Folia Forestalia Polonica, series A, 2009, Vol. 51 (2), 176–180

METHODOLOGICAL ARTICLES

Forecast of the forest area in Poland with the use of artificial neural networks

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Abstract

The article presents prognostication concerning the forest area in Poland based on a few changing parameters which influence the condition of forest. An attempt was made to determine which of the parameters revealed the biggest influence. The forest area was forecasted with regard to the area of forest stands damaged by the influence of gas and dust pollutants, the area of forest fires and the area of forested grounds. Based on the data from the years 2002–2006, there was simulated the state of forests in Poland's individual voivodeships in subsequent five years. The forecasting was conducted with the use of artificial neural networks. The results of forecasting indicated which of the analyzed parameters could negatively or positively affect the forest area in the nearest future. The generated parameters prove high probability of about 95%, which was verified by the average square error.

Key words

artificial neural networks, forecast, forest area

Introduction

Forests constitute the indispensable factor for ensuring ecological balance. The factor which directly translates into a lot of other parameters including biological diversity, climate change mitigation as well as the protection of air and water. Forests also play a significant role in an extent of protection against water erosion at the same time having beneficial influence on the frequency and amount of atmospheric precipitation. The area of Poland used to be prevailed by forests. As a result of a number of economic and social processes, the area of our country has gradually undergone deforestation. At present, the area of Poland's forested grounds is lower than the European average and ammounts to 28.9% (Raport 2007). According to scientific estimates (Raport 2007), afforestation of the country up to 1/3 of its area shall ensure ecological safety to Poland. As the measurement of forest condition, a level of reduction of tree assimilatory apparatus is considered (Raport 2007).

Forests in Poland belong to the most damaged in Europe. Only in Ukraine and in the Czech Republic, a share of trees with crown defoliation 0–10% is smaller than in Poland while the proportion of trees with assimilatory loss above 25% is bigger (Jaszczak 1999).

Received 2 June 2009 / Accepted 10 November 2009

The functions of forests can be divided into the following:

– production functions – capacity of renewable production of biomass (first of all timber),
– ecological functions – shaping of landscape, protection against steppe and erosion, regulation of water relations and soil climate, flood and landslide prevention, etc.,
– social functions – conditions benefitial for human health and recreation, valuable for the society, enrichment of the labour market (Raport 2004).

Forest vulnerability in Poland belongs to the highest in Europe due to simultaneous influence of many factors which induce unfavorable changes in forest environment. The reasons of deforestation are of various nature and risk factors can be divided into the following hazard groups:

– endogenic natural factors – natural succession processes in forest environment, developmental tendencies of tree stands, effects of mutual influences of life forms;
– exogenous natural factors – effects of changes in micro-climate and landscape which occur without influence of human activities;
– paraendogenic factors – evoked as a result of human activity in forest ecosystems and physiocenoses**,** for example introduction of tree species unsuitable for a particular habitat type, intensive soil cultivation;
– antropoexogenous factors – evoked by human activity which influences forest ecosystems, for example: pollution of air with industrial pollutants, inappropriate forest exploitation connected with tourism and recreation. (Jaszczak 1999).

One of the serious hazards is emission of pollutants. The biological resistance of forests in Poland is low (Broda 2000). Artificially introduced forest stands in the form of pine and spruce monocultures are hardly resistant to atmospheric air pollution (Broda 2000). It would be worth to restore coniferous forests towards deciduous forests, since the latter have bigger ability to absorb carbon and are less flammable. On the other hand, however, in Poland there prevail pine forests that are most susceptible to fires, Coniferous species constitute 78,7% of the State Forests area and 74.1% of private forests. These forests demonstrate smaller biological resistance to biotic, abiotic and anthropogenic factors (Jaszczak 1999). The fire risk is bigger in the case of younger forests (40–60 years old) because they are thicker in the lower storeys. In Poland's geographical and climatic conditions fires for natural reasons do not usually happen. The most common cause of forest fires is arson.

Destruction of forests can be one of the cause of the greenhouse effect. Burnt forests cause a substantial increase in the concentration of CO, CO_2, CH_3Cl and NO_x in the atmosphere. Lack of forest regeneration results in soil erosion. One of the countries which are seriously threatened by desertification is China. The effects of desertification processes are for example sand storms reaching even Japan. Measurements and simulations in the scope of prognostication of the number of storms and sand storms are carried out with huge success (Zhou *et al*. 2007). At the same time, for a few years, the desert area in China has begun to decrease, owing to activities undertaken in this respect, which consist of intensive afforestation.

It is necessary to stop mass deforestation of tropical forests because of the surplus of CO_2 concentration caused by this process (Więckowski 2000). It was estimated that afforesting of 3700 thousand km^2 could bind the surplus of 1 Gtone of carbon (Okken *et al*. 1989). Considerable climatic changes are predicted, caused by mass and thoughtless forest clear-cutting. Initial hazards such as atmosphere pollution, side effects of climate change, excessive forest penetration by people, as well as secondary hazards such as forest pests and diseases tohether with forest ageing, will not vanish. What is more, it is predicted that the influence of these factors will be increasing (Jaszczak 1999). Just tree species with a wide range of tolerance will have the biggest chance to survive (Więckowski 2000).

In Poland, forests constitute an important element of country ecological safety. One of the components of the national forest policy is to increase the forest cover up to 30% by the year 2020. The National Augumentation Program provides for accomplishment of this goal on the area of 680 thousand hectares in the years 2001–2020. The timing and the amount of afforestation are predicted as follows (Andrzejewski and Weigle 2003):

– the years 2001–2005 – 120 thousand hectares,
– the years 2006–2010 – 160 thousand hectares,
– the years 2011–2020 – 400 thousand hectares.

The means that have so far been allocated to the protection of environment and nature have been insuf-

ficient to counteract the growth of contaminated areas and all irreversible harm. Because of diverse natural conditions, different spatial roles of forests, a growing range of threats as well as various needs of local communities, the regional diversification of forest policy programs is necessary (Więckowski 2000). On the other hand, because of Poland's membership in the European Union, the formulation of the objectives forest policy at a national level needs simultaneous consideration of international conditions (Więckowski 2000).

In order to improve the state of forests in Poland, as well as their protection, rational forest management should be conducted. This should manifest among others, in:

- raising the state of health and stand resistance to biotic and abiotic factors,
- minimizing application of chemicals (pesticides, mineral fertilizers, mineral oils, etc.),
- improving methods of fire hazard elimination including enhancement of systems of fighting with forest fires,
- increasing ecosystem, species and genetic variety of forest biocenosis based on natural patterns,
- regulating game density to the level which would not affect forest silviculture and protection goals,
- controlling recreation and tourism on the forest areas (Więckowski 2000).

This study was carried out with the use of artificial intelligence tools in order to specify whether changes of analyzed parameters could affect the total forest area in Poland and to identify factors with the biggest influence on the condition of forests.

Methods

Because of their universality, neural networks are applied to solve a number of problems, and also those connected with forest management and protection (Chuanwen and Jihong 2006). A steady growth of neural networks popularity is visible in many fields, starting with simple analyses, and ending with prognoses.

The research was carried out based on data from the years 2002–2006 (www.stat.gov.pl) for each of Poland's administration districts (voivodeships). Forecasting of the forest area for subsequent 5 years was performed, based on changing values of selected parameters. These were the parameters which can affect more or less the condition of forests: the area of forest stands damaged by the influence of gases and dust, the area of forest fires and the area of afforestation. These factors directly or indirectly affect the forests condition. The aim of analyses was to demonstrate whether there was a correlation between changes in magnitude of the parameters and the total forest area. The forecast was made at a voivodeship level. The analyses were conducted with the use of the neural network: Flexible Bayesian Models on Neural Networks, Gaussian Processes, and Mixtures (FBM) when working in the UNIX/Linux environment, FBM networks create a possibility of application even with limited training data which is an advantage in comparison with traditional learning methods of neural networks, (Neal 1996, 2004). The use of FBM in practice is feasible using Markov chain Monte Carlo techniques (Neal 1996). To obtain the response network as close as credible, the Bayesian parameters should be optimally set. The most reliable probability of the results was given by the verification of data. The probability is higher if the network answer is most similar to training data. As the final stage, the probability of the results was verified on the basis of the average square error.

Results

The Bayesian parameters quality provides optimal progress of learning networks process (Fig. 1). In the case of this study, the parameters are 0.2 and 0.632 respectively, staying within the acceptable range.

The forecast showed the parameters for achievement of the forest area maximum and circumstances with negative influences on the state of forests which should be avoided. A considerable number of results was obtained, however only those for the years 2009 and 2011 are presented, for which the largest (Fig. 2 a, b) and the smallest (Fig. 3 a, b) areas of forest was observed when different parameters were used in the simulations.

Already in the first analysis it was visible that in some regions the parameters of similar values – almost constant, influenced the forest area, for example in the voivodeships: Dolnośląskie (Lower Silesia), Mazowieckie (Mazovia), Opolskie, Podkarpackie, Świętokrzyskie and Zachodniopomorskie (West Pomerania).

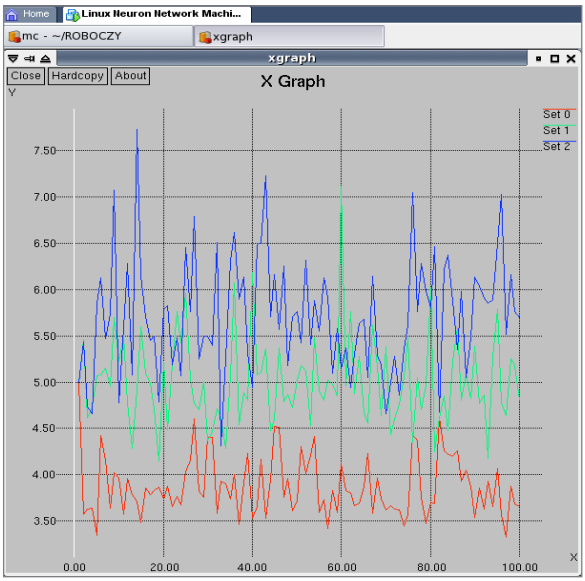

Fig. 1. Selected numerical and graphic parameters of learning Flexible Bayesian Model of Neural Network

Fig. 2. Values of factors for which the largest forest areas in Poland were obtained in the selected years: a) 2009, b) 2011

Fig. 3. Values of factors for which the smallest forest areas in Poland were obtained in the selected years: a) 2009, b) 2011

Rational management of forest resources at the level of voivodeship influences the state of forests on the scale of the entire country. There are numerous factors which influence and decide about the state of forests. Each of the voivodeships has to be considered individually. It is possible to detect certain general tendencies for individual regions.

The analysis of the results showed that different factors can more adversely affect the forest areas depending on the region. The analyzed parameters can have an impact on forest areas in Poland's voivodeships, In the regions described below the forecast showed the following effects of analyzed factors:

– Dolnośląskie – the strongest negative factors affecting the forest area were forest fires,
– Kujawsko-Pomorskie – no influence of analyzed factors on the condition of forest was observed,
– Lubelskie – most negative impact on the forest area had the area of stands damaged,

– Lubuskie – high quantity of tree damages resulted in the smallest forest area observed,
– Łódzkie – a decrease of forest area was observed with high forest stands damages,
– Małopolskie – changes in the forest area were observed with a change of forested area,
– Mazowieckie – no influence of analyzed factors on the condition of forest was observed,
– Opolskie – the lowest value of the forest area was observed with high numbers of damaged trees; the amount of afforestation will have a significant effect;
– Podkarpackie – impoverishment of the forests area was a result of increased number of fires,
– Podlaskie – significant impact of forest stands damaged was observed
– Pomorskie – no influence of analyzed factors on the condition of forest was observed,
– Śląskie – an increase of afforestation could have significant effect on the forest area,
– Świętokrzyskie – the number of damaged trees had an impact on the forest area,
– Warmińsko-Mazurskie – an inncrease of the forest area with the low number of fires and small tree damage was observed,
– Wielkopolskie – no influence of analyzed factors on the condition of forest was observed,
– Zachodniopomorskie – with unfavorable conditions of the high number of fires and damaged trees the forest area impoverishment was observed.

Conclusions

Forecasting forest conditions with the use of the artificial neural networks is an innovative approach. The neural models, thanks to the process of learning based on real data provide satisfactory precision of the forecast. FBM networks create the possibility of using even limited training data,

Through verification of the collection of learning of data with the validating collection, high probability of results reception was obtained which amounted to 95% when based on the average square error.

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