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GROWTH POTENTIAL OF HYBRID BLACK POPLAR(POPULUS x CANADENSIS Moench) IN ROMANIA'S EAST PLAIN

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Abstract

The realized investigations intended to evaluate the stand volume and current annual increment for the hybrid black poplar. The research was realized on the surface of 375 parcels, between 2010 and 2015. The following elements were evaluated: consistency, density, volume stand and current annual increment. Statistical analysis methods were used together with many numeric analysis methods. The approximation methods based on using neural networks are not very efficient. Furthermore, the interpolation method through analytical polynomial function with mixed terms used successfully in the systems characterized by significant changes in regard with certain state parameters, was used successfully in this case.

Keywords: *Interpolation method; Polynomial function; Hybrid black poplar; Volume stand; Stand age.*

Introduction

Poplars are among the most widespread tree species due to their fast growth, easy vegetative replication methods and growth in different site conditions. Furthermore, a large part of the success of poplar plantations is caused by the apparition of poplar hybrids that have a rapid growth, are resistant to diseases and can offer an important benefit of generating carbon offsets [1-6]. In the northern hemisphere regions, characterized by a lack of natural forests, the species is the main source of wood being a valuable alternative source of biomass due to their high growth rate and cold hardiness [7-10].

Even though it contributes scarcely to the worldwide wood provision, the surface of fields planted with poplars is in a rapid growth, especially in China, India, South Korea and the United States. The 1992 Report of the International Poplar Commission has included nine countries with at least 10.000 hectares of planted poplars and seven countries with more than 100.000 hectares; at least eleven countries are sustaining programs for poplar reproduction [11, 12]. In India for example, poplar has been promoted by the Western India Match Company (WIMCO) as agroforestry (poplar- based agroforestry) since 1984, so that poplar is now being

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grown on an increasing scale as an agroforestry crop by the farmers on their field bunds and within the fields, primarily for sale [13]. Agroforestry is mentioned by IPCC as one of the most important instruments to fight climate change. Agroforestry systems may become over time an efficient tool in climate change mitigation and adaptation stages [14].

Poplars are a main source for a large array of wood products, from lumber to beams and other construction elements in agricultural economies, followed by paper fabrication and plywood. It was also used for the production of wooden sculptures in northwestern part of Italy dating back to the XVIIth – XVIIIth centuries, for Biedermeier furniture since the 19^{th} century [15, 16]. There are also handmade wooden objects which were made of poplar wood such as a reel wheel and a winder dating from the first half of 20^{th} century [17]. Furthermore, the species has received an increased attention as a renewable biomass energy source [8]. Even though the poplar was proved to be extremely adequate for biomass production due to its fast growth rate in a single vegetation season, a higher biomass production can be obtained by genotype optimization as well as through an adequate management of cultures [18,19]. In order to achieve an intensive poplars culture, a better understanding of the mechanisms that determine its productivity is required.

As such, the objective of the present investigation is to compare the available methods and approaches for estimating the data sets regarding stand volume and current annual increment by considering the hybrid black poplar (*Populus x canadensis* Moench) as a case study. Another objective is to offer managers and forest researchers a base for choosing the adequate method for improving forest practices and planning forest management plans by incorporating forest growth performances.

Experimental

Materials and methods

The investigation was realized in the Romanian East Plain, more exactly in Siret Plain from Buzău-Siret Plain, on the range of Hanu Conachi forest unit, in III Independența production unit (UP) (Fig. 1). The stands from this production unit are vegetating on loess deposits belonging to Siret meadow. The geological formations from this UP are argyle sandy of quaternary age.

Fig. 1. Place of investigation: Hanu Conachi forest unit, UP III "Independența"

The relief form is low meadow, while the field's configuration is generally plain, with an altitude ranging between 4m and 30m. The hydrographic network is represented by the Siret River. In regard to the climatic aspect, the investigated surfaces are situated in the plain climate, characterized by an annual average temperature of 10.5°C and annual average precipitations of 419.6mm. The most widespread soils are those from the Protisoil class, namely fluvisoils: eutric fluvisoil (44%), entic fluvisoil (23%), entic-gleyic fluvisoil (23%) and gleyic fluvisol (8%), [20-23]. At a national level, fluvisoil occupies 2.707.213ha, namely 12% from the total country surface, while fluvisoils situated under forests occupy 330.564ha, namely 5% of the total forest soil surface [24-26].

The study was realized on 356 forest sectors (management plan units). The present article includes the results obtained on the lots that present a composition of 100% of the hybrid black poplar species (*Populus x canadensis* Moench). Measurements were realized every year, close to the end of the growth season (September-October). The following parameters were recorded: current age, surface, composition, consistency, stand density, volume and current annual increment.

Statistical analysis methods**:** variation analysis methods (ANOVA) of a multi-factorial type were used. Furthermore, multi-varied statistical analysis methods were also used – such as the PCA method.

Numerical analysis methods: a number of techniques for analysis and numerical interpolation were used [27, 28]. Software programs were mainly used for the interpolation methods as they contain predefined interpolation procedures and methods. As such, interpolation methods with predefined types were used for all studied cases: a) square; b) interpolation method of the lowest square type; c) nonlinear interpolation by using neural networks and d) specific multidimensional polynomial interpolation method with mixed terms. Sum of Square Errors (SS) [29-31] was the general criteria for optimizing the interpolation.

Results and discussion

The first step in analyzing the data was calculating the correlation coefficients for the parameters being monitored.

The first observation refers to the correlation coefficient between stand volume and current stand age. The value of this coefficient emphasized the strong relation between the current stand age and the registered volumes. Based on the correlation coefficient, calculated by using databases for each year, we have developed a PCA (Principal Component Analysis) analysis that emphasizes the grouping method of measured parameters in factors and main groups. The results for each year are rendered in figure 2.

During the study's first four years (Fig. 2a, b, c and d), there is a strong correlation between consistency, growth rate and density, forming a first group of parameters afferent to factor 2 and an interesting arrangement between current age and volume. In the fifth and sixth years (Fig. 2e and f), the growth rate is associated more with the second main factor (vertical axis), being less correlated with the density. This interesting aspect can originate from the fact that the recorded growth rate is also strongly affected by external, anthropic factors.

The fact that neighboring forest parcels (with the same stand structure and climatic conditions) have indicated different current annual increments with different coefficients is extremely interesting. This observation has led to realizing an ANOVA statistical analysis. The research generated an important conclusion: consistency, namely the equivalent surface covered by trees' crown on the surface unit, plays an important role.

The ANOVA analysis coefficients reveal that both studied parameters (current age and stand consistency) have a clear influence on the current annual increment ($p < 0.001$).

Table 1 presents the characteristics of the test for the model proposed – namely the possibility of creating a linear statistic model for modeling growth rate by using linear dependencies regarding the current age and consistency value. The *p* coefficient value shows that this model is acceptable and can be used ($p < 0.0001$).

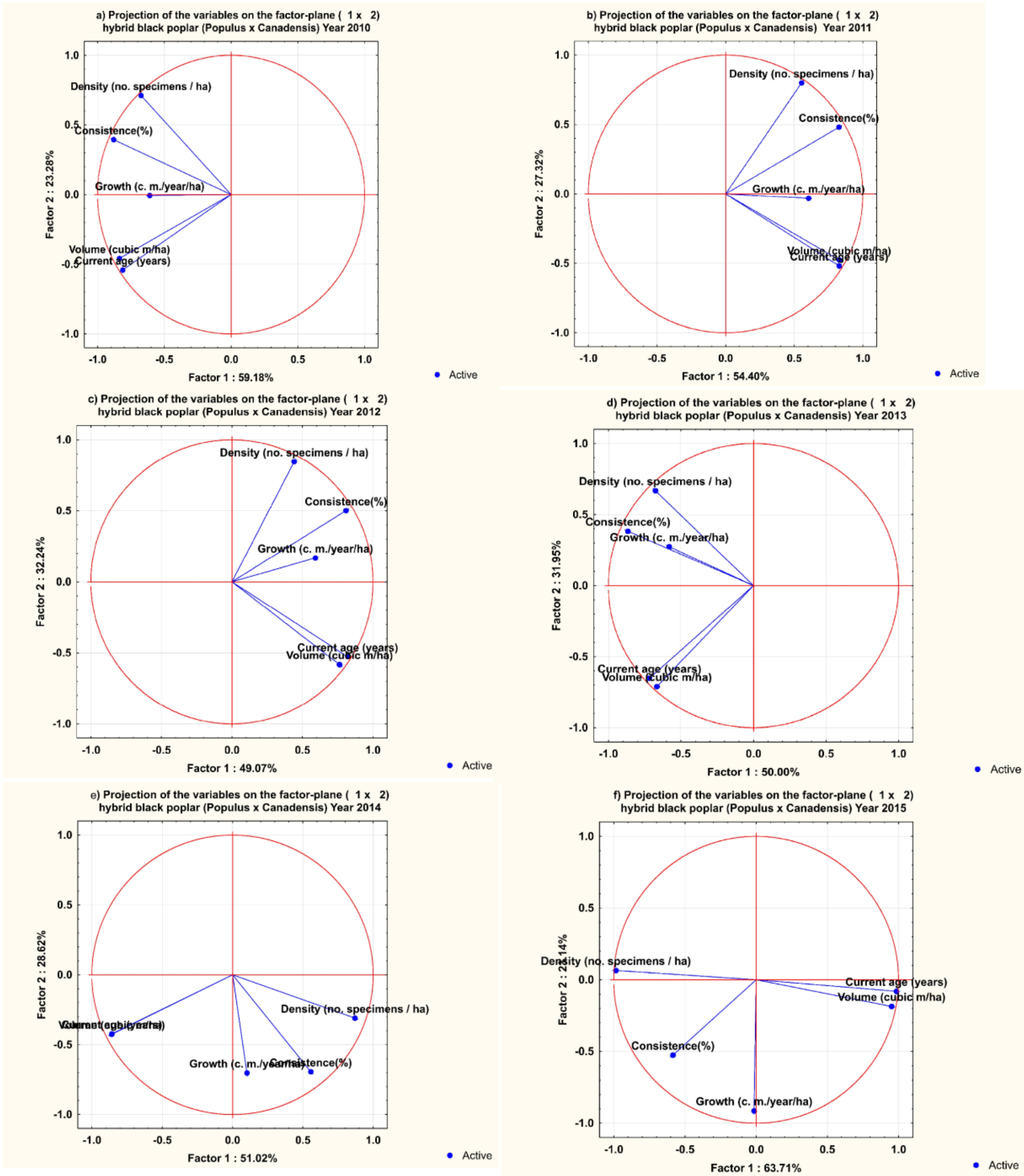

Fig. 2. The PCA analysis method results

Both values for the quality evaluation model, meaning R-square, R-square adjusted values and *p* coefficient values, emphasize the quality of this model. What must be noted is the extent of SS value, which represents the sum of square errors and registers the value of 919.47 (Table 1).

As a necessity, the way in which the growth rate has varied based on the measured state parameters was also examined and investigated. The results of this analysis are presented in figure 3 and are based on the solutions found by using the PCA method applied on each year's database.

An important variation of surface forms can be observed, from high growth tendencies based on age at high-consistency values (Fig. 3a), to modest growth rate values based on age at higher consistency values (Fig. 3b), up to the form of a surface characteristic to some dynamic unstable equilibriums with local peaks around the age of 15 (Fig. 3d, e and f).

Table 1. The test of SS whole Model vs. SS residual (*Populus x canadensis* database)
Test of SS Whole Model vs. SS Residual (hybrid black poplar (Populus x canadensis) _database) - p=0.000000

Current annual increment	Multiple - R	Multiple - R²	Adjusted - R²	SS - Model	df - Model	MS - Model	SS - Residual	df - Residual	MS - Residual	F
(c. m./ year / ha)	0.405	0.16412	0.1582	919.47	3	306.491	4683.033	422	11.0972	27.619

In contrast with other works from the literature in which only the interpolation quality is followed by mixing different model types and forms, the present paper has used preponderantly mathematical analytical interpolation models, having a common evaluation criterion.

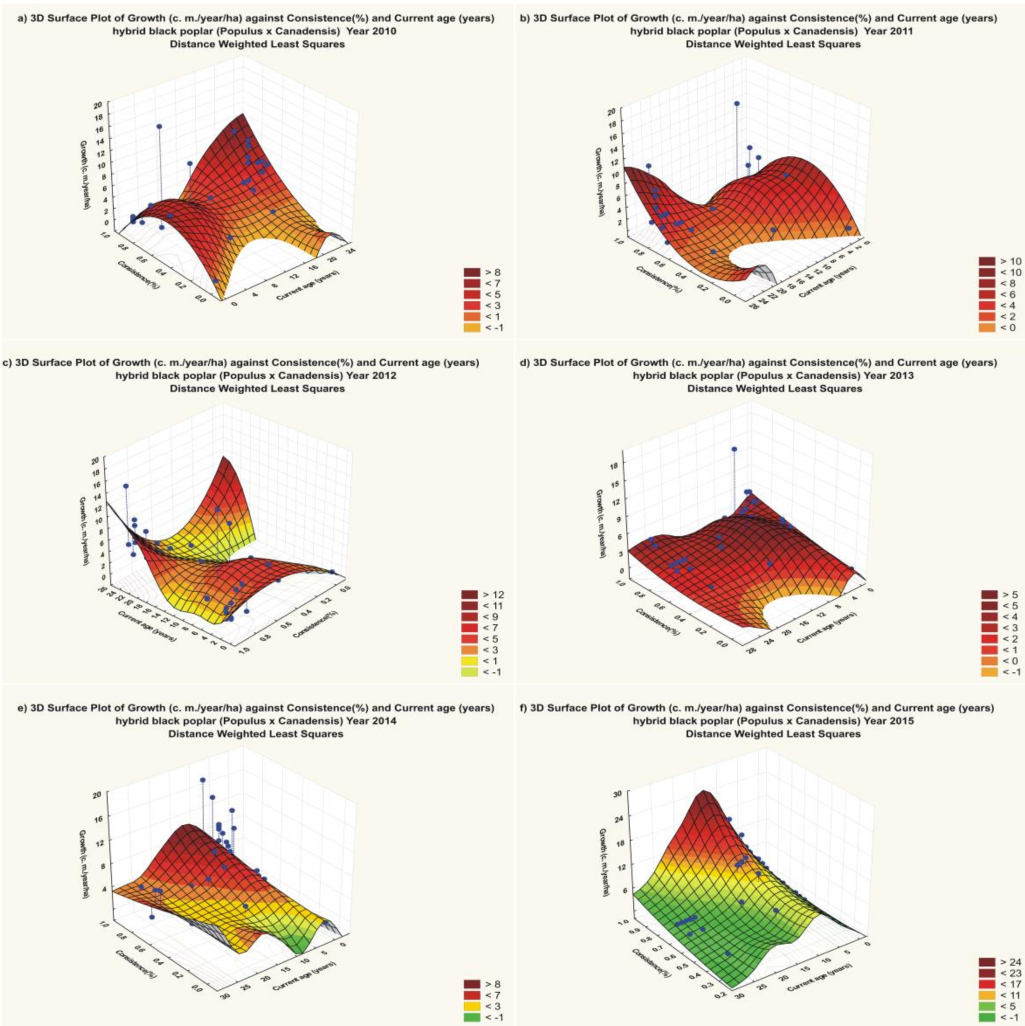

Fig. 3. The growth rate variation against current age and consistency using PCA method

All of the models presented hereafter are improvements of this representation.

The following model of square functions represents an improvement of the previous statistical model. The expression for this model family is the quadratic multidimensional type and has the following form:

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

where: x - represents consistency value and y - current age value. Figure 4 represents the models obtained for each studied year.

Even though these square models are more performing than the above mentioned ones (the residual SS value is smaller), they still have some deficiencies. One of these deficiencies comes from the significant alteration of the results obtained from one year to another. Thus, for the database associated to the period between 2010 and 2011, the maximum growth rate on surface unit has an increasing tendency related to current age at high consistency values (Fig. 3a and b). It presents a relative maximum at small ages domain, whilst for the last three years of the study, the maximum growth rate corresponds to the age of 15 years, presenting an unstable dynamic equilibrium with a local maximum at high consistency values. Slight transformation continuity from one year to another can be observed for the response surface form, with the emphasizing of some local maximum in the figures belonging to the last years of the study (Fig. 3e and f).

The approximation model constructed through the smallest square model represents an additional improvement of the previous quadratic model. Even though the obtained results for the first databases do not differ substantially, for the representations belonging to the last three years, significant changes over the shape and contouring tendencies can be observed, with a local maximum in the large consistencies domain and around the ages of 10-15. A significant inconveniency is represented by the doubling of the growth rate maximum value in the case of a high consistency.

The next type of studied model is based on the usage of neural networks (Fig. 4). In this case, based on the values between the two monitored parameters – consistency and current age (considered as entry parameters), evaluation of the current annual increment can be obtained – considered as exit values. The sampling was realized so that 70% were data used for training, 20% for testing and 10% for validation. These models have a greater efficiency than the previous models because the previously obtained results were compared and proved to be superior [26]. For these models, a total number of 20 RBF and MLP structures were considered, followed by a selection of the first, most performing six models. For these six models, training and testing errors were under 1%.

The ANN structure of RBF and MLP types are recommended for the multidimensional interpolation of function that appear in significant variations of the evolution process. Therefore, by respecting the network, the data set was used for sampling, for training and testing and for validating the model. On the other hand, these neural networks need databases with many recordings [32].

Figure 5 presents the results of constructed models. In order to simplify the analysis, the experimental points were also shown for comparison. It must be remembered that these models offer lower prognosis values than the experimental values (Fig. 5a-f). Even though the errors obtained in the training stage are pretty low, the final values do not always correspond to the experimental values.

As a first remarkable aspect, it can be observed that the shape of answer surfaces presents a certain stability together with the existence of a maximum growth rate (Fig. 4a, b and c). The last two models did not show this characteristic (Fig. 4e and f). On the other hand, it can be observed that the growth rate has a tendency to increase towards higher consistency values, a fact that was previously identified with the help of other models. Furthermore, there is a tendency to form a maximum growth rate for lower consistency but at high values of growth rate (Fig. 4a, b and c).

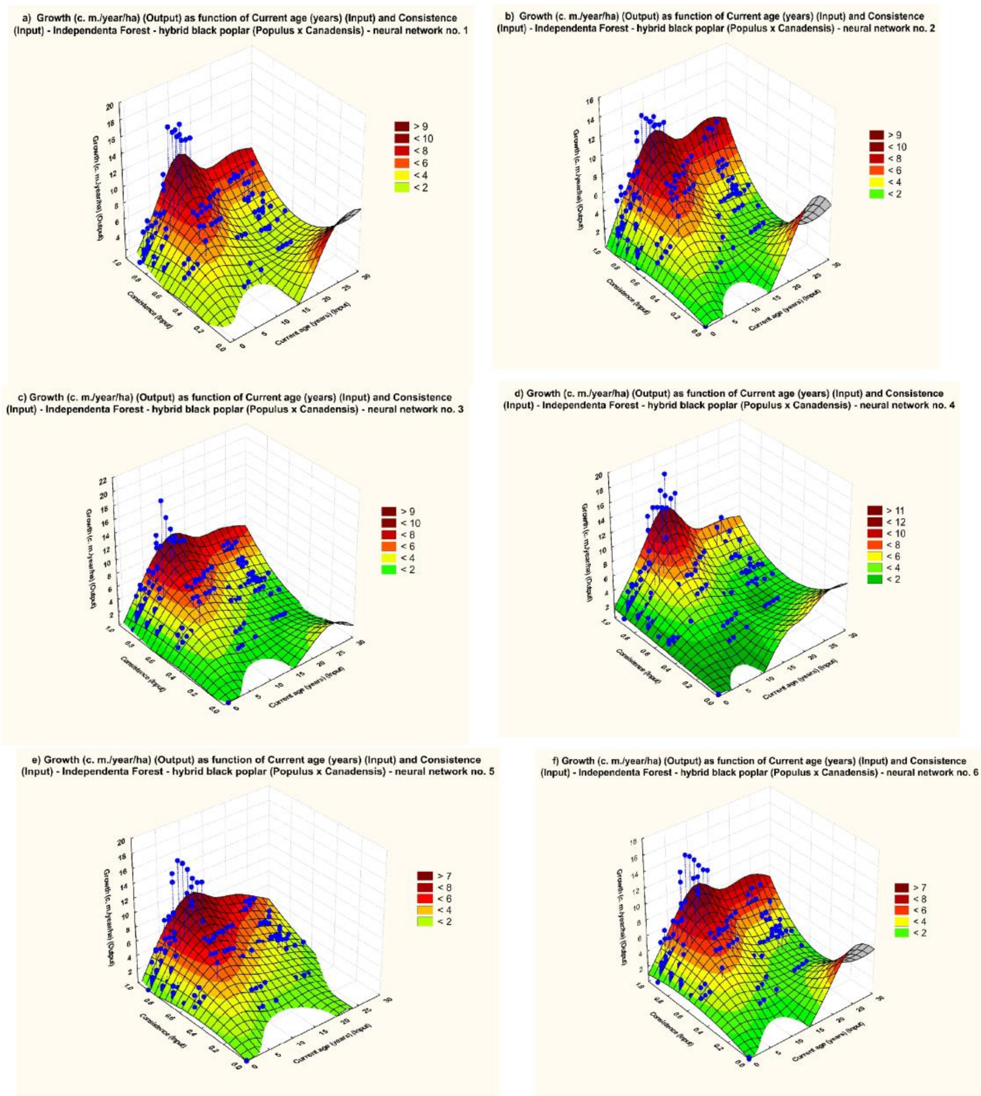

Fig. 4. The current annual increment models using neural network interpolation method

This fact has led us to the idea of constructing a specific model for improving the results obtained until now. The multidimensional interpolation polynom that uses mixed terms represents an improvement of the previous linear model. The expression for these models has the following 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 current age, x - consistency value and y - value of current age. Figure 5 represents the results obtained for the increase of SS value in comparison with the polynomial range of multidimensional models for each independently considered parameter. Under this representation, the vertical axis represents the SS magnitude, while the horizontal axis represents the polynomial range for the time series, consistency measure and current age. It can be observed that the time series do not bring significant improvements. The best performances are obtained for the consistency polynomial expansion series and especially for the current age polynomial expansion series (Fig. 5).

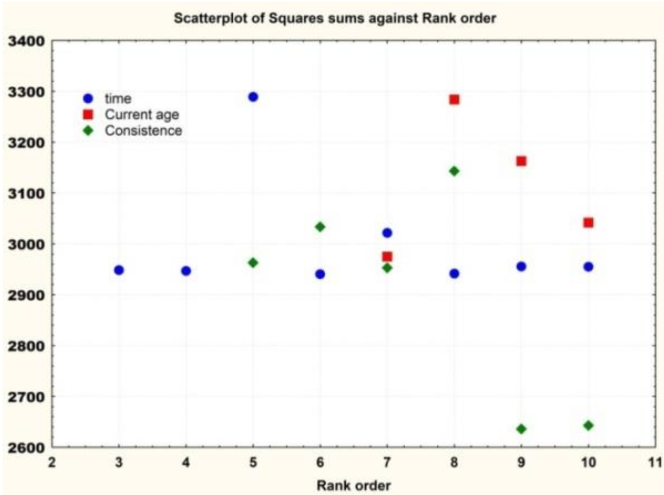

Fig. 5. The obtained results for SS magnitudes against the polynomial rank of the multidimensional models for each of the considered independent parameter

The contributions of mixed terms introduced by D and E coefficients (2) succeed in eliminating the Runge phenomenon effects for interpolating the high order polynom [28]. In this way, we can obtain a precise model, with much lower evaluating errors in comparison with the models discussed above (Fig. 6).

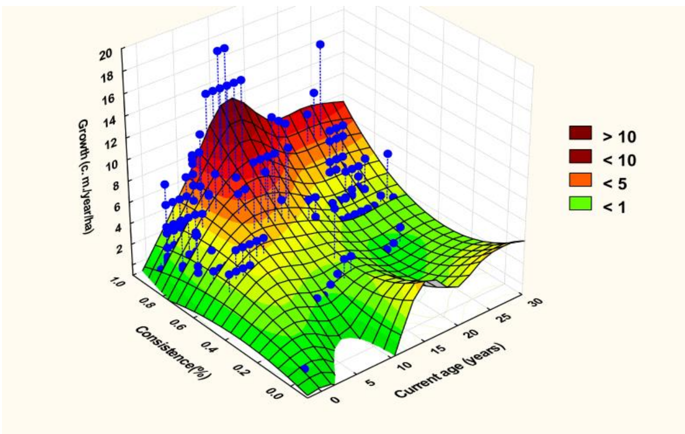

Fig. 6. The representation for the optimal multidimensional model with mixed terms configuration . 3D Surface plot – Growth magnitude (c.m./year/ha) against Consistence (%) and Current age (years) for hybrid black poplar (Populus x Canadensis)

Table 2 presents a series of configurations and respectively the optimal polynomial model identified – model 6 expressed through the relation 2 and represented in figure 6. Thus, the best analytical model for evaluating the current annual increment for hybrid black poplar can be obtained in comparison with the measured state parameters.

Table 2. The multidimensional polynomial configuration for optimal result

No crt.	Polynomial rank for time series	SS magnitude	Polynomial rank for consistence series	SS magnitude	Polynomial rank for current age	SS magnitude
1	3	1491.943077	5	1491.943077	7	2974.73594
2	4	1498.170268	6	1498.170268	8	3283.8406
3	5	1516.363699	7	1516.363699	9	3162.738
4	6	1513.405674	8	1513.405674	10	3041.63603
5	7	1474.639669	9	1474.639669	11	2974.73594
6	8	1473.909667	10	1473.909667	12	2953.568342
7	9	1483.962850	11	1483.962850	13	2964.568223

Conclusions

The value of the correlation coefficient between stand volume and its age stipulates the strong relation between them. The two parameters – actual age and stand consistency – have a clear influence over the current annual increment ($p < 0.001$).

A series of 8 technological parameters that have evaluated the influence over the current annual increment were monitored. In order to obtain an evaluation of the current annual increment and to construct an evaluation model, we have tested a range of analysis methods.The approximation numerical methods included in different statistical analysis programs proved to be inefficient. Furthermore, it was proved that the approximation methods based on the usage of neural networks are not very efficient. Due to this cause, a specific mathematical model with a special structure was constructed. The evaluations realized with this model proved to be superior to all previous tested representations. The construction algorithm and results are presented in this article which focuses on hybrid black poplar.

The obtained conclusions have a general character, while the interpolation method through analytical polynomial function with mixed terms can also be applied for other stands even though it is based on the data gathered in a certain region of the country. The future usage of other data originating from different areas could lead to new contributions for improving these models. However, it must be mentioned that the hybrid black poplar is cultivated only in certain areas, with a certain soil and climatic specificity, so that the used primary data (numerous and registered for a sufficient number of years) can be considered as specific to the studied species. The situation can be completely different for some stands composed of local species that have a larger geographic and climatic spreading variability, such as common beech, fir, oak etc. The method's main advantage is that it allows a polynomial interpolation with a degraded increase of the interpolation order, avoiding as such the apparition of Runge effect. This effect, which causes oscillations obtained through fictional functions, has negative consequences over the implications resulted from using these models. This method successfully used in systems that have significant changes in regard with certain state parameters, was successfully used in this case study. Based on all the information presented above, we consider that this method is extremely interesting, it poses a high degree of novelty and can be taken into consideration for future ecological studies.

References

[1] J.E. Eckenwalder, *Systematics and evolution of Populus*, **Biology of Populus and its Implication for Management and Conservation** (Editors: R.F. Stettler, H.D. Bradshaw Jr., P.E. Heilman and T.M. Hinckley), National Research Council Canada, Ottawa, ON, 1996, pp. 201–222.
[2] P.E. Heilman, *Planted forests: poplars*, **New Forests, 17**(1-3), 1999, pp. 89–93.
[3] H.D.Bradshaw Jr., R. Ceulemans, J. Davis, R.F. Stettler, *Emerging model systems in plant biology: poplar (Populus) as a model forest tree*, **Journal of Plant Growth Regulation, 19**(3), 2000, pp. 306–313.
[4] D.I. Dickmann, K.W. Stuart, **The Culture of Poplar in Eastern North America,** Hickory Hollow Associates, Dansville, MI, 1983.
[5] J.A. Anderson, A. Long, M.K. Luckert, *A financial analysis of establishing poplar plantations for carbon offsets using Alberta and British Columbia's afforestation protocols*, **Canadian Journal of Forest Research, 45**(2), 2015, pp. 207–216.
[6] D. Henkel-Johnson, S.E. Macdonald, E.W. Bork, B.R. Thomas, *Influence of weed composition, abundance, and spatial proximity on growth in young hybrid poplar plantations*, **Forest Ecology and Management, 362**, 2016, pp. 55–68. DOI: 10.1016/j.foreco.2015.11.010.
[7] R. Ceulemans, G.E. Scarascia-Mugnozza, B.M. Wiard, J.H. Braatne, T.M. Hinckley, R.F. Stettler, J.G. Isebrands, P.E. Heilman, *Production physiology and morphology of Populus species and their hybrids grown under short rotation. I. Clonal comparison of 4-year growth and phenology*, **Canadian Journal of Forest Research, 22**(12), 1992, pp. 1937–1948. DOI: 10.1139/x92-253.
[8] J.J. Balatinecz, D.E. Kretschmann, *Properties and utilization of poplar wood*, **Poplar Culture in North America,** Part A, Chapter 9, (Editors: D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder and J. Richardson), NRC Research Press, National Research Council of Canada, Ottawa, ON KIA OR6, 2001, pp. 277-291.
[9] M. Weih, *Intensive short rotation forestry in boreal climates: present and future perspectives*, **Canadian Journal of Forest Research, 34**(7), 2004, pp. 1369–1378. DOI : 10.1139/x04-090.
[10] A. Park, E.R. Wilson, *Beautiful plantations: can intensive silviculture help Canada to fulfill ecological and timber production objectives?* **Forestry Chronicle, 83**(6), 2007, pp. 825–839. https://doi.org/10.5558/tfc83825-6.
[11] * * *, **Poplars and Willows in Wood Production and Land Use,** FAO (Food and Agriculture Organization of the United Nations), Rome, 1980.
[12] * * *, **Synthesis of national reports on activities related to poplar and willow areas, production, consumption and the functioning of national poplar commissions,** Note from the Secretariat, FO:CIP:Misc/92/1, Nineteenth Session, 23–25 September, International Poplar Commission, Zaragoza, Spain, 1992.
[13] K. Kareemulla, R.H. Rizvi, K. Kumar, R.P. Dwivedi, R. Singh, *Poplar agroforestry systems of Western Uttar Pradesh in Northern India: A socio-economic analysis*, **Forests, Trees and Livelihoods, 15**(4), 2005, pp. 375-381. https://doi.org/10.1080/14728028.2005.9752537.
[14] S. Chavan, R. Newaj, A. Keerthika, A. Ram, A. Jha, A. Kumar, *Agroforestry for adaptation and mitigation of climate change*, **Popular Kheti, 2**(3)**,** 2014, pp**.** 214–220.

[15] N. Macchioni, S. Lazzeri, L. Sozzi, R. Vitiello, *Wooden sculptures from XVII and XVIII centuries in the region of Asti (Italy): scientific identification of the species,* **International Journal of Conservation Science, 2**(4), 2011, pp. 251-260.
[16] M.C. Timar, L. Gurau, M. Cionca, M. Porojan, *Wood species for Biedermeier furniture – A microscopic characterisation for scientific conservation,* **International Journal of Conservation Science, 1**(1), 2010, pp. 3-12.
[17] M.C. Timar, L. Gurau, M. Porojan. *Wood species identification, a challenge of scientific conservation.* **International Journal of Conservation Science, 3**(1), 2015, pp. 11-22.
[18] T.S. Barigah, B. Saugier, M. Mousseau, J. Guittet, R. Ceulemans, *Photosynthesis, leaf area and productivity of 5 poplar clones during their establishment year,* **Annales des Sciences Forestieres, 51**(6), 1994, pp. 613–625.
[19] I. Laureysens, A. Pellis, J. Willems, R. Ceulemans, *Growth and production of a short rotation coppice culture of poplar. III. Second rotation results,* **Biomass and Bioenergy, 29**(1), 2005, pp. 10–21.
[20] L. Dinca, O. Badea, G. Guiman, C. Braga, V. Crisan, V. Greavu, G. Murariu, L. Georgescu, *Monitoring of soil moisture in Long-Term Ecological Research (LTER) sites of Romanian Carpathians,* **Annals of Forest Research, 61**(2), 2018, pp. 171-188.
[21] L.C. Dincă, M. Dincă, D. Vasile, G. Spârchez, L. Holonec, *Calculating organic carbon stock from forest soils,* **Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 43**(2), 2015, pp. 568-575.
[22] R.A. Mandal, I.C. Dutta, P.K. Jha, S.B. Karmacharya, *Effects of Forest Carbon on Ecological Value of Species in Collaborative Forests, Tarai, Nepal,* **International Journal of Conservation Science, 6**(3), 2015, pp. 391-400.
[23] L. Dinca, I. Chisalita, I.-C. Cantar, *Chemical properties of forest soils from Romania's West Plain,* **Revista de Chimie, 70**(7), 2019, pp. 2371-2374.
[24] L. Dinca, G. Sparchez, M. Dinca, *Romanian's forest soil GIS map and database and their ecological implications,* **Carpathian Journal of Earth and Environmental Sciences, 9**(2), 2014, pp. 133-142.
[25] G. Sparchez, L. Dinca, G. Marin, M. Dinca, R.E. Enescu, *Variation of eutric cambisol's chemical properties based on altitudinal and geomorphological zoning,* **Environmental Engineering and Management Journal, 16**(12), 2017, pp. 2911-2918.
[26] A. Onet, L.C. Dinca, P. Grenni, V. Laslo, A.C. Teusdea, D.L. Vasile, R.E. Enescu, V.E. Crisan, *Biological indicators for evaluating soil quality improvement in a soil degraded by erosion processese,* **Journal of Soils and Sediments, 19**(5), 2019, pp. 2393-2404.
[27] B, D. Truax, Gagnon, J. Fortier, F. Lambert, *Yield in 8 year-old hybrid poplar plantations on abandoned farmland along climatic and soil fertility gradients*, **Forest Ecology and Management, 267**, 2012, pp. 228–239.
[28] G. Romanescu, C. Zaharia, D.T. Juravle, A.V. Sandu, *The annual and multi-annual variation of the minimum discharge in the miletin catchment (Romania). An important issue of water conservation,* **International Journal of Conservation Science, 6**(4), 2015, pp. 729-746.
[29] G. Romanescu, A. Tirnovan, G.M. Cojoc, I.G. Sandu. *Temporal Variability of Minimum Liquid Discharge in Suha Basin. Secure Water Resources and Preservation Possibilities.* **International Journal of Conservation Science, 7**(4), 2016, pp.1135-1144.
[30] G. Murariu, C. Iticescu, L. Georgescu, I. Mocanu, C. Topa, M. Dobre, *Optimization of urban selective waste collection activity: Galati city case study,* **Environmental Engineering and Management Journal, 14**(10), 2015**,** pp. 2471-2492.

[31] D. Bora, *Distribution of angiospermic monotypic taxa in north east India and their conservational importance.* **International Journal of Conservation Science, 6**(2), 2015, pp. 223-232.

[32] G. Murariu, V. Hahuie, A.G. Murariu, L. Georgescu, M.A. Calin, D. Buruiana, I. Soare, M. Onica, G.B. Carp, *Growth rate modeling for white poplar in the southeastern part of Romania: an important issue of forest conservation,* **Environmental Engineering and Management Journal, 8**(2), 2017**,** pp. 303-316.

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