} \tag{5}$$

Through this process, we were able to achieve good results in comparison with the photographers offered by specialized services. In the case of the present study between the first photograms we had a difference of 3-4 years and for the last photogram considered as witness, the time interval was half the time between the first two images.

Thus, this procedure works relatively well for photographic surveys of the forest bodies taken in 2005 and 2009, on the basis of which we can predict with sufficient precision the spectrum for 2010 and 2011.

2.4.1.2 Nonlinear mathematical models used in studying the reflection spectrum

The method of interpolation using neural networks is not new, being a classic interpolation method. This process is based on the construction of matrix mathematical models with a number of inputs (for each input parameter being considered such input) and a convenient number of outputs (for each parameter being defined, such output is defined). The structure considered by this mathematical model is quite simple: between the first layer of input sizes (called layer of input neurons) and the last layer - that of the outputs (called the layer of output neurons) can also be inserted intermediate layers .

RBF (Radial Basis Function) and MLP (Multi Layer Percepton), respectively, are the established structures (from the literature).

In this case, using satellite spectrum spectra from the previous 2 or 3 years, we succeed, based on neural RBF neural networks with a flexible structure, having a single layer of neurons, a model that manages to predict predictive errors below 1%. In this case, the degree of correlation obtained between the model and the actual data series.

Table 2.5 Values of correlation coefficients with the data series for the neural network model used in the study of reflection spectra for the Balabanesti forest

Rețeaua neuronală	Blue Channel 2106 Train	Red Channel 2016' Train	Green Channel 2016' Train
1.MLP 10-11-3	0.995474	0.997963	0.991399
2.MLP 10-9-3	**0.997298**	**0.998506**	**0.992571**
3.MLP 10-5-3	0.995869	0.997787	0.986805
4.MLP 10-11-3	0.997279	0.998302	0.995006
5.MLP 10-12-3	0.997367	0.998160	0.992989

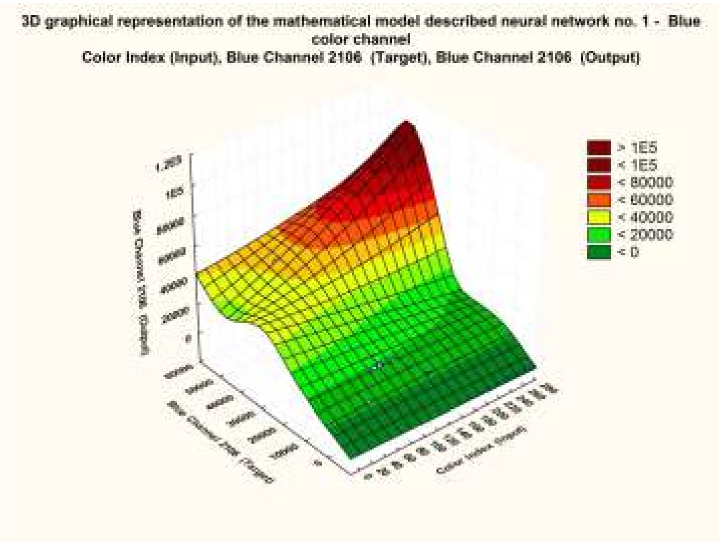


Fig. 2.9 - The result of the model based on the use of neural networks, in which the two axes are the intensity (color indexes) for the blue color channel and the intensity for each index in part and on the vertical is represented the result obtained - the color index resulting from the model

2.4.1.3 Methods used to study color distributions

In this sense, we built an algorithm and then a program that initially builds a distribution in the representative RGB stitch with the different colors of the studied photo, and then, using the k-mens cluster method, it is possible to separate the groups, identify the distribution of Colors and calculates the area of each color. The color group that it takes into account is a variable that the user determines. Considering the finite and small number of compositions found in each of the 4 forest areas, we ran for all forest bodies considered program under the same conditions, assuming a number of 6 color groups (Figure 2.10).

The method has been applied in all four cases, and we have found good correlation of evolution with the variation in the composition of forests studied.

Calculated and actual densities differ as approximately 10% and in terms of compositional variation over time, we also have good results here.

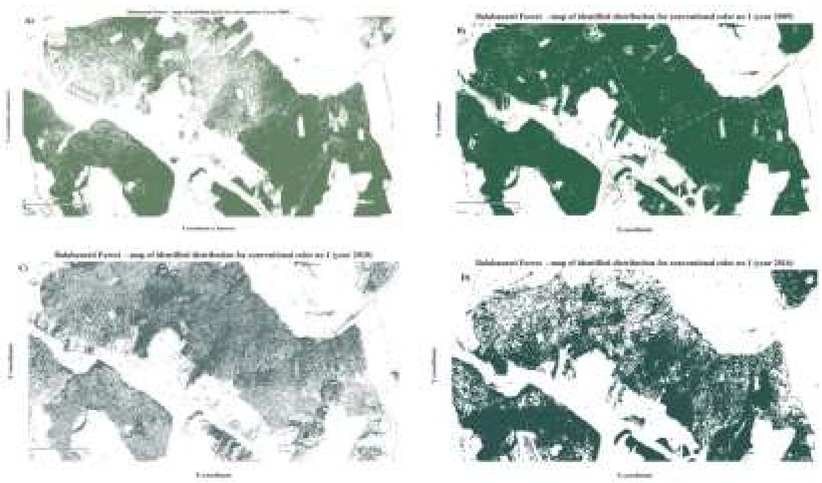


Fig. 2.10 – Color distribution over time - color of group 1 - Bălăbăneşti forest (2005 - 2016)

2.4.1.4 Geometric methods used to study the outline of wooded areas

Fractal dimension is a real number between the topological dimension of the object and the size of the space in which it is defined in literature .

Naturally, considering a forest as a photogram, it can be assimilated to a fractal. By calculating the number of dimensional objects with radius ℓ that can cover the contour L of the forest whose surface we call the size of the fractal corresponding to the number given by the relation

$$d = \lim \frac{\log(N)}{\log(1/\ell)} \quad (6)$$

In this sense, we were able to use both the MATLAB and Fiji programs - Image J that included a fractal calculus unit.

Fig. 2.12 – Fractal related to the image of the Bălăbăneşti forest (2005)

This method has been systematically applied and studied and its effectiveness has been limited.

2.5 Conclusions

In these chapters I have reviewed the main studied forest bodies (they are actually more than 8 wooded elements) and we also reviewed the main 4 methods of analysis applied in this study.

In the same way we reviewed the main 4 study methods used in monitoring and assessing the health of the wooded areas.

CHAPTER 3.

RESULTS AND DISCUSSIONS

In this chapter, we will describe only a forest body of the studied ones and we will present in great detail the results of the analyzes and investigations carried out for this body.

3.1 Forest body Bălăbăneşti

The Băbăbăneşti forest body is located in the northern part of Galaţi County, on the border with Vaslui County.

3.1.1 – Spectral reflection analysis by linear methods

Below we will present a case study, carried out on a forest in the county of Galati. This study is part of a larger program, in collaboration with ROMSILVA representatives.

In this study, mm chose a forest body with a rather rapid dynamics. This is relatively common in the South and East due to the large deforestation operations carried out here.

In this sense, photos from this portal were taken from the INSPIRE portal and, based on the application developed in our Department, we were able to perform image analysis for each individual channel.

Fig. 3.1.1.1 Representation of the map of the Bălăbăneşti forest body.

As we have shown in previous papers, we can not obtain interesting and accurate information to study vegetation evolution based on the use of the NDVI (normalized difference vegetation index) [5, 6]. This section describes the use of applications developed within our laboratory to use as a marker a color index based on the use of historical information. The case of Bălăbăneşti forest is discussed, and in figures 3.1.1.2a-d are represented the images obtained in 2005 by separation on color channels.

As described in the second chapter, each photograph in the set of figures 3.1.1.2bd should be analyzed using the MATLAB script developed in the LASAC Laboratory (http://erris.gov.ro/European-Centre-of-Excellenc -1), then analyzing the spectra for each image.

As described in the second chapter, each photograph in the set of figures 3.1.1.2bd should be analyzed using the MATLAB script developed in the LASAC Laboratory (http://erris.gov.ro/European-Centre-of-Excellenc -1), then analyzing the spectra for each image.

In figure 3.1.1.3.a is represented the spectrum of the green channel corresponding to the image Fig. 3.1.1.2.b. In figure 3.1.1.3.b is represented the spectrum of the red channel corresponding to the image Fig. 3.1.12.c.

Fig. 3.1.1.2.a Satellite map of the Balabanesti forest area - year 2005

Fig. 3.1.1.2.b Satellite map of the forest area of Balabanesti - year 2005 - the green spectrum

Fig. 3.1.1.2.c Satellite map of the Bălăbăneşti forest area - year 2005 - red color channel

Fig. 3.1.1.2.d Satellite map of the Bălăbăneşti forest area - year 2005 - blue color channel

Using these obtained spectra for each elementary color a specific histogram - called color index (Fig 3.1.1.3.a, Fig 3.1.1.3.b and Fig 3.1.1.3.c) is obtained.

There is a Gaussian distribution with approximately equal values. We also notice the tendency, especially in the case of the red and green spectrum, of the existence of two local maxima, possibly due to the fact that there are three different species with individual absorption indices for each spectrum.

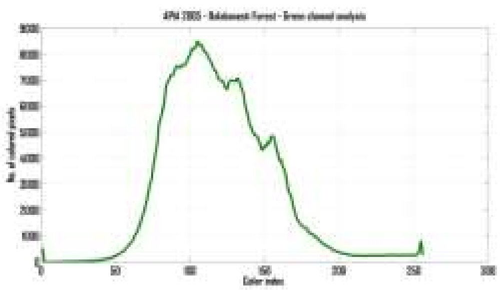


Fig. 3.1.1.3.a Representation of the histogram obtained for the Balabanesti forest - 2005 - the green channel

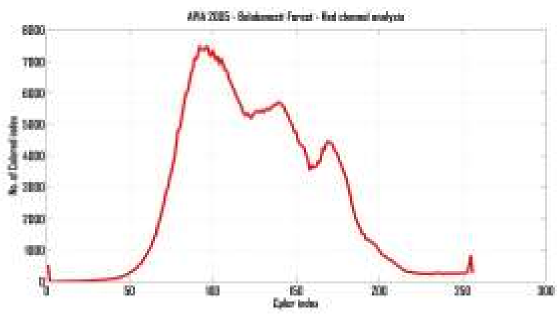


Fig. 3.1.1.3.b Representation of the histogram obtained for the Balabanesti forest - 2005 - the red channel

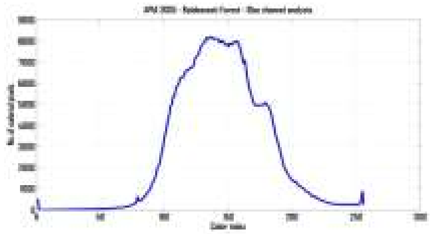


Fig. 3.1.1.3.c Representation of the histogram obtained for the Balabanesti forest - 2005 - the blue channel

In Figures 3.1.1.4 and 3.1.1.5 are represented the images obtained in 2009 and 2010

Fig. 3.1.1.4. Satellite Map of the Bălăbăneşti Forest Area - 2009

Fig. 3.1.5 Satellite Map of the Bălăbăneşti Forest Area – 2010

By comparison with Figures 3.1.1.3 a-c there is a rather obvious change in the histogram forms. What is to be noted is that the area of the small values has increased, which indicates a much reduced reflection phenomenon for both the red channel and the blue one. Movements of histogram maxima to minimum values only mean that the number of pixels colored in black increased, i.e.. The vegetation is lower or the coefficient of reflection is greatly reduced.

Analyzing the histogram transformation mode for each color channel during the 5 years, one can notice that there is a continuous transformation of the spectra, the maximum having a tendency to move to the area of the small values for each color index.

At this point, the question arises as to whether we can build a model and application that can capture this continuity of histogram transformation, i.e., If we can obtain a linear model which, using the data for the years 2005 and 2009, we can present a benchmark for 2010.

The application based on a 1 st model involves iteratively solving a number of 256 equation systems in order to obtain a value corresponding to the evaluation for each index.

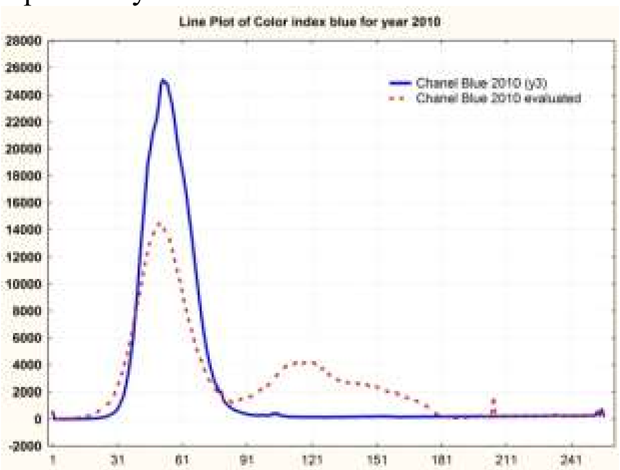


Fig. 3.1.1.6.a Representation of histogram obtained and evaluated histogram for the Bălăbăneşti forest - 2010 - the blue channel

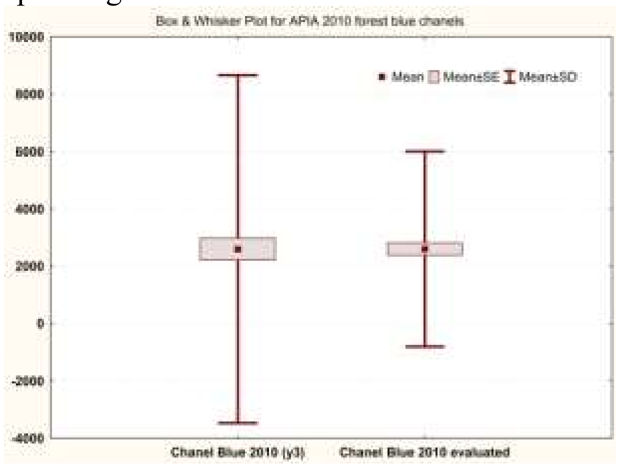


Fig. 3.1.1.6.b Representation of histogram obtained and evaluated histogram

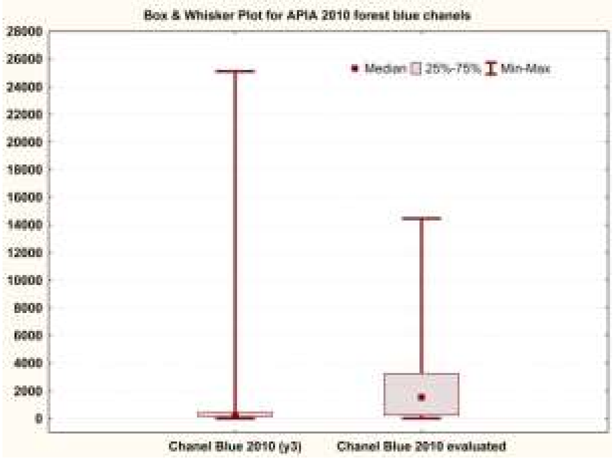


Fig. 3.1.1.6.c Statistical analysis of histogram obtained and evaluated histogram For the Bălăbăneşti forest - 2010 - the blue channel

In Figures 3.1.1.6 a-c are the spectral obtained values on the basis of the model described above and that obtained from the satellite photograms. Also, the average values obtained by the model are presented, and the elements of primary statistics - average value, standard error, mean square, median, etc. are also presented.

The fact that the average value is absolutely comparable, and for the intervals determined by the standard error, the average square error is obtained with lower values, it is explained only on the fact that in reality the Bălăbăneşti forest area contains different species with evolutionary speeds And different modifications, which the 1st order model we built failed to surprise.

In Figures 3.1.1.7a-d are represented the images obtained in 2016 by color channel separation, using the same procedure, and in Figures 3.1.1.8.a-c are presented the spectra obtained for photograms for the year 2016.

Fig. 3.1.7.a Satellite map of Bălăbăneşti forest area - year 2016

Fig. 3.1.7.b Satellite map of the Bălăbăneşti forest area - year 2016 - the green spectrum

Fig. 3.1.7.c Satellite map of the Bălăbăneşti forest area - 2016 - red color channel

Fig. 3.1.7.d Satellite map of the Bălăbăneşti forest area - 2016 - blue color channel

As in previous cases, we applied the same procedure to obtain the spectra on each channel.

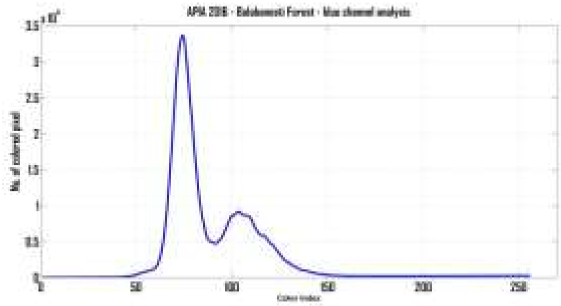


Fig. 3.1.1.8.a Representation of the histogram pattern obtained for the Balabanesti forest - year 2016 - the blue channel

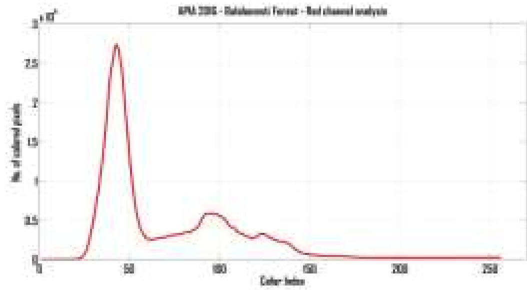


Fig. 3.1.1.8.b Representation of the histogram obtained for the Balabanesti forest - 2016 - the red channel

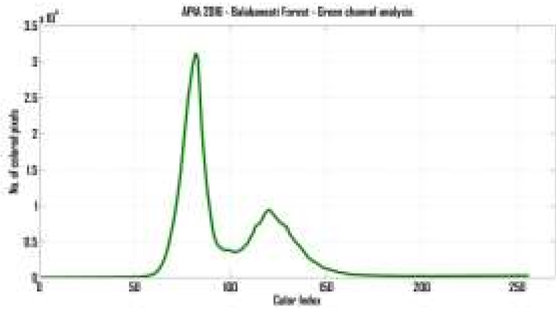


Fig. 3.1.1.8.c Representation of the histogram obtained for the Balabanesti forest - 2016 - the green channel

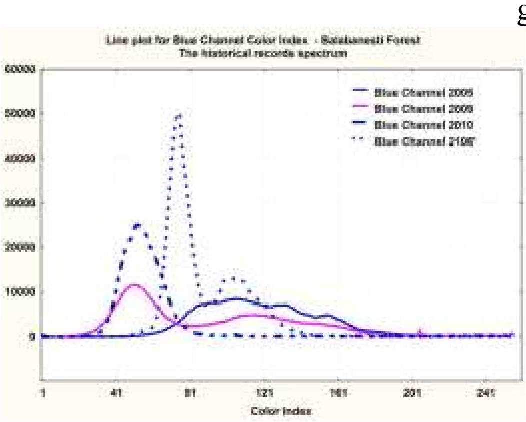


Fig. 3.1.1.9.a Representation of the histogram obtained for the Bălăbăneşti forest - the blue channel

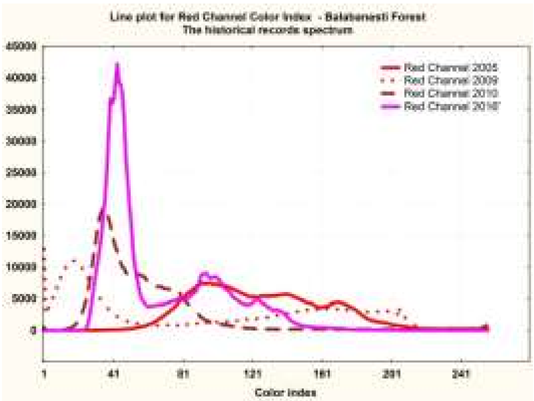


Fig. 3.1.1.9.b Representation of the histogram obtained for the Balabanesti forest - 2016 - the red channel

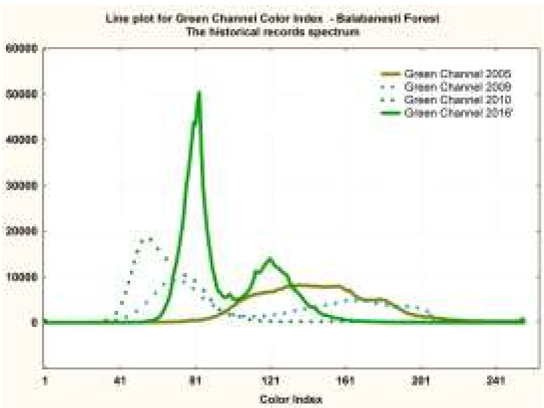


Fig. 3.1.1.9.c Representation of the histogram obtained for the Balabanesti forest - 2016 - the green channel

To make a comparison, we could represent the experimental data obtained so far, and we could see that the order-1 model and even a 2-nd model are not enough to get a good enough prediction.

In this case, algebraically constructed models have proved ineffective (Fig 3.1.1.10). Needless to say, in order to obtain a global model that can make predictions of spectrum and color distribution, literature procedures [10, 11] have proven to be effective.

In fact, the values of the correlation coefficients between the different series of data clearly show a rather pronounced decora- tion between 2016 and the previous data series.

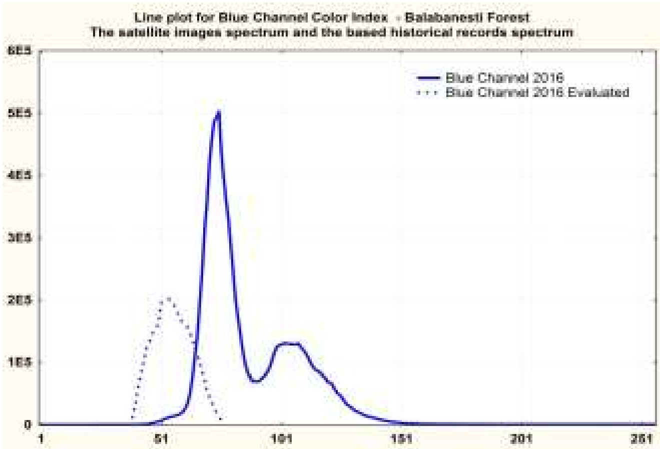


Fig. 3.1.1.10 Representation of the histogram obtained for the Bălăbăneşti forest - 2016 - the blue channel, based on a model of the 2nd order

Table 3.1 - the values of the correlation coefficients between the data series of the blue channel

	Means	Blue Channel 2005	Blue Channel 2009	Blue Channel 2010	Blue Channel 2106 - s	Blue Channel 2016 Evaluated
Blue Channel 2005	**2578.152**	**1.000000**	**0.237125**	**-0.249949**	**0.388259**	**-0.498926**
Blue Channel 2009	**2594.746**	**0.237125**	**1.000000**	**0.842996**	**0.156627**	**0.599268**
Blue Channel 2010	**2594.746**	**-0.249949**	**0.842996**	**1.000000**	**0.054679**	**0.934816**
Blue Channel 2106 - s	**4288.213**	**0.388259**	**0.156627**	**0.054679**	**1.000000**	**0.004407**
Blue Channel 2016 Evaluated	**2559.899**	**-0.498926**	**0.599268**	**0.934816**	**0.004407**	**1.000000**

Table 3.2 - Correlation coefficient values between red-line data series

	Means	Red Channel 2005	Red Channel 2009	Red Channel 2010	Red Channel 2016'	Red Channel 2016 Evaluated
Red Channel 2005	**2578.152**	**1.000000**	**-0.234213**	**-0.288609**	**-0.052433**	**-0.057563**
Red Channel 2009	**2594.746**	**-0.234213**	**1.000000**	**0.039112**	**-0.092700**	**-0.518077**
Red Channel 2010	**2594.746**	**-0.288609**	**0.039112**	**1.000000**	**0.743648**	**0.832017**
Red Channel 2016'	**4288.213**	**-0.052433**	**-0.092700**	**0.743648**	**1.000000**	**0.695174**
Red Channel 2016 Evaluated	**2559.899**	**-0.057563**	**-0.518077**	**0.832017**	**0.695174**	**1.000000**

Table 3.3 - Correlation coefficient values between the green channel data series

	Means	Green Channel 2005	Green Channel 2009	Green Channel 2010	Green Channel 2016'
Green Channel 2005	2578.152	**1.000000**	**0.154052**	**-0.367407**	**0.050715**
Green Channel 2009	2594.746	**0.154052**	**1.000000**	**0.618560**	**0.485016**
Green Channel 2010	2594.746	**-0.367407**	**0.618560**	**1.000000**	**0.302148**
Green Channel 2016'	4288.213	**0.050715**	**0.485016**	**0.302148**	**1.000000**

3.1.2 – Reflection analysis by non-linear methods

In this way, Neural Networks type MLP and RBF were built. For this purpose, a total of 10 ANN neural networks were built and trained, in a process where 10% of the records were used for validation. Next we present the results and selection mode for the top 5 best mathematical models. Table 3.4 shows the characteristics of the neural networks built with the best results. The optimization criterion was Sum of Errors (SOS) for all.

Table 3.4 - values of the correlation coefficients between the green channel data series

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error
1	**MLP 9-12-3**	0.996281	0.995058	0.993973	0.000408	0.000560	0.000245
2	**MLP 9-9-3**	0.998359	0.998389	0.995732	0.000169	0.000200	0.000254
3	**MLP 9-13-3**	0.997225	0.997152	0.996439	0.000276	0.000287	0.000122
4	**MLP 9-10-3**	0.996362	0.994023	0.992233	0.000374	0.000593	0.000364
5	**MLP 9-11-3**	0.997652	0.997609	0.992730	0.000266	0.000246	0.000312

In Figures 3.1.1.11.a-c the values obtained after the training and validation process for the neuronal retina no. 1. There is a good performance in training (over 99%) and small errors in training (less than 1 in one error), respectively in testing and validation (both with errors below 1 in a thousand) - Table 3.5.

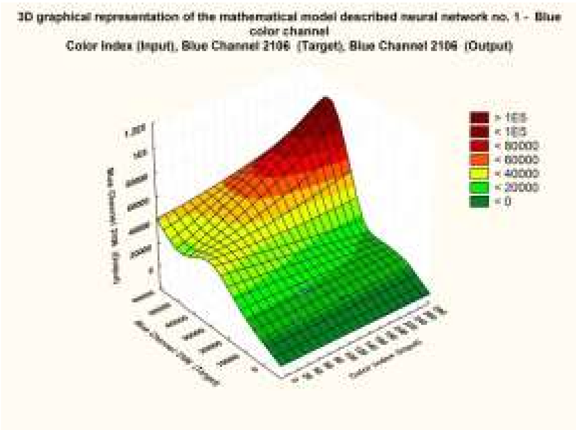


Fig. 3.1.1.11.a Representing the result of the neural network no. 1 - Blue channel according to color index values and values used for driving

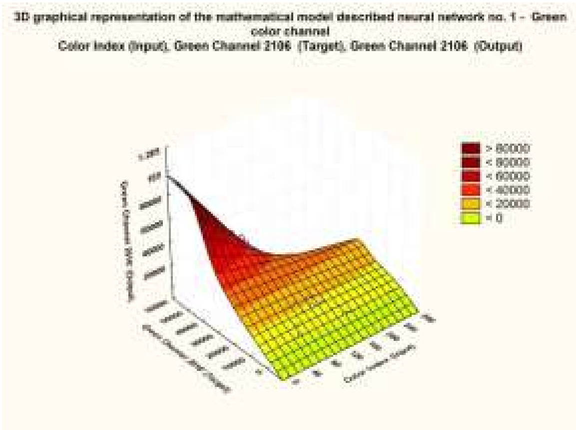


Fig. 3.1.1.11.b Representing the result of the neural network no. 1 - Green channel according to color index values and values used for driving

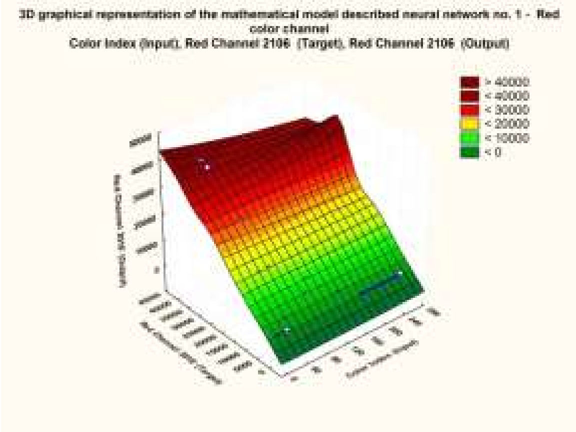


Fig. 3.1.1.11.c Representing the result of the neural network no. 1 - Red channel according to color index values and values used for driving

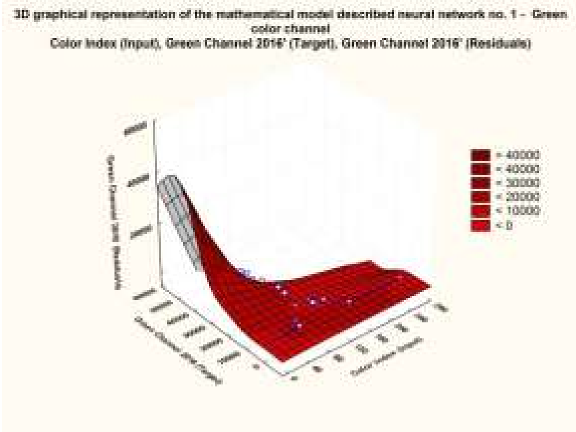


Fig. 3.1.1.11.d Representation of residual values of the neural network no. 1-channel green depending on the color index values and the values used for the drive

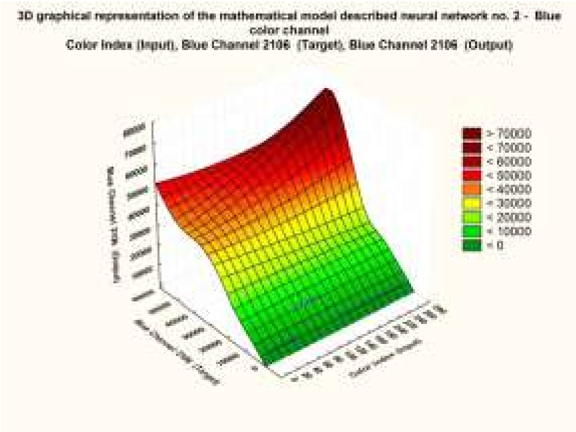


Fig. 3.1.1.12.a Representing the result of the neural network no. 2. The blue channel according to the color index values and the values used for the drive

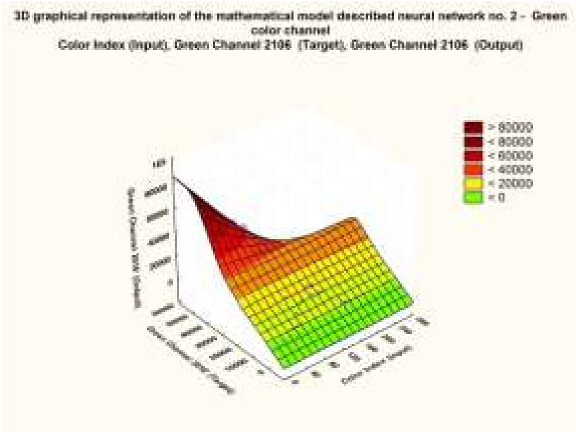


Fig. 3.1.1.12.b Representing the result of the neural network no. 2. The green channel according to the color index values and the values used for the drive

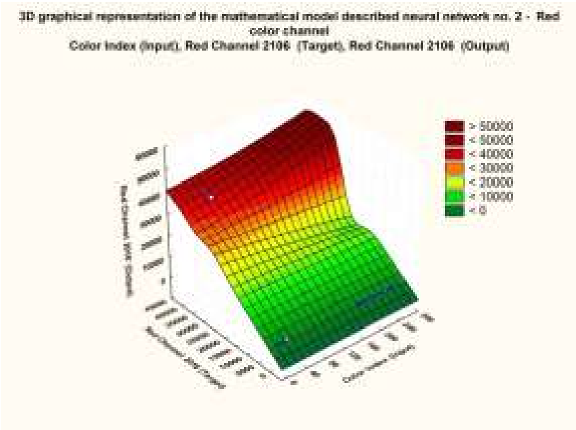


Fig. 3.1.1.12.c Representing the result of the neural network no. 2. The red channel according to the color index values and the values used for the drive

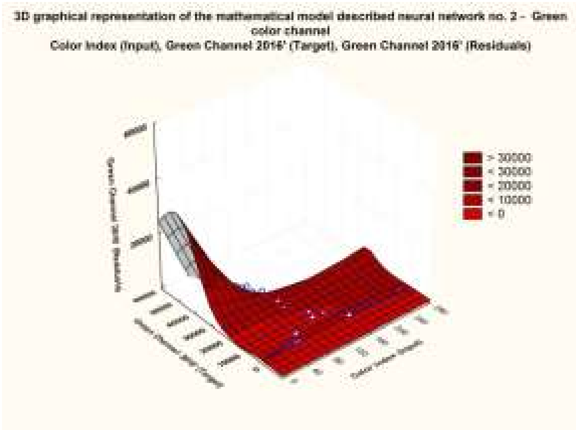


Fig. 3.1.1.12.d Representation of residual values of the neural network no. 2-channel green depending on the color index values and the values used for the drive

In Figures 3.1.1.12.a-c the values obtained after the training and validation process for the neuronal retina no. 2. It is also noticeable for this neural network a good performance in training (over 99%) even better than the network no. 1. Low drive errors (less than 1 in one error), respectively testing and validation (both with errors below 1 in a thousand) - see Table 3.5, with even better performance than previous network.

Table 3.5 - Correlation coefficient values between constructed models and 2016 data series used for training

Net. name	Blue Channel 2106 Train	Red Channel 2016 Train	Green Channel 2016 Train
1.MLP 10-11-3	**0.995474**	**0.997963**	**0.991399**
2.MLP 10-9-3	**0.997298**	**0.998506**	**0.992571**
3.MLP 10-5-3	**0.995869**	**0.997787**	**0.986805**
4.MLP 10-11-3	**0.997279**	**0.998302**	**0.995006**
5.MLP 10-12-3	**0.997367**	**0.998160**	**0.992989**

All these results show that nonlinear mathematical models can be obtained that can accurately identify and construct the histograms for each color channel for this forest over the time span.

This aspect is certainly a novelty issue - the use of nonlinear models in constructing the behavior of a reflection spectrum on the three fundamental channels.

3.1.3 Chromatic analysis and color distribution method

Using the method described in the second chapter, sub-paragraph 2, developed programs developed within the LASAC Laboratory to determine the number of color shades and identify the dynamics of these color sets. This could be a way of assessing the health of a forest.

Fig. 3.1.2.1. Representing initially defined pitch positions to define the list of base colors that will then be searched in all the photos in the set.

In this case, the algorithm, as described in Appendix 2 of this thesis, aligns the photos on the same area, and, based on a predefined list of positions, builds a list of basic colors that will then be searched in all the photos of the studied set.

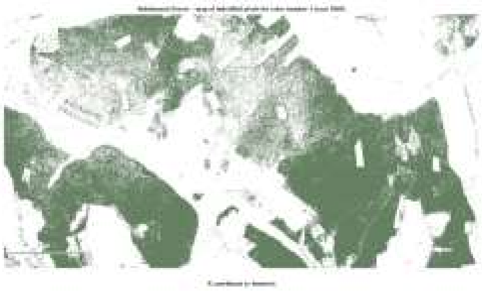


Fig. 3.1.2.2.a Representing the result obtained by selecting the color distribution of area 1 from the 2005 color photograph

Fig. 3.1.2.2.b Representing the result obtained by selecting the color distribution in area 1 from the 2009 photogram

Fig. 3.1.2.2.c Representing the result obtained by selecting the color distribution in area 1 from the 2010 photogram

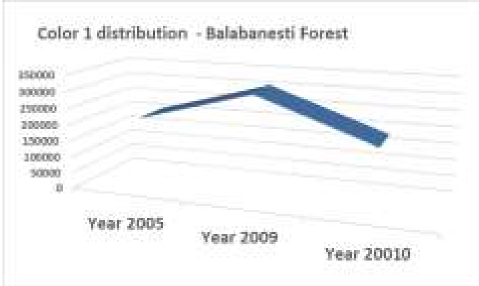


Fig. 3.1.2.2.d Representation of the obtained result for color distribution in reference zone 1

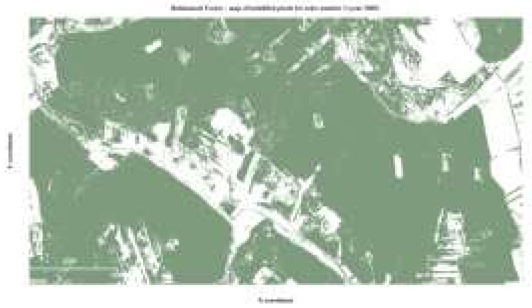


Fig. 3.1.2.3.a Representing the result obtained by selecting the color distribution in area 2 from the 2005 color photograph

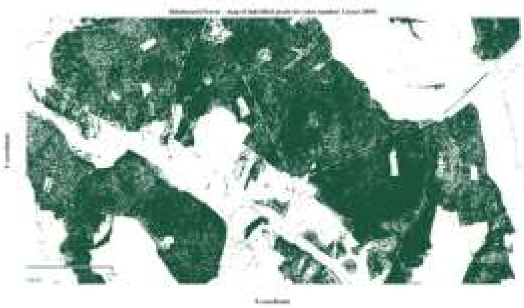


Fig. 3.1.2.3.b Representing the result obtained by selecting the color distribution in area 2 from the 2009 color photograph

Fig. 3.1.2.3.c Representing the result obtained by selecting the color distribution in area 2 from the 2010 color photograph

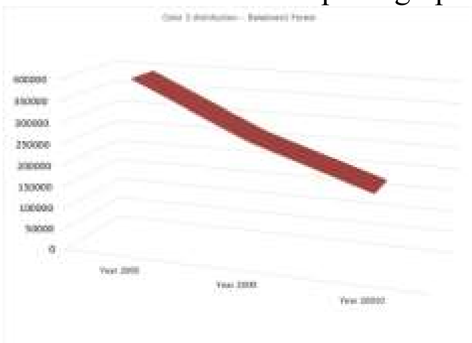


Fig. 3.1.2.2.d Representation of the obtained result for color distribution in reference zone 2

Table 3.6 - Bălăbăneşti ecosystem structure

Nr. crt.	Zona de interes	rata recoltate (mc/an/ha)	Consistenta	Desime (nr.arbori/ha)	Varsta medie (ani)	Volum mediu m.c./ha	Crestere medie m.c./an/ha
0	1	2'	3	4	5	6	7
3	Balabanesti (GL,VS) -2005	2	0.830	975.00	37	121.000	5.200
4	Balabanesti (GL,VS) -2006	2.5	0.781	916.98	37	113.800	4.891
5	Balabanesti (GL,VS) -2007	2	0.730	857.43	37	106.409	4.573
6	Balabanesti (GL,VS) -2008	2.5	0.685	804.47	37	99.836	4.290
7	Balabanesti (GL,VS) -2009	2	0.638	749.75	37	93.046	3.999
8	Balabanesti (GL,VS) -2010	1	0.597	701.41	37	87.047	3.741

Based on the fact that for this forest body, the composition is based on a limited set of tree species, we ran the application iteratively, considering the satellite photograms in 2005, 2009 and 2010 respectively.

Next, we present the results obtained when the base color number is built on 6 reference areas.

Running was done on a graphics station and, due to the large number of iterations, the running time is quite long.

For the first selected area, the results are presented in Figures 3.1.2.2a-d. There is a relative increase in the number of pixels, which is transposed by increasing surface coverage over the period 2005-2009, followed by a decrease for this distribution. What is important to emphasize is that in the 2010 image (Figure 3.1.2.2c), removal areas can be identified across the surface, not only at the edges, which means that technological processes have been harvested.

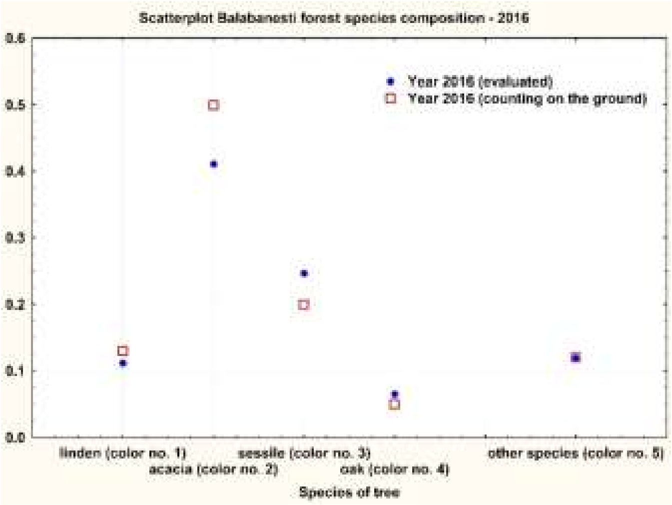


Fig. 3.1.2.10. Representation of the result obtained for conventional color distributions following field identification

For the second selected area, the results are presented in Figures 3.1.2.3a-d. There is a steady decrease in the number of pixels associated with what is transposed by the constant decrease in surface coverage over the period 2005-2010. What is important to emphasize is that in all images we can identify areas of sight, which means harvesting / cutting across the entire mass of forest.

We will briefly present the results obtained by this method for the whole study period between 2005-2016.

Table 3.6 presents field assessments for years for this forest body.

The encouraging results allowed us to continue this analysis for the other forest bodies as well.

3.1.4 For the geometric analysis of the fractal dimension

A fractal analysis was made for the Bălăbăneşti forest. The method was the Box-Count method (the method being found in the literature and described in detail in Chapter 2).

Figures 3.1.3.1a, 3.1.3.1b and 3.1.3.1c respectively represent the results of fractal geometric analysis for determining the fractal dimension of the forested area in the Bălăbăneşti area. The program used was the Fiji-Imago J program and the protocol used was extensively described in Chapter 2. The classical method used in literature - the Box-Count method has obtained histograms of the number of dimensional domains that cover the contour of the area image studied. In Figures 3.1.3.1a, 3.1.3.1b and 3.1.3.1c respectively are the logarithmic values of these numbers identified according to the logarithm of the size of the considered domain. From the graph gradient, the value of the fractal dimension is obtained, as defined. There is an increase of this value by about 2.66%.

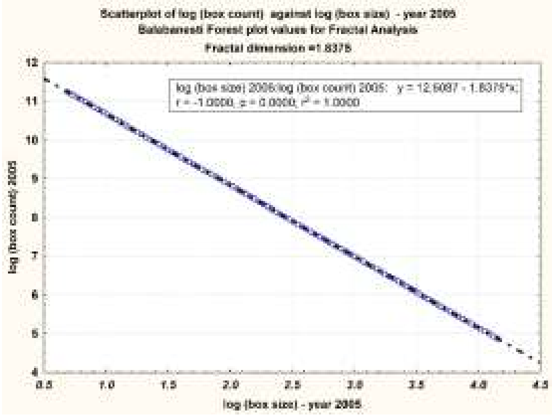


Fig. 3.1.3.1a – Bălăbăneşti Forest - representation of the logarithm of the number of blocks counted according to the size of the selected block - for the determination of the fractal dimension (2005)

What should be noted, in correlation with the other types of analysis, is that the wooded area from Băbăbăneşti suffered a slight reduction of the number of large crown-sized trees inside the area (the reflection spectrum suggests this) and the number of Small elements increased, as suggested by the geometric analysis described above.

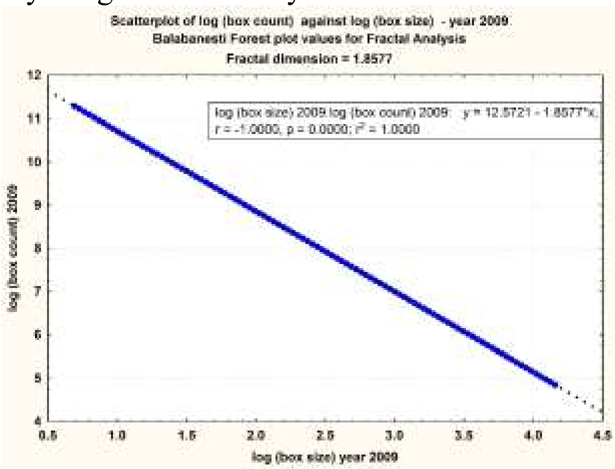


Fig. 3.1.3.1b – Bălăbăneşti Forest - representation of the logarithm of the number of blocks counted according to the size of the selected block - to determine the gradient dimension (2009)

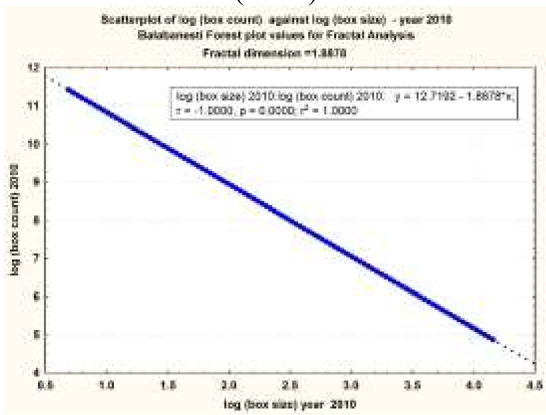


Fig. 3.1.3.1c – Bălăbăneşti Forest - representation of the logarithm of the number of blocks counted according to the size of the selected block - to determine the gradient dimension (2010)

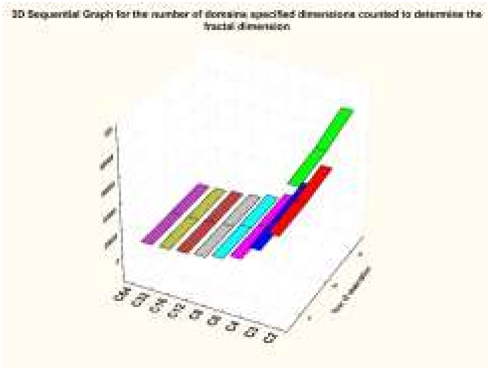


Fig. 3.1.3.2 – Bălăbăneşti Forest - representation of the histograms of the number of blocks counted according to the size of the block considered - for the determination of the fractal dimension

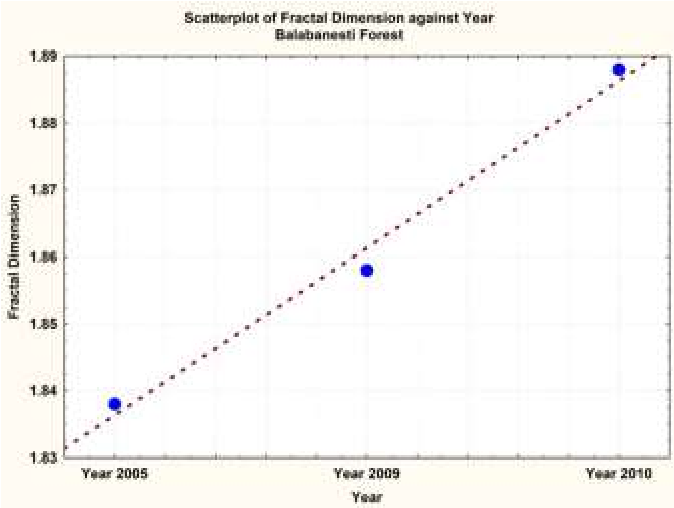


Fig. 3.1.3.3 – Bălăbăneşti Forest - representing the variation of the fractal dimension according to the studied year

CHAPTER 4.
MATHEMATICAL MODELS OF OPTIMIZATION THE EVOLUTION OF THE FOUNTAINS

In this chapter we will describe extensively the studied forests and present the results of the analyzes and investigations carried out for Independenta - Hanu Conachi Forest Body to expose our study method.

4.1 The system of plots in the forest body Independenta - Hanu Conachi

Study Locations

The study sites are all located in southeastern Romania, on publicly-owned forested land in the eastern part of Galati County (Fig. 4.1). Galati County is the main economic and industrial centre of southeastern Romania, and is situated in the eastern part the state, on the convergence of the Siret and Prut rivers with the Danube. The Galati region has an area of 4466 square kilometres, which is about 1.9% of the country surface.

Fig. 1. The location of the forest land study area

Two different parts belonging to the area of forest flora of the Covurlui Plateau have been selected for this study. The zone is characterised by a continental weather, with cold winters and long, dry summers.

The areas were divided into different parts according to the predominant species of trees, in order to produce homogenous sectors in terms of tree age and species. A particular geographical feature of this region is that the Prut and Siret valleys are oriented in such a way as to function as genuine couloirs that lead towards the centre of the county air masses pending from the steppe.

Although some sectors are located on hilly terrain, all the studied areas are located on flat land with a slope almost always less than 5%. Since the land shape is such that the majority of large watercourses drain southwards, and because of the way the air moves across the seasons, producing small quantities of rains that make up the additional core of hydrographic network, Galati County is located in what is the dry area of the country.

The weather conditions described above were shaped and evolved soils in the area, the terraces, with the parent material loess and loess deposits and fluvial deposits in the meadow and river-lake.

Experimental design

The study was led on 356 sectors of forest. This paper presents the outcomes of the plots with 100% species of white poplar. Measurements were made every year nearby the end of the growing period (September–October). In each experimental plot, an area equal to the surface unit was nominated, and measurements were carried out. The following parameters were taken into account: current age, composition, consistency, average density, allocation unit of surface area, volume of harvest.

Recording of the field measurements and methods of analysis

For authenticating the results, two sets of measurements were led for each plot. To determine the production volume, techniques described in the literature were applied.
The numerical analysis procedures engaged are those found in the specialised literature, by resorting to statistical analysis software (StatSoft Statistics) or specific calculation procedures (MATLAB).
The used methods are:

1. Method of field records: this procedure includes a standard set of measurements conducted for each section of the studied area. The sectors' limits were shaped so as to be similar in terms of composition, consistency and the current age of the trees. The reason behind this division was primarily technical.

Field interpretations were used to fetch the raw database records. This was followed by the procedures for checking and validating the sizes. In total, entirely of the 365 sectors were monitored between 2010 and 2015, and thus a reliable database was obtained. In this article the statistics for 36 parcels containing only white poplar, found in the conditions described above, have been used.

The following factors were evaluated for each monitored sector: current age, growth rate, composition — the concentration of the various species of trees per unit area, consistency and density — the number of copies per unit of surface area, the volume of the timber produced per unit of surface.

2. Methods of statistical analysis: methods for analysis of variance (ANOVA) of multifactorial type were used. Similarly, statistical analysis methods and multi-variety type, such as PCA, were also used.

The value of the confidence coefficient which characterizes is considered to be equal to 0.05 (acceptable value in most studies). The used programs are recognized and used worldwide (StatSoft Statistica X and MATLAB).

The numerous correlation coefficients between the measured magnitudes were assessed.

3. Numerical procedures: in the present study, we have used several techniques for numerical analysis and interpolation. For interpolation, as a rule there were used primarily software programs that contain procedures and predefined interpolation methods. Thus, in all studied cases the interpolation approaches were used with predefined type: (a) quadratic; (b) distance weighted least square interpolation method; (c) non-linear interpolation by considering that the neural network; and (d) multi-dimensional specific polynomial interpolation method with mixed terms. The general condition for optimizing interpolation was considered to be the Sum of Square Errors (SS). As is known, this criterion needs that the sum of squares of deviations to be the minimum for optimal interpolation.

3.a) For quadratic interpolation type we could highlight the dynamic character of the identified models. At the same time we have emphasized the limited character of these second-order mathematical models.

3,b) For polynomial predefined interpolation methods in the statistical analysis they were also able to put out the dynamic character of the identified models. At the same time it showed the quality of interpolations to be superior to those obtained by second-order mathematical models. For these representations it was revealed yet about and limited character of these models.

3.c) methods of interpolation and fitting by using neural networks are very effective approaches used in recent years. Inevitably for high performance, Radial Basis Function (RBF) and Multilayer Perceptron (MLP) neural network type have been chosen. These structures were shown to be efficient, especially when 3 layers of neurons were used. For the present study, a total of 20 different neural network structures of RBF and of MLP type were built, of which the best six were retained.

3.d) interpolation method by analytical polynomial function with mixed terms. This method is less found in the literature, because of the complexity and huge volume of calculations. The advantage of the method is that it allows increased degree polynomial interpolation, thus avoiding the appearance of the Runge effect. The Runge effect causes oscillations obtained from fictitious functions, and it has negative concerns on the implications resulting from the use of these models. This specific method was used successfully in systems that have significant changes in relation to certain state parameters,.

Results and Discussions

The first step in data analysis was the computation of the correlation coefficients for the monitored magnitudes. The coefficients of correlation are presented in Table 4.2.

Table 4.2. The coefficients of correlation

	Current age (years)	Consistence (percent)	Volume (m^3/ha)	Growth (m^3/year/ha)	Extracted volume (m^3 production unit)	Density (no. specimens / ha)
Current age (years)	1.0000	.3422	**.9136**	.4739	.2071	-.1657
	(p= ---)	(p=.000)	(p=0.00)	(p=.000)	(p=.002)	(p=.015)
Consistence		1.0000	**.3398**	.4751	.0325	**.8129**
		(p= ---)	(p=.000)	(p=.000)	(p=.636)	(p=0.00)
Volume (cubic m/ha)			1.0000	.4416	.1649	-.1768
			(p= ---)	(p=.000)	(p=.015)	(p=.009)
Growth (c. m./year/ha)					.0289	.2122
					(p=.673)	(p=.002)
Extracted volume (c.m./ production unit)					1.0000	-.0964
					(p= ---)	(p=.159)
Density (no. specimens /ha)						1.0000
						(p= ---)

The primary observation relates to the coefficient of correlation between the volume of production per unit area, and the current age of the manor. The value of this coefficient specifies the strong link between the age of the trees and the volumes recorded. It should be noted that the registered volume of production for the unit of surface is actually only the incorporation result of the value of the growth rate over time.

Necessarily, there have been inspected and investigated how the growth rate varied depending on the current age. The outcomes of this analysis are shown in Fig. 2. In contrast to other papers from the literature in which only the interpolation quality by mixing different types of models is followed, in the present paper a single form of mathematical models has been used.

The fact that neighbouring forest sectors with the same declared soil structure and the same climatic conditions, indicated different growth rates with different coefficients is very interesting. This observation prompted a univariate test of significance for Growth, i.e. an ANOVA statistical analysis, with a very interesting assumption: the consistence, i.e. the equivalent area covered by the tree crown per surface unit, shows an important role. The ANOVA analysis amounts are shown in Table 4.3, and represents the first model.

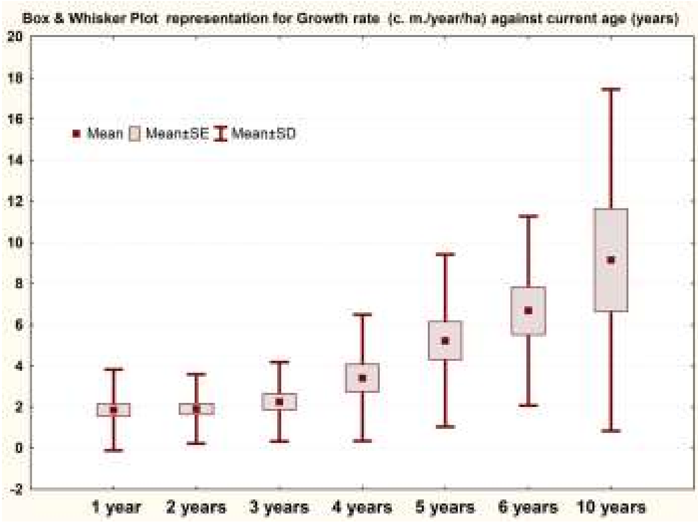


Fig. 4.2. The growth rate variation depending on current age

Table 4.3. The univariate test of significance analysis coefficients

	SS	Degrees of Freedom	MS	F	p
Intercept	2.383	1	2.3832	0.26235	0.609043
Current age (years)	307.172	1	307.1720	33.81447	0.000000
Consistence	336.682	1	336.6817	37.06299	0.000000
Error	1934.901	213	9.0840		

From Table 4.3 it can be realized that both parameters — current age and the consistence of the studied plantations – have a clear influence on the rate of growth ($p < 0.001$). One such theme is less studied in the literature and therefore the analysis of the effect of the consistence on the growth rate is valuable issue in this respect.

Table 4.4 presents the test characteristics for the proposed model in Table 3 —namely the possibility of explaining the growth rate magnitude on the two monitored parameters — the current age and the consistence. The p coefficient value exposes that this pattern is acceptable and can be used ($p < 0.0001$).

Table 4.4. The test of SS whole Model vs. SS residual (Populus alba database)

	Multiple - R	Multiple - R²	Adjusted - R²	SS - Model	df - Model	MS - Model	SS - Residual	df - Residual	MS - Residual	F	p
Growth rate	0.92473	0.85513	0.83393	234.514	6	39.0857	39.7288	41	0.968995	40.336	0.000

Both magnitudes for quality assessment model, i.e. R-square and Adjusted R-square, and the p coefficient size highlight the quality of this model. Note the size of SS, which represents the sum of squared errors (Table 4.3). However, the ANOVA method is considered to be a distinct case of linear regression, which in turn is a special case of the general linear representation. All the following processes consider the aim to be the sum of a model (fit) and a residual (error) to be minimized. All the next presented representations will be improvements of this model.

The quadratic methodology model represents an progress of the previous linear model. The expression for these models is of the form:

$$F = a_0 + a_1 x + a_2 x^2 + b_0 xy + b_1 y + b_2 y^2 \qquad (1)$$

Where x represents the consistence value and b is the current age magnitude.

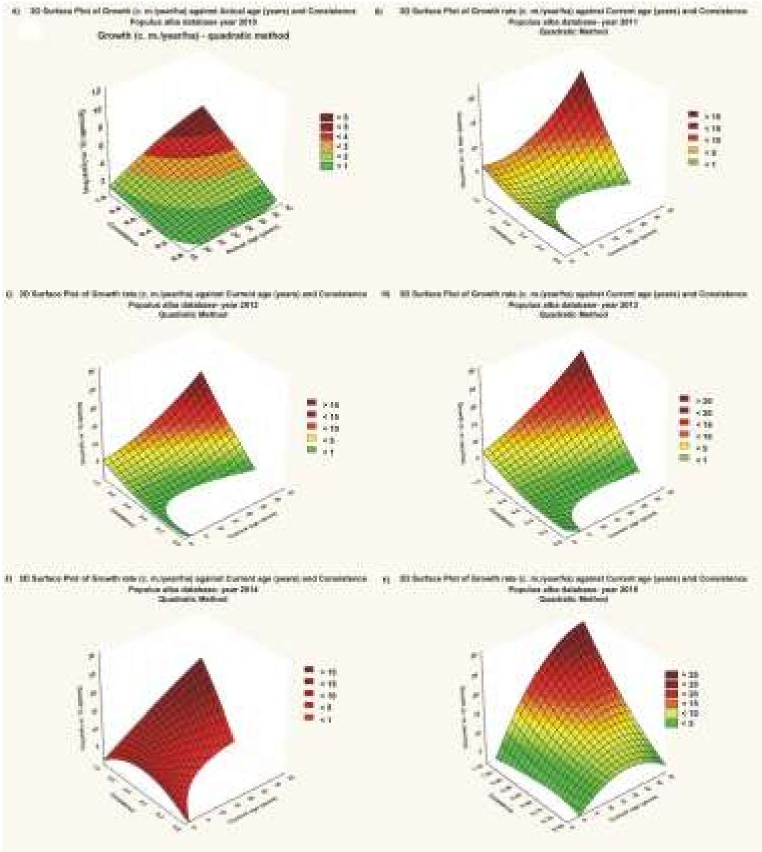


Fig. 4.3. The growth rate models using quadratic interpolation expressions

In figure 4.3 are represented the obtained models for each year of investigation. In this picture the vertical axis represent the growth rate magnitudes, and the horizontal axes are the consistence and the current age. The representations from Fig. 4.3 depicted the models found for the recorded database for each year. Even though these quadratic models are more performant than above (the size for SS being smaller), these representations still have some inadequacies. One deficiency comes from the significant change of the obtained results from one year to another. Thus, if in 2010 the maximum level of growth rate per unit of surface obtained for trees of 30 years old reached a value 10 cubic meters, for the next year the value doubled (Fig. 3b). Another shortage relates to a drastic change in the shape of the represented surface, which corresponds to s significant change in the evolution of production (Fig. 3f).

The distance weighted least squares approach model represents an supplementary improvement of the previous quadratic model (Fig. 4.4). The distance-weighted least squares method fits a curve to the data by using a specific procedure: a second-order polynomial regression is computed for each value on the X variable scale to determine the corresponding

Y value such that the influence of the individual data points on the regression decreases with their distance from the particular X value. Although the distance weighted least squares models are more adequate than quadratic representations, these approaches still have some inadequacies. A major deficiency lies in the high value of the growth rate in the case of a void consistence (Fig. 4.4e).

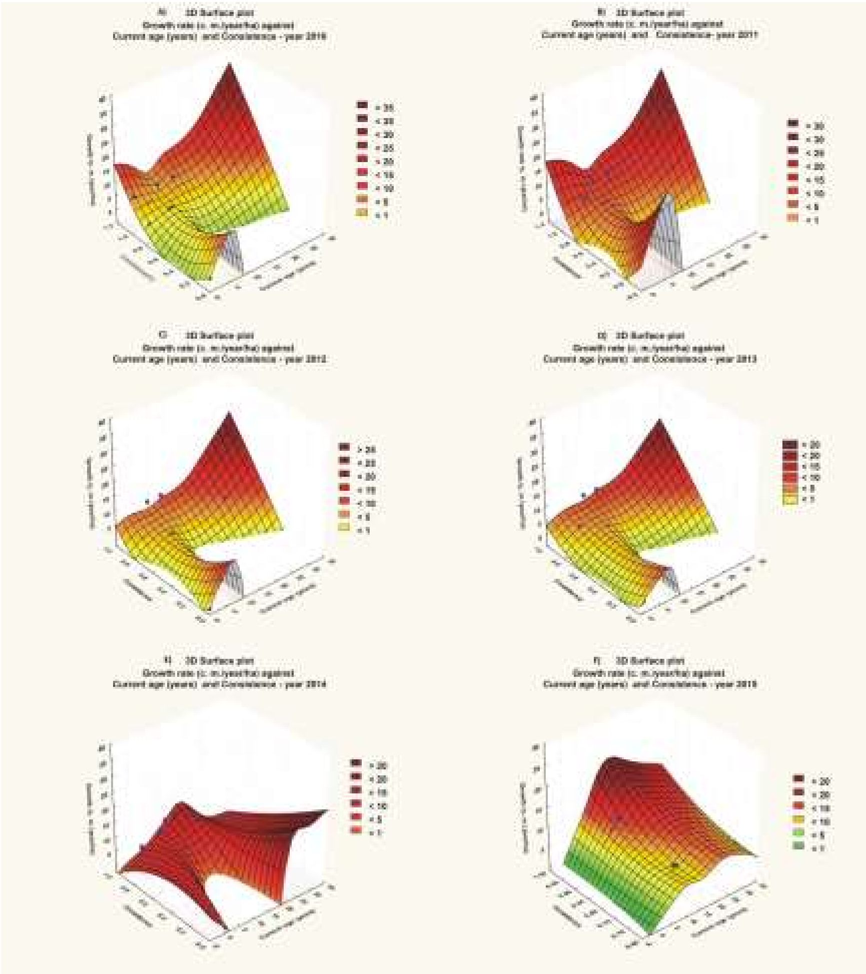


Fig. 4.4. The growth rate models using distance weighted least squares interpolation method

The next type of studied models is based on the usage of neural network (Fig. 4.5). In this case, based on the values of the two monitored parameters, i.e. consistence and current age (considered as input factors), we can obtain assessments of growth rate magnitude, regarded as an output value. These models have better efficiency than previous representations. In this approach it was used the previous obtained outcomes in the interpolation method field. For these models a total number of 20 different RBF and MLP type structures were constructed, and the most performant 6 models were retained. Effectiveness data are shown in Table 4.5.

The ANN structures of RBF and MLP type are recommended for multi-dimensional interpolation of magnitudes that occur in significant variations in the fitting process. Many papers in this field have shown that the use of these structures led to remarkable results. Pursuant to this approach, the data set was used in sampling, for the operation of drill and testing and model authentication, respectively. Sampling was done according to other common works in the literature - i.e. 80% of the data were used for exercise and testing of the networks, and the remaining 20% for the validation of models. On the other hand, these neural networks need databases with very large entries, as each parameter for performance match each structure with the best results (Table 4.5). The important parameters for each network are presented in Table 4.6.

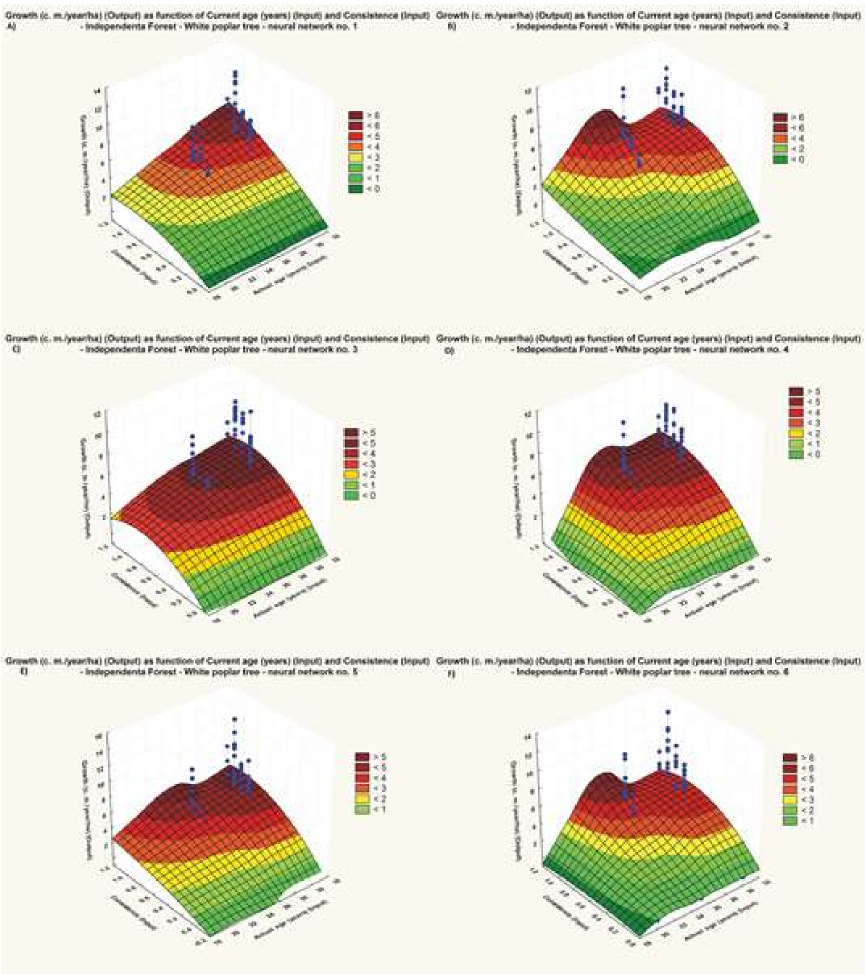


Fig. 4.5. The growth rate evaluation models using neural network interpolation method

In Figure 4.5 are shown the results of the built models. For ease of analysis, the data points were shown for comparison drives. Note that these models offer lower values than the experimental ones (Fig. 4.5a – 4.5f). Even though the training errors are quite small, the final results do not always correspond to the experimental values.

This led us to the idea of building a specific model, to increase the performance of the obtained results up to that point. In this respect, a special technique was used taken from other systems which changes their properties relatively than the change of status factors.

Table 4.5. The neural network interpolation performance

No. crt.	Net. Type	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error
1	RBF	0.617001	0.579831	0.454419	0.029046	0.036605	0.051537
2	RBF	0.719975	0.591009	0.617389	0.021189	0.034348	0.039542
3	MLP	0.659374	0.586917	0.452141	0.024967	0.034581	0.050288
4	RBF	0.693041	0.584725	0.491657	0.022864	0.034798	0.047879
5	MLP	0.654044	0.582093	0.459993	0.025232	0.035040	0.049566
6	MLP	0.717736	0.618197	0.594872	0.021339	0.032467	0.040531

Table 4.6. The neural network structural parameters

No. crt.	Net. Type	Training algorithm	Error function	Hidden activation	Output activation
1	RBF	BFGS 37	SS	Logistic	Exponential
2	RBF	BFGS 73	SS	Logistic	Logistic
3	MLP	BFGS 54	SS	Logistic	Tanh
4	RBF	BFGS 101	SS	Logistic	Logistic
5	MLP	BFGS 57	SS	Logistic	Exponential
6	MLP	BFGS 43	SS	Exponential	Exponential

The multidimensional polynomial with mixed terms models approach represents an improvement of the previous non-linear model. The expression for these models is of the form:

$$F = A_0 + A_1 t + A_2 t^2 + .. + D_0 xt + .. + B_1 x + B_2 x^2 + .. + \\ + C_1 y + C_2 y^2 + E_0 yt + .. \qquad (2)$$

where t represents the current age, x represents the consistence value and y is the current age magnitude. In figure 4.6 are represented the obtained results for SS magnitudes against the polynomial rank of the multidimensional models with mixed terms for each of the considered independent parameter. In this representation, the vertical axis represents the SS magnitude, and the horizontal axis lists the polynomial rank for time series, consistence magnitude and, respectively, for current age. It could be observed that the time series carries no significant improvements. The best results are by the consistence polynomial development series and especially by the current age polynomial expansion series (Fig. 6).

In table 4.7 are presented a series of configurations and the optimal polynomial model – i. e. model no. 6 expressed by the relation (2) and represented in figure 4.7. In this way it can be obtain the finest analytical model for white poplar growth rate evaluation against the state measured parameters.

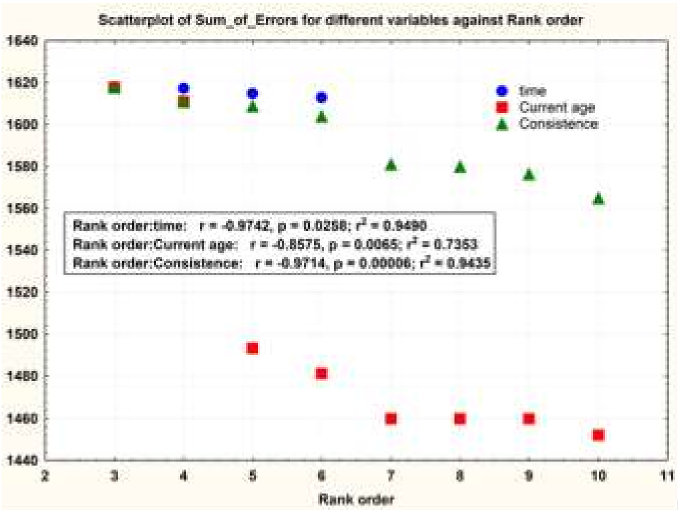


Fig. 4.6. The obtained results for SS magnitudes against the polynomial rank of the multidimensional models for each of the considered independent parameter

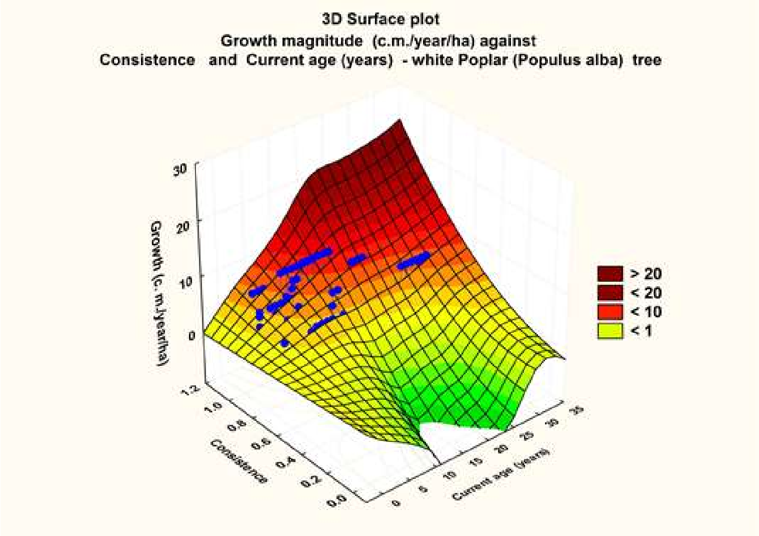


Fig. 4.7. The representation for the optimal multidimensional model with mixed terms configuration

Table 4.7. The multidimensional polynomial configuration for optimal result

No. crt.	Polynomial rank for time series	Polynomial rank for consistence series	Polynomial rank for current age	Polynomial rank for D and E coeff.	SS magnitude
1	7	10	10	5 - 5	1491.943077
2	8	10	10	5 - 5	1498.170268
3	7	10	11	5 - 5	1516.363699
4	7	10	11	5 - 6	1513.405674
5	7	10	11	8 - 6	1474.639669
6	7	10	11	10 - 6	1473.909667
7	7	11	11	9 - 5	1483.962850

Conclusion

This study showed that the least studied factors like consistence and density are the main factors that must be considered in order to obtain high yield in the plots with poplar. The significant influence of these factors resulted in a greater effect on the growth rate and harvest production volume. The analysis was made based on numerous methods, and was performed by comparison. The influence of the environmental gradient has proved to be of secondary importance, and these effects have been neglected.

The problem of use and exploitation of forests is a current issue of worldwide concern. The optimization of costs and maximisation of production purposes are carefully sought nowadays, due to a national demand for preserving forests. We believe that the resolution advanced in this study provides a solution of international interest.

Bibliografie

1. *Academia Republicii Populare Române*, Dicționar Enciclopedic Român, Editura Politică, București, 1962-1966
2. *Aerts R., Chapin F.S.,* 2000. The mineral nutrition of wild plants revisited: a reevaluation of processes and pat- terns. Advances in Ecological Research 30: 1–67. DOI: 10.1016/S0065-2504(08)60016-1..
3. *Alberti G.,* Boscutti F., Pirotti F., Bertacco C., De Simon G., Sigura M., Cazorzi F., Bonfanti P., 2013. A LiDAR- based approach for a multi-purpose characterization of Alpine forests: an Italian case study. iForest - Bio gesciences and Forestry 6: 156-168. DOI: 10.3832/ ifor0876-006.
4. *Anttila P.,*. On the accuracy of treewise attributes obtained by analytical stereoplotter and aerial images. MSc thesis, University of Joensuu, Faculty of Forestry, Joensuu, 36 p. *1998*
5. *Anttila P.,* Assessment of manual and automated methods for updating stand-level forest inventories based on aerial photography. PhD thesis, University of Joensuu, Faculty of Forestry, Joensuu, 42 p. Web: http:// www.metla.fi/dissertationes/df9.pdf. *2005*. Accessed: 2013.
6. Arcangeli C., Klopf M., Hale S.E., Jenkins T.A.R., Hasenauer H., 2013. The uniform height curve method for height–diameter modelling: an application to Sitka spruce in Britain. Forestry 87: 177-186. DOI: 10.1093/ forestry/cpt041.
7. *Balenović I.,* Alberti G., Marjanović H., 2013. Airborne Laser Scanning - the Status and Perspectives for the Ap- plication in the South-East European Forestry. South-east European forestry 4 (2): 59-79. DOI: 10.15177/see- for.13-07.
8. *Balenović I.,* Seletković A., Pernar R., Marjanović H., Vuletić D., Paladinić E., Kolić J., Benko M., 2011. Digital photogrammetry – State of the art and potential for application in forest management in Croatia. South- east European forestry 2 (2): 81-93. DOI: 10.15177/ seefor.11-09.
9. *Badea N. O.* , "Forest Condition Monitoring in Romania" 1990-1996
10. *Badea N. O.* , "Manual privind metodologia de supraveghere pe termen lung a stsrtt eeosistemelor forestiere aflate sub ectiunee potusrii atmosferiee ~i mod ifieari lor elimatiee". 2008
11. *Badea N. O.* „Revista Padurilor nr.3,4" 2010
12. *Popa, I.,* , Diagrame climatice şi indici bioclimatici utilizaţi în silvicultură., În Cheval, S. (ed.) Indici şi metode cantitative utilizate în climatologie. Editura Universităţii din Oradea, pp. 53-59, 2003.
13. *Popa I., Barbu, I., Iacoban, C. ,* Monitoringul intensiv al depunerilor atmosferice în perioada anilor 1997-1998 în 7 ecosisteme forestiere din România, Revista Pădurilor, 4:16-20., 2000
14. *Clinovschi F.*, Dendrologie, Editura Universităţii Suceava, ISBN 973-666-157-1
15. *Măciucă A, Clinovschi F., Tomescu C., Palaghianu C.*, Ecosisteme forestiere, format electronic Editura Universităţii Suceava, ISBN 973-87584-5-9, 2006;
16. *Balenović I.,* Seletković A., Pernar R., Marjanović H., Vuletić D., Benko M., 2012. Comparison of classical terrestrial and photogrammetric method in creating management division. In Pentek T., Poršinsky T., Šporčić M. (eds) ''Forest Engineering - Concern, Knowledge and Accountability in Today's Environment'', 8-12 October
17. *Beldie Al.,* Flora României, Determinator ilustrat al plantelor vasculare, Editura Academiei Republicii Socialiste România, 1977
18. Benavides R., Douglas G.B., Osoro K., Silvopastoralism in New Zealand: review of effects of evergreen and deciduous trees on pasture dynamics. Agroforestry Systems 76: 327-350. DOI: 10.1007/s10457-008-9186-2009.
19. *Benko M.,* Procjena taksacijskih elemenata sastojina na infracrvenim kolornim aerosnimkama [Assessment of stands elements on colour infrared aerial photo- graphs]. Glasnik za šumske pokuse 29: 199-274, 1993.
20. *Benko M., Balenović I., 2011*. Prošlost, sadašnjost i budućnost primjene metoda daljinskih istraživanja pri inventuri šuma u Hrvatskoj [Past, present and future of application of remote sensing methods in Croatian forest inventory]. Šumarski list 135(13): 272-281.

21. *Bohlin J.,* Wallerman J., Fransson J.E.S., Forest variable estimation using photogrammetric matching of digital aerial images in combination with a high-resolution DEM. Scandinavian Journal of Forest Research 27(7): 2012.
22. *Borz S.A.,* DinulicaF., Barda M., Ignea Gh., Ciobanu V.D., PopaB. Time consumption and productivity of skidding Silver fir (Abiesalba Mill.) round wood in reduced accesibility conditions: a case study inwindthrow salvage logging form Romanian Carpathians. Annals of Forest Research56 (2) pag 363-375. (2013)
23. *Coops N.C.,* Hilker T., Wulder M.A., St-Onge B., Newnham G., Siggins A., Trofymow J.T., 2007. Estimating canopy structure of Douglas-fir forest stands from discrete-return LiDAR. Trees 21(3): 295-310. DOI: 10.1007/s00468-006-0119-6.
24. *Davis C.S.*, 2002. Statistical Methods for the Analysis of Repeated Measurements. Springer, New York, 415 p.
25. *Dobre, A*., Raport de Cercetare : Estimarea unor elemente de interes (Briophyta, Caryophylaceae, Araneae, Coleoptere, Herpetofauna) din arii protejate din sudul Dobrogei, Revistă de politică a ştiinţei şi scientometrie, Număr special, 2005.
26. *Dragoi M.,* Popa B.,Blujdea V., Improving communication among stakeholders through ex-post transactional analysis – case study on Romanian forestry, Forest Policy and Economics 13 (2010), pag. 16-23. (2010)
27. Dubrovnik. Forestry Faculty of University Zagreb, 13 p. 692-699. DOI: 10.1080/02827581.2012. 686625. 2012,
28. Eid T., Gobakken T., Næsset E., 2004. Comparing stand inventories for large areas based on photo-interpretation and laser scanning by means of cost-plus-loss analyses. Scandinavian Journal of Forest Research 19(6): 512- 523. DOI: 10.1080/02827580410019463.
29. *Falkowski M.J.,* Smith A.M.S., Hudak A.T., Gessler P.E., Vierling L.A., Crookston N.L., Automated esti-mation of individual conifer tree height and crown diameter via two-dimensional spatial wavelet analysis of lidar data. Canadian Journal of Remote Sensing 32(2): 153-161. DOI: 10.5589/m06-005. 2006.
30. *Ferdinent J.J.,* Padmanaban R.C., Development of a methodology to estimate biomass from tree height using airborne digital image. International Journal of Ad- vanced Remote Sensing and GIS 2(1): 49-58. 2013.
31. *Florin Mingireanu*, Gabriel Murariu, Lucian Georgescu, Ionut Mocanu, Daniel Constantin Improved observation monitoring system using UAV Optoelectronic Techniques and Environemntal Monitoring, ISSN 20066-8651, pag.168-175, 2011,
32. *Gagnon P.A.,* Agnard J.P., Nolette C., Evaluation of a soft-copy photogrammetry system for tree-plot measurements. Canadian Journal of Remote Sensing 23(9): 1781-1785. DOI: 10.1139/x93-225. 1993.
33. *Gruber M.,* Ponticellia M., Bernögger S., Leberl L., Ultracamx, the Large Format Digital Aerial Camera System by Vexcel Imaging/Microsoft. In: Chen J., Jiang J., Baudoin A. (eds.). Proceedings of ISPRS XXIst Con- gress “Silk Road for Information from Imagery”, 3-11, 2008.
34. *Iancu, I,* Iancu V, Mehedinţi V, Niţu C., Pătrăşcoiu N. Mică enciclopedie a pădurii, Editura Ştiinţifică şi Enciclopedică, Bucureşti, 1982
35. ***Hahuie V.,*** E. Dănilă, A. Dănilă, L. Georgescu, Annals of “Dunarea de Jos” University of Galati, Mathematics, Physics, Theoretical Mechanics, Fascicle II Year VII, No. 1, 26-32,(2015)
36. **Hahuie Valentin**, Lucian Georgescu, Catalina Iticescu, Gabriel Murariu, Investigation on Satellitar and UAV Cadastral Results. Case Study - Independenta Forest Areas, Annals of “Dunarea de Jos” University of Galati, Mathematics, Physics, Theoretical Mechanics, Fascicle II Year VII, No. 1, 26-32,(2015)
37. Heurich M., 2008. Automatic recognition and measurement of single trees based on data from airborne laser scanning over the richly structured natural forests of the Bavarian Forest National Park. Forest Ecology and Management 255(7): 2416-2433. DOI: 10.1016/ j.foreco. 2008.01.022.
38. Hill T., Lewicki P., 2007. STATISTICS: Methods and Applications. StatSoft, Tulsa, OK.
39. Höhle J., Höhle M., 2009. Accuracy assessment of digital elevation models by means of robust statistical methods. ISPRS Journal of Photogrammetry and Remote Sensing 64(4): 398-406. DOI: 10.1016/ j.isprsjprs.2009.02.003.

40. Holmgren J., Persson A., Söderman U., 2008. Species identification of individual trees by combining high resolution LIDAR data with multispectral images. Inter- national Journal of Remote Sensing 29(5): 1537-1552. DOI: 10.1080/01431160701736471.
41. *Honkavaara E.,* Arbiol R., Markelin L., Martinez L., Cra- mer M., Bovet S., Chandelier L., Ilves R., Klonus S., Marshal P., Shläpfer D., Tabor M., Thom C., Veje N., Digital airborne photogrammetry - a new tool for quantitiative remote sensing? A state-of-the-art review on radiometric aspects of digital photogrammetric images. Remote Sensing 1(3): 577-605. DOI: 10.3390/ rs1030577. 2009.
42. *Hoxha B.,* Two-phased inventory of standing volume in mountain forests with the use of aerial photographs. Folia Forestalia Polonica 54(2): 123-133. 2012.
43. *Hunter M.O.,* Keller M., Vitoria D., Morton D.C., Tree height and tropical forest biomass estimation. Biogeosciences Discussions 10: 10491-10529. DOI: 10.5194/bgd-10-10491-2013. 2012.
44. Hyyppä J., Hyyppä H., Leckie D., Gougeon F., Yu X., Mal- tamo M., 2008. Review of methods of small-footprint airborne laser scanning for extracting forest inventory data in boreal forests. International Journal of Remote Sensing 29(5): 1339-1366. DOI: 10.1080/014311607 01736489.
45. Järndstedt J., Pekkarinen A., Tuominen S., Ginzler C., Ho- lopainen M., Viitala R., 2012. Forest variable estimation using a high-resolution digital surface model. ISPRS Journal of Photogrammetry and Remote Sensing 74: 78-84. DOI: 10.1016/j.isprsjprs.2012.08.006. July 2008, Beijing. ISPRS, Vol. XXXVII, Part B1, pp. 665-670.
46. Ke Y., Quackenbush L.J., 2011. A review of methods for automatic individual tree-crown detection and delineation from passive remote sensing. International Journal of Remote Sensing 32(17): 4725-4747. DOI: 10.1080/0 1431161.2010.494184.
47. *Korpela I.,* Individual tree measurements by means of digital aerial photogrammetry. Silva Fennica mon. 3: 1-93. 2004.
48. Korpela I., Anttila P., 2004. Appraisal of the mean height of trees by means of image matching of digitised aer- ial photographs. Photogrammetric Journal of Finland 19(1): 23-36.
49. *Kovats M.,* A large-scale aerial photographic technique for measuring tree heights on long-term forest in- stallations. Photogrammetric Engineering and Remote Sensing 63(6): 741-747. 1997.
50. *L. Barrett,* A. Kulkarni, International Journal on Soft Computing (IJSC) 6, No. 1, 1-14., (2015)
51. *Lemmens M.,* Digital Photogrammetric Workstations - Status and Features. GIM International 25: 12. Web: http://www.gim-international.com/issues/articles/ id1797-Digital_Photogrammetric_Workstations.html. 2011. Accessed 2013.
52. *Lin Y.,* Hyyppä J., Kukko A., Jaakkola A., Kaartinen H., Tree height growth measurement with singlescan airborne, static terrestrial and mobile laser scanning. Sensors 12(9): 12798-12813. DOI: 10.3390/ s120912798. 2012.
53. *Linder W.,* Digital photoogrammetry - A practical course. Springer, Berlin. 220 p. DOI: 10.1007/978-3- 540-92725-9. 2009.
54. *Magnusson M.,* Fransson J.E.S., Evaluation of aerial photo-interpretation for estimation of forest stem volume at stand level. In: Olsson H (ed.) "Operational Tools in Forestry Using Remote Sensing Techniques", 31 May-3 June, 2005, Borås. Swedish Forest Agency, Report 8, Vol C, pp. 102-106. 2005.
55. *Magnusson M.,* Fransson J.E.S., Olsson HAerial photo-interpretation using Z/I DMC images for estimation of forest variables. Scandinavian Journal of Forest Research 22(3): 254-266. DOI: 10.1080/02827580701 262964. ., 2007.
56. *Meyer P.,* Staenz K., Itten K.I., Semi-automated procedures for tree species identification in high spatial resolution data from digitized colour infrared-aerial photography. ISPRS Journal of Photogrammetry and Remote Sensing 51(1): 5-16. DOI: 10.1016/0924- 2716(96)00003-2. 1996.
57. *Michailoff I.,* Zahlenmässiges Verfahren für die Ausführung der Bestandeshöhenkurven. Cbl. und Thar. Forstl. Jahrbuch 6: 273-279. 1943.
58. *Mingireanu Florin*, Gabriel Murariu, Lucian Georgescu, Ionut Mocanu, Daniel Constantin Improved observation monitoring system using UAV, Optoelectronic Techniques and Environemntal Monitoring, ISSN 20066-8651, pag.168-175, 2011

59. Mihaela Cudalbeanu, **Valentin Hahuie**, Lucian Georgescu, Catalina Iticescu, Gabriel Murariu, The Annual Dynamics that Characterize the Physico-Chemical Parameters For Water Quality in the Grindu Area
60. *Morgan J.L.,* Gergel S.E., Coops N.C., Aerial photography: A rapidly evolving tool for ecological management. BioScience 60(1): 47-59. DOI: 10.1525/ bio.2010.60.1.9. 2010.
61. Murariu G., **V. Hahuie**, A. Murariu, C. Iticescu, L. Georgescu, C. Vlad, Annals of "Dunarea de Jos" University of Galati, Mathematics, Physics, Theoretical Mechanics, Fascicle II, Year VIII, No. 1, 118-127,(2016).
62. *Murariu G.,* **V. Hahuie**, L. Georgescu, M. Arseni, A. G. Murariu, Investigation on satellitar and UAV cadastral results. Case study - Galati county forest areas, TIM 15-16 Physics Conference, Timisoara 27 May 2016
63. *Murariu G.*, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni, Adrian Gabriel Murariu and Catalina Iticescu, Improving orthophotoplans and patterns construct of land by using aerial photographs captured using. Case study - Forest Garboavele, AMERICAN INSTITUTE of PHYSICS - Conference Proceedings, 2016
64. Murariu G., **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni, Adrian Gabriel Murariu and Catalina Iticescu, INVESTIGATION ON SATELLITAR AND UAV CADASTRAL RESULTS. CASE STUDY - GALATI COUNTY FOREST AREAS, AMERICAN INSTITUTE of PHYSICS - Conference Proceedings, 2016
65. Murariu Gabiel , **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni, Adrian Gabriel Murariu and Catalina Iticescu, STUDY ON THE INFLUENCE OF ATMOSHERIC PARAMETERS ON THE ACCURACY OF THE GEODETIC MEASUREMENTS, AMERICAN INSTITUTE of PHYSICS - Conference Proceedings
66. Murariu Gabriel , **Valentin Hahuie**, Adrian Gabriel Murariu, Lucian Georgescu, and Catalina Iticescu, Uses of ANN to improve the color index evaluation, submitted to Romanian Jounral of Physics
67. Murariu Gabriel, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, Improving orthophotoplans and patterns construct of land by using aerial photographs captured using. Case study - forest Garboavele, Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE West University of Timisoara, 26th – 28th of May 2016
68. Murariu Gabriel, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, Investigation on satellitar and uav cadastral results. Case study - Galati county forest areas, Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE, West University of Timisoara, 26th – 28th of May 2016
69. Murariu Gabriel, **Valentin Hahuie**, Lucian Georgescu, Maxim Arseni and Adrian Gabriel Murariu, Study on the influence of atmosheric parameters on the accuracy of the geodetic measurements, Conferinta internationala - TIM 15 - 16 - INTERNATIONAL PHYSICS CONFERENCE, West University of Timisoara, 26th – 28th of May 2016
70. Næsset E., Predicting forest stand characteristics with airborne scanning laser using a practical two-stage procedure and field data. Remote Sensing of Environment 80(1): 88-99. 2002b. DOI: 10.1016/S0034- 4257(01)00290-5.
71. Næsset E., 1996. Determination of number of stems in co- niferous forest stands by means of aerial photo-interpre- tation. Scandinavian Journal of Forest Research 11(1): 76-84. DOI: 10.1080/02827589609 382914.
72. Næsset E., Determination of mean tree height of forest stands by means of digital photogrammetry. Scan- dinavian Journal of Forest Research 17(5): 446-459. 2002a. DOI: 10.1080/028275802320435469.
73. Næsset E., Gjevestad J.G., 2008. Performance of GPS Pre- cise Point Positioning Under Conifer Forest Canopies. Photogrammetric Engineering & Remote Sensing 74: 661-668. DOI: 10.14358/ PERS.74.5.661.
74. *Nurminen K.,* Karjalainen M., Yu X., Hyyppä J., Honka- vaara E., Performance of dense digital surface models based on image matching in the estimation of plot-level forest variables. ISPRS Journal of Photogram- metry and Remote Sensing 83: 104-115. DOI: 10.1016/ j.isprsjprs.2013.06.005, 2013.
75. Dimitre Oancea, Cazimir Swizewski, - "Judeţul Galaţi", Ed. Academiei RSR, Bucureşti, 1979

76. *Paine D.P, Kiser J.D.,* 2012. Aerial photography and image interpretation. Third Edition. John Wiley & Sons, Inc., Hoboken, New Jersey. DOI: 10.1002/9781118110997.
77. *Pernar R.,* Ančić M., Seletković A., Primjena ICK aerosnimaka za utvrđivanje oštećenosti šuma na području UŠP Gospić [Application of colour infrared aerial photographs for the assessment of forest dam- age in the Gospić Forest Administration]. Šumarski list 131(11-12): 507-521 2007b.
78. *Pernar R.,* Način i pouzdanost određivanja oštećenosti hrasta lužnjaka (Quercus robur L.) na infracrvenim ko- lornim (ICK) aerosnimkama [Method and reliability of assessing pedunculate oak (Quercus robur L.) damage on colour infrared (CIR) aerial photographs]. Glasnik za šumske pokuse 31: 1-34. 1994.
79. *Pernar R.,* Seletković A., Ančić M., Utvrđivanje oštećenosti šuma Spačvanskog bazena primjenom in- fracrvenih kolornih aerosnimaka [Assessing forest dam- age in the Spačva basin with colour infrared aerial pho- tographs]. Šumarski list 131(7-8): 315-322. 2007a.
80. *Popescu S.C.,* Wynne R.H., Seeing the Trees in the Forest: Using Lidar and Multispectral Data Fusion with Local Filtering and Variable Window Size for Estimating Tree Height. Photogrammetric Engineering and Remote Sensing 70(5): 589-604. DOI: 10.14358/ PERS.70.5.589. 2004.
81. *Târâlă Traian,* Originea Dunelor de nisip de la Hanu Conachi*,* Arhiva Ocolul silvic Hanu Conachi (2004).
82. *Rikimaru A.,* Landsat TM Data Processing Guide for Forest Canopy Density Mapping and Monitoring Model, Proceedings of ITTO Workshop on Utilization of Remote Sensing in Site Assessment and Planning for Rehabilitation of Logged-Over Forest, Bangkok, Thailand, July 30-August 1, 1996, 18-24 (1996).
83. *Rikimaru A.,* P.S. Roy, S. Miyatake, Tropical Ecology 43, 1, 39-47, (2002).
84. *Sandau R.,*. Digital Airborne Camera, Introduction and Technology. Springer, Dordrecht, 343 p. DOI: 10.1007/978-1-4020-8878-0. 2010.
85. *Dumitru Sârbu*, Ghid pentru identificarea si inventarierea pajistilor seminaturale din Romania, Alo, Bucuresti, 2001, ISBN 9739966683, 9789739966689.
86. Shapiro S.S., Wilk M.B., 1965. An analysis of variance test for normality (complete samples). Biometrika 52: 591- 611. DOI: 10. 1093/biomet/52.3-4.591.
87. Shapiro S.S., Wilk M.B., Chen H. J., 1968. A comparative study of various tests for normality. Journal of the American Statistical Association 63: 1343-1372. DOI: 10.1080/01621459.1968.10480932.
88. Simionică A., Simionică R. L., 2012 – Potenţialul edafic şi vegetal din esteul Câmpiei Înalte a Covurluiului şi Lunca Joasă a Prutului Inferior, judeţul Galaţi, arhiva OJSPA Galaţi)
89. *Spencer R.D.,* Hall R.J.,. Canadian large-scale aerial photographic systems (LSP). Photogrammetric Engi- neering and Remote Sensing 54(4): 475-482. 1988
90. *Georgescu Lucian, Iticescu Cătălina,* ***Hahuie Valentin,*** Reconstrucție și revitalizare ecologică, ISBN 978-606-628-129-4, Edit.Europolis Galați, 2015.
91. *St-Onge B.,* Jumelet J., Cobello M., Véga C., Mea suring individual tree height using a combination of ste- reophotogrammetry and lidar. Canadian Journal of For- est Research 34: 2122-2130. DOI: 10.1139/x04-093. 2004.
92. *St-Onge B.,* Véga C., Fournier R.A., Hu Y., Map- ping canopy height using a combination of digital ste- reo-photogrammetry and lidar. International Journal of Remote Sensing 29(11): 3343-3364. DOI: 10.1080/014 31160701469040. 2008.
93. *Tuominen S.,* Pitkänen J., Balazs A., Korhonen K. T., Hyvönen P., Muinonen E., NFI plots as comple- mentary reference data in forest inventory based on air- borne laser scanning and aerial photography in Finland. Silva Fennica 48 (2): article id 983. DOI: 10.14214/ sf.983. 2014.
94. *Van Laar A., Akça A.,* Forest mensuration. Springer, Dordrecht, 376 p. DOI: 10.1007/978-1-4020-5991-9. 2007.
95. *Véga C.,* St-Onge B., Height growth reconstruction of a boreal forest canopy over a period of 58 years using a combination of photogrammetric and lidar models. Remote Sensing of Environment 112(4): 1784-1794. DOI: 10.1016/j.rse.2007.09.002, 2008.
96. I. UJVARI , Geografia Apelor Romaniei, 1972

97. *White J.C.,* Wulder M.A., Vastaranta M., Coops N.C., Pitt D., Woods M., The utility of image-based point clouds for forest inventory: A comparison with airborne laser scanning. Forests 4(3): 518-536. DOI: 10.3390/ f4030518. 2013.
98. *Worley D.P.,* Landis G.H., The accuracy of height measurements with parallax instruments on 1:12000 photographs. Photogrammetric Engineering 20(1): 823- 829. 1954.
99. *Milescu Ioan,* Cartea Silvicultorului, ISBN 973-87458-0-2, Edit.Petru Maior,2006.
100.