SOME RESULTS OF FOREST ECOSYSTEM SERVICES MODEL ON THE TERRITORY OF YUNDOLA AND TETEVEN

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ABSTRACT

Some results, obtained by the work of international research project: Integrated future-oriented management of forest landscapes - INTEGRAL are presented. The decision support system (DSS) SYBILA were partly adapted and used for the first time in Bulgaria. The results of indicators changes model: total volume of standing timber, volume and yield class structure of possible timber cutting volume and total biomass volume under different forest management regimes on the territory of Yundola and Teteven for the period of 50 years are analysed.

Key words: forest and forestry management, forest ecosystem services modelling, decision support system

GENERAL INFORMATION AT CASE STUDY AREAS (CSA)

The CSA Yundola is placed in the southwestern part of Bulgaria (Fig.1) on the boundary between two Bulgarian mountains (Rila and Rodopi) and occupies an area of 5 211 hectares. 91 % (4 750 ha) of that area is covered by forests. They are very productive coniferous forests. Agricultural landscapes are presented by meadows located near the village of Yundola and the other surrounding villages. The whole wooded area belongs to the Experimental Forest Department „Youndola“ and is managed by the University of Forestry in Sofia as an outdoor classroom and research facility.

Figure 1: Location of the areas.

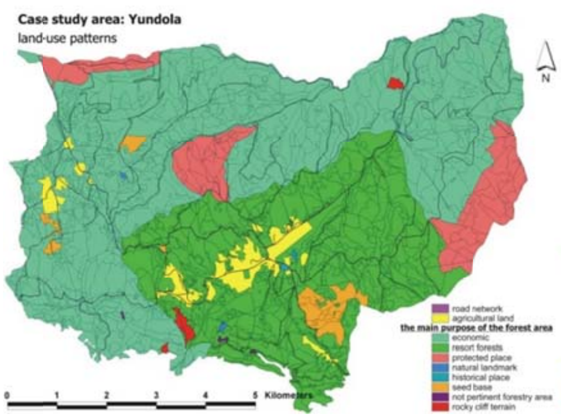
The CSA Teteven is placed in a mountainous area in the North Central region of Bulgaria (Fig. 1). It is located on the northern slopes of the Stara planina mountain and is named after its administrative centre - the town of Teteven (10 000 people), crossed by the River Vit. The distance from the town of Teteven to Sofia is 120 km. Teteven Municipality covers an area of approximately 697 km^2. There are 13 settlements in the municipality, inhabited by 22,016 people (December 2009). The area is forest-agricultural with forests in the south part and agricultural in the north. The upper part of forest area is covered by beech and fir-beech forests, but the lower parts by oak-hornbeam forests. The largest share of Forestry woodland (37 %) have the forest stands with a predominant European Beech (Fagus silvatica, L.). About 21 % accounted for the planting of predominant Carpinus orientalis, which is typical for karst terrains. Quercus cerris has being the predominant species at lower altitudes accounting for about 11 %. 10 % cover the plantations with predominant white pine (Pinus silvestris, L.), while Carpinus betulus, Pinus nigra and Quercus petraea put together cover about 15%. Spruce (Picea excelsa, A. Dietr), Pseudotsuga douglasii, Quercus frainetto, Robinia pseudoacacia and Quercus rubra put together cover 6 % and 17 other species have only 1 %. [2]

The forests at these CSA are managed continuously by forest management plans that are valid for a decade. Current land use planning is generally consistent with the multipurpose forest management and with the conservation and sustainable development of forest landscapes in the modern socio-economic conditions.

PHYSICAL DESCRIPTION OF THE SITES IN TERMS OF LANDSCAPE AND LAND USE

All forests in Yundola are state property. The presence of some protected areas raises the need for different approaches in forestry practices and therefore generally it can be defined only two forest owner types. Due to the relatively monotonous forest ownership and to achieve a more equitable representation of the structure of the behavior matrix is proposed to be included also some functional characteristics of forests (Fig. 2) that determine different approaches in forestry practices. In this situation, the result is a roughly even distribution of the area into three parts, as follows:

- high mountain area of spruce forests, forests of white fir or dwarf pine and alpine pastures (altitude over 1700 m a.s.l.). More of stands are under the natural conservation statute and there is necessary close to nature tending of the vulnerable forest landscapes;
- forests with recreational importance where tending does not change the appearance of forest landscapes. The main management goal is creation of various types of forest landscapes according to the site-types;
- forests for timber production and non-timber forest products. The forests in these areas can successfully perform important social functions besides the wood harvesting and environmental functions by means of sustainable tending, which ensure constant yields which do not exceed the increment. [1]



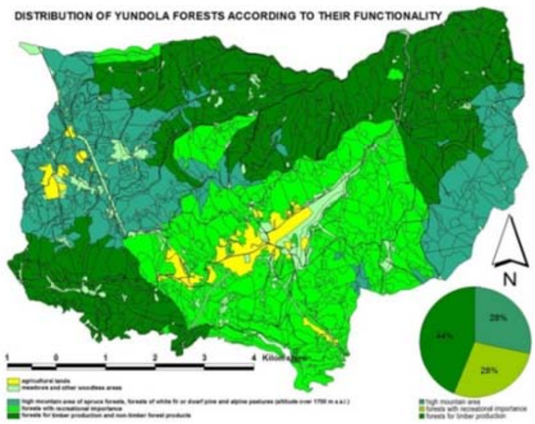


Figure 2: Land-use patterns and distribution of Yundola forests according to their functionality.

Figure 3 shows the areas occupied of different land-cover patterns and distribution of Teteven forests according to their ownership and functionality.

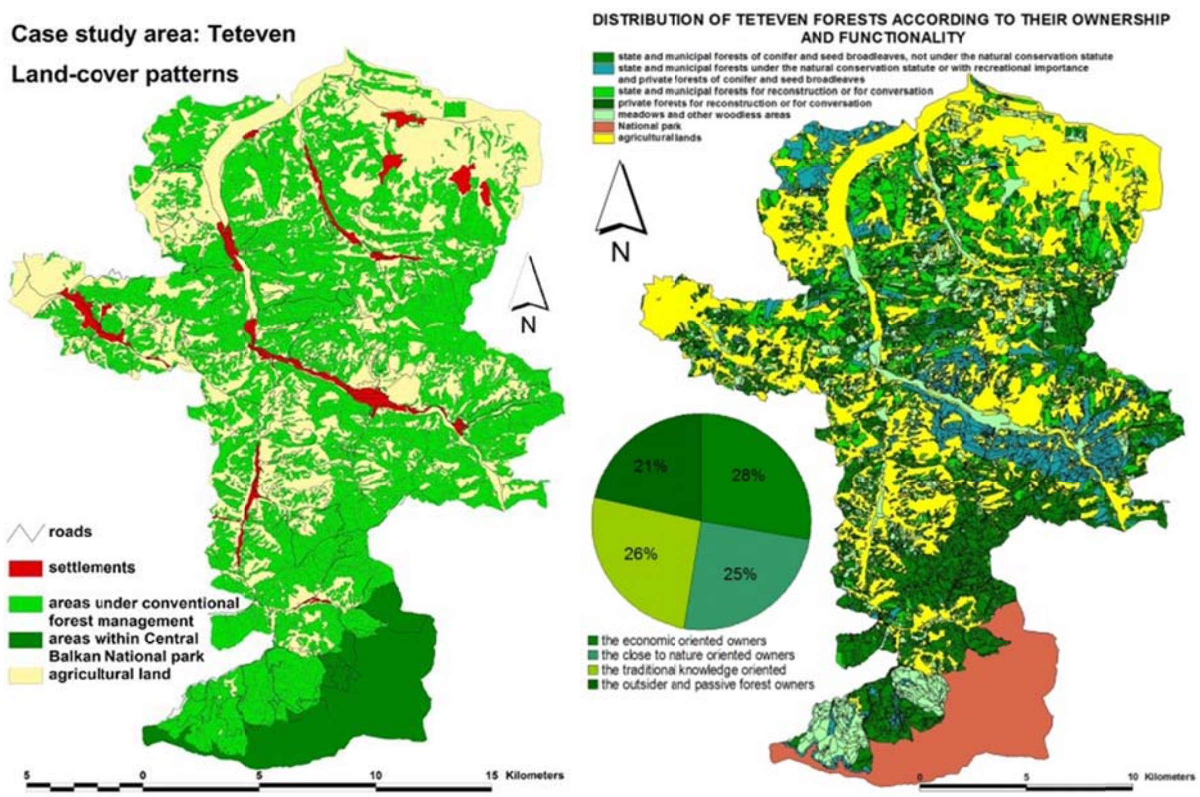


Figure 3: Land-cover map and distribution of Teteven forests according to their ownership and functionality.

DESCRIPTION OF THE DECISION SUPPORT SYSTEM

The Decision Support System (DSS) utilized for the analyses is SIBYLA, a Slovak developed software package, kindly provided to us by our colleagues of the Technical university in Zvolen. (Fig. 4)

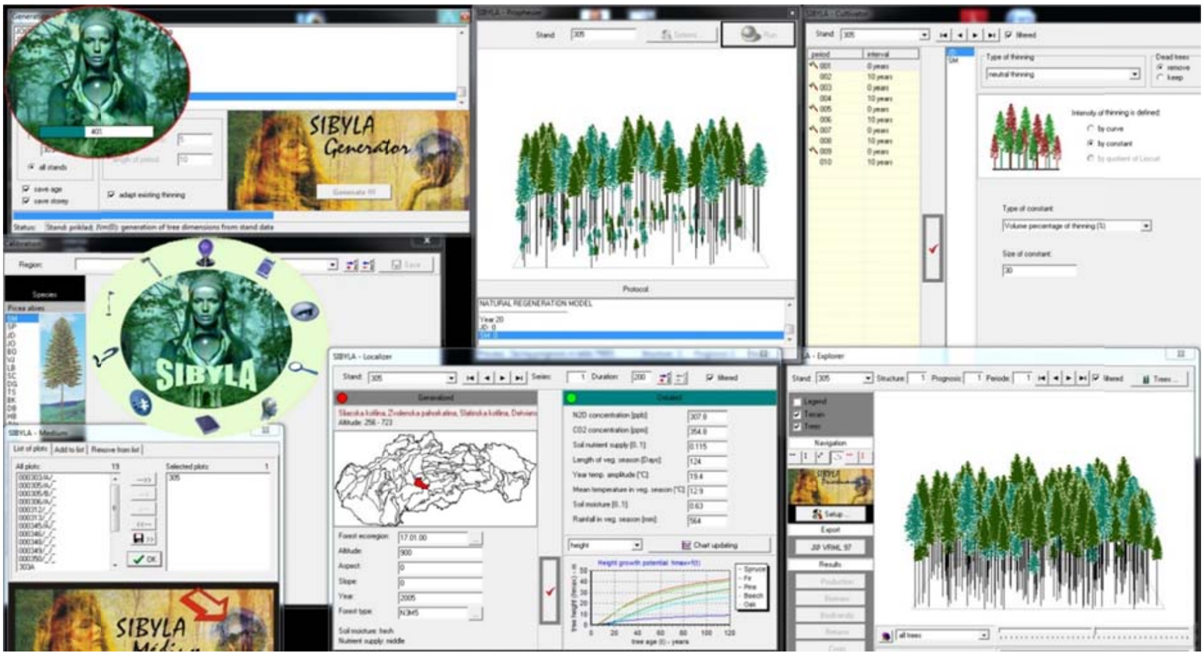


Figure 4: SIBYLA modules for generate data, selection forest stands and set up climate, soil and air characteristics for them, as well as set treatment measures and run growth simulations, and finally aggregate results of them.

SIBYLA is single tree based, with smallest growth period 1 year. The growth model is based on change of tree diameters, and tree heights. The exchange of parameters is based on modeling of growth potential. Growth potential is sensitive to site description: CO2 and NOx concentration in the air, soil moisture, soil nutrient content, mean temperature in vegetation period, annual temperature amplitude, precipitations in vegetation period, days of vegetation period. The potential is polymorphical interpolated from growth range. Crown parameters (diameters, base, shape and surface) are derived from tree heights and diameters. Stand growth is influenced by natural mortality of trees. Natural mortality depends on differences between current stand basal area and maximal basal area. Maximal basal area depends on upper height of stand. Selection of dead trees is solved by logistic regression depending on tree parameters. Eventually incidental cuttings are possible (by wind, snow, ice, bark beetles, foliage beetles, fungi, air pollution, fire, extreme dry conditions, and illegal cuttings). The model is heuristic and stochastic based. Stand production is influenced also by thinning. The following thinning are possible: from bellow, from above, neutral, crop trees oriented, target diameter oriented, target frequency curve oriented, and clear cutting method. The model includes stochastic components: generated residuals of diameter and height increments, tree mortality, and illegal cutting (if they are activated). The model can repeat structure generation and prognosis. Different results are produced. Mean values and standard deviations can be calculated. Differences between scenarios and variants can be statistically tested. [4]

CURRENT STATUS OF THE ES

According to the taxation descriptions from forest management plans the distribution of forest stands by their timber stock looks like it is depicted on Fig. 5.

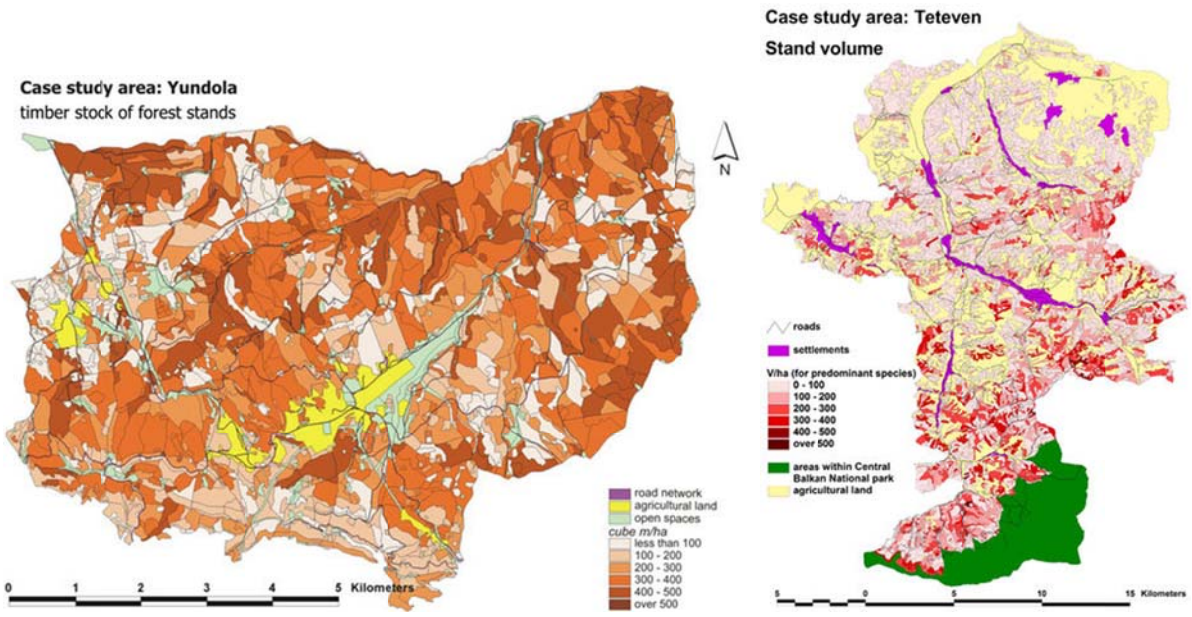


Figure 5: Forest areas classified by timber stock of forest stands.

The forests in Yundola have a timber stock of 1516503 m3.

Projected annual volume of the timber production of 21686 m^3 representing 1.43 % of the total timber stock. In the previous audit period (the previous decade), this value was 1.15 %.

The total timber production is distributed as:

- Large timber – 11434 m^3;
- Average timber – 3800 m^3;
- Small timber – 659 m^3;
- Firewood – 3249 m^3;
- Brushwood – 256 m^3.

The stock of forest stands within Teteven municipality ast is deite on the Fig.5 forest stands were differentiated into seven categories according to their timber stock per hectare. As limits for these categories are taken values multiples of 100 m^3/ha. The largest share have these forest stands with stocks 1–100 m^3/ha (57 % of the Forestry woodland), in the second place are these with stocks 101–200 m^3/ha (23 %), the third are these with stock 201–300 m^3/ha (14 %), fourthly are these with stock 301–400 m^3/ha (6 %) and finally are those with stock over 400 m^3/ha (less than 1 %).

POTENTIAL OF THE ES

The potential of the case study areas has been calculated in four sub analyses. For each subanalysis has been made eleven simulations according to different methods of forest stand tending:

- Strict restrictions in forest (Using no cutting model including mortality. Mortality is leave in forest.);
- Extended restrictions in forest (Using cutting model „Without cutting except mortality“ for all samples of forest stands);
- Restriction of today in forest area (Using cutting model „Thinning from below - stand density not less 0,7“ for all samples of forest stands);
- Restriction of today in forest area (Using cutting model „Neutral thinning – 15 %“ for all samples of forest stands);
- Maximum harvest (Using cutting model „Method of target diameter“). Consistently have been carried out

simulations with values: 18, 24, 30, 36, 42, 48 and 54 cm.

RESULTS

The results are published on the project website: https://forestwiki.jrc.ec.europa.eu/integral_devel/index.php/Category:Bulgaria

Volume production. Landscape capacity to supply woody biomass calculated on on real data from forest management plans, according to different methods of forest stand tending method. The production of forest landscape capacity has been calculated from real data (Forest management plan and inventory of forest) by taking a representative sample of forest plantations due to technical restrictions on the volume of output in one session of the program. The representative samples of inventory data use forest management plans. The sample consists of the largest in area stands containing all features and reproduces the structure of all stands in values needed as input information for performing simulations. (Table 1).

Table 1. Data from Forest management plan which were necessary as an input to SYBILA simulations.

Abbreviation	Field content	Metrics
species	tree species abbreviation based on tree species code list	code
d	tree species mean diameter in cm	cm
Vha	tree species stand volume per hectare in m^3	m^3
h	tree species mean height in m	m
t	mean age of tree species in years	age
percentage	proportion of a tree species from the number of trees in per cent	%
nutrient	soil nutrient supply (relative value in the range from 0 to 1)	code
season	number of days of the vegetation period (days with daily mean temperature above 10°C)	count
amplitude	annual temperature amplitude (the difference between annual minimum and maximum temperature in °C)	°C
temperature	daily mean temperature in vegetation period in °C (April to September)	°C
moisture	soil moisture (relative value in the range from 0 to 1)	code
rainfall	precipitation amount in vegetation period in mm (from April to September)	mm

Figures 6 and 7 show the dynamics of total volume (m^3) and of cutting volume (m^3) for both CSA according to the different forest stand tending methods in the time horizon of 50 years.

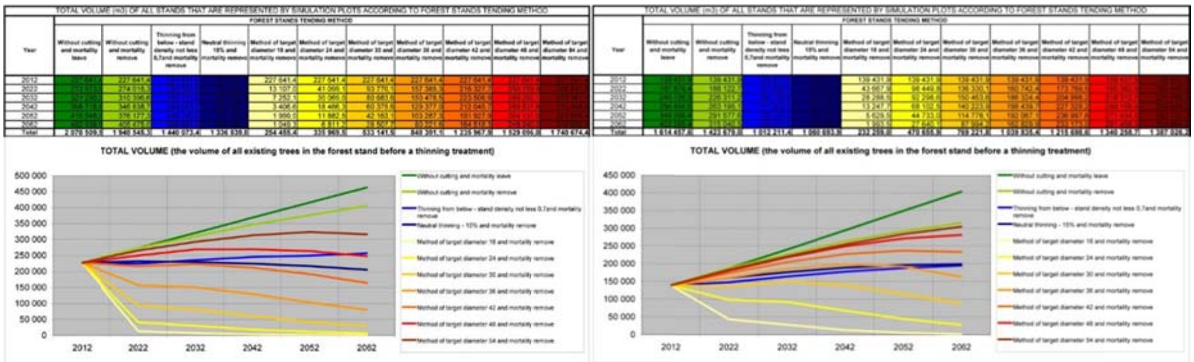


Figure 6: The dynamics of total volume (m^3) for Yundola (to the left) and for Teteven (on the right).

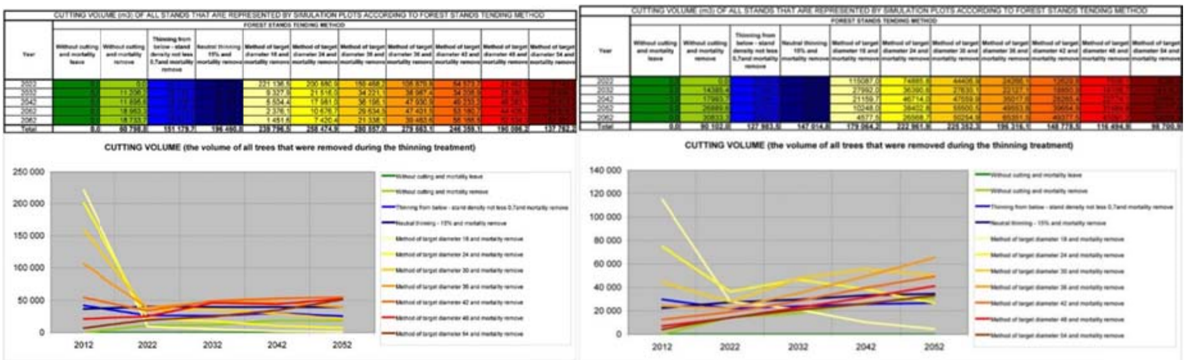


Figure 7: The dynamics of cutting volume (m^3) for Yundola (to the left) and for Teteven (on the right).

Quality of wood. Figures 8 and 9 represent the quality of wood as a percentage in years according to the different forest stand tending methods.

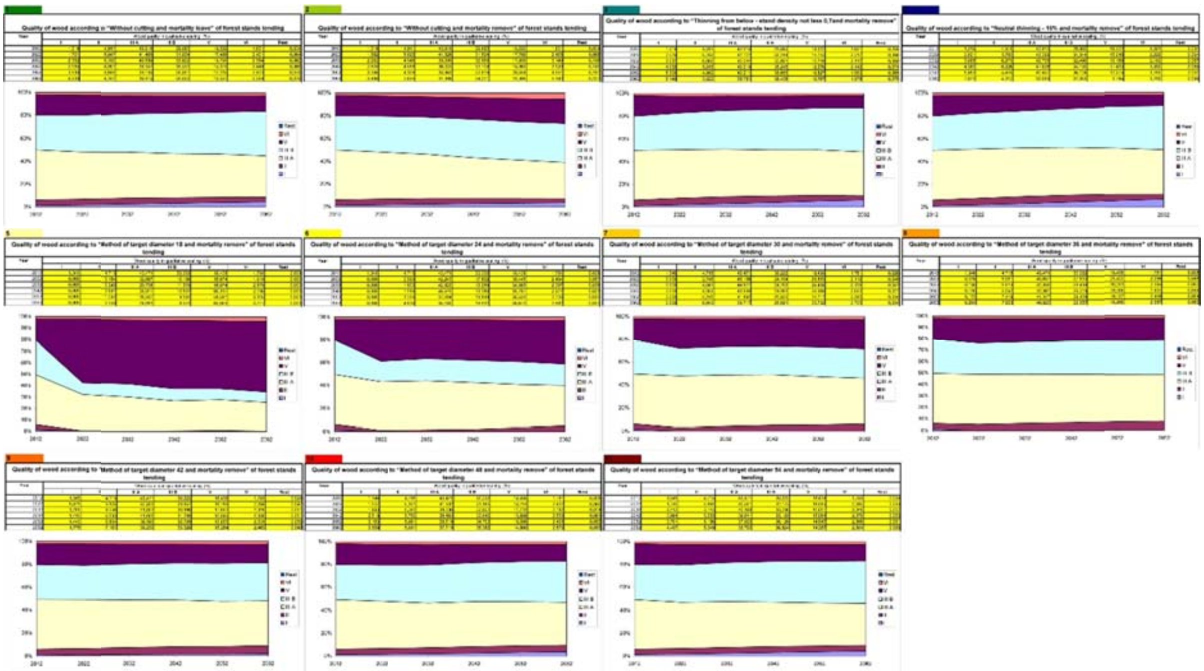


Figure 8: Quality of wood in CSA Yundola according to forest stands tending method.

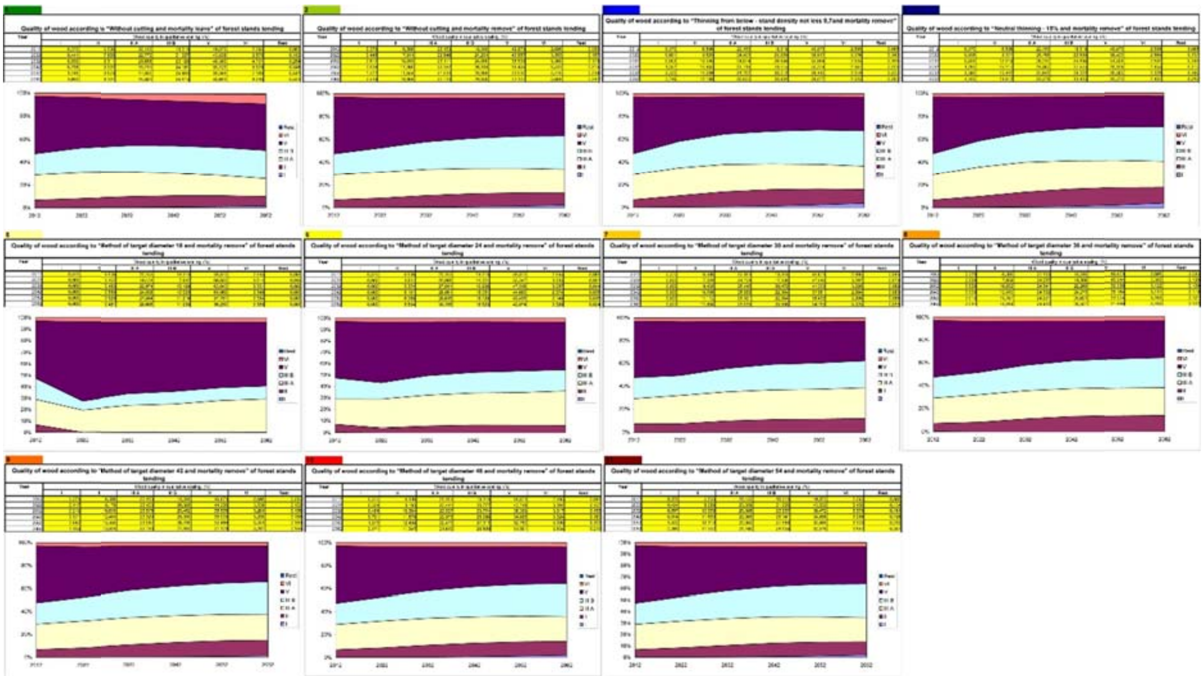


Figure 9: Quality of wood in CSA Teteven according to forest stands tending method.

Diversity of forest ecosystems depend on the synthesis of the expressed combinations of abiotic, biotic and anthropogenic influences.

The impact of selected management measures on forest diversity was simulated with Sibyla [4] in both two Bulgarian case study areas. For this analysis we selected representative sample of inventory data using forest management plans for chosen forest management units. However, each forest management unit has a different area, which affects mainly information on species diversity (known nonlinear relationship between the investigated area and species diversity). Considering the above, the analysis of the impact of management measures on the diversity of forests in case study areas, has been performed using the principles of rare-fraction method [6] https://forest-wiki.jrc.ec.europa.eu/integral_devel/in-dex.php/Kysuce – cite_note-Sanders-5 so that the number of species has been modeled on the area of forest unit. Comparing species richness is calculated at a standardized area of hypothetical samples. Due to time-demanding calculation, modeling of species richness was performed for three periods of the simulation, i.e. the beginning of the simulation, middle of the simulation and the end of the simulation at the age of fifty years.

For the evaluation of the structural diversity we used two indices: aggregation index R [3] (Fig. 10) and the index of differentiation TM [5] (Fig. 11 and 12).

Aggregation index R describes the horizontal distribution of trees using the ratio of the average distance between the central tree and its closest neighbors to the expected distance between them at random distribution of trees at the forest unit. Clark - Evans index R can theoretically take values from zero at the maximum clusters of trees to the value of 2.1491, which is reached by a regular hexagonal distribution of trees. The index value 1 says that trees are distributed randomly over the area of the forest. Forest stands with an index above 1 show a tendency towards regular distribution, while values below 1 represent a tendency towards clustering.

An important parameter of the structural diversity is differentiation of trees. We can calculate it from various tree parameters (diameter, circumference, basal area, height, and volume). For the calculation of the structural diversity tree diameter is often used, because it is easily detectable and easily measurable. Fuldner 1995 quantifies the differentiation index of TM. Index TM takes the values between 0 and 1. For forest, with small diameter variability of trees, index value of TM is close to zero. On the contrary, in forests with large variability of tree diameter, index value approaches the value of one. For better interpretation of the index, the author proposes to use the following differentiation scale: small (0.0–0.3), medium (0.3–0.5), strong (0.5–0.7) and very strong (0.7–1.0) differentiation.

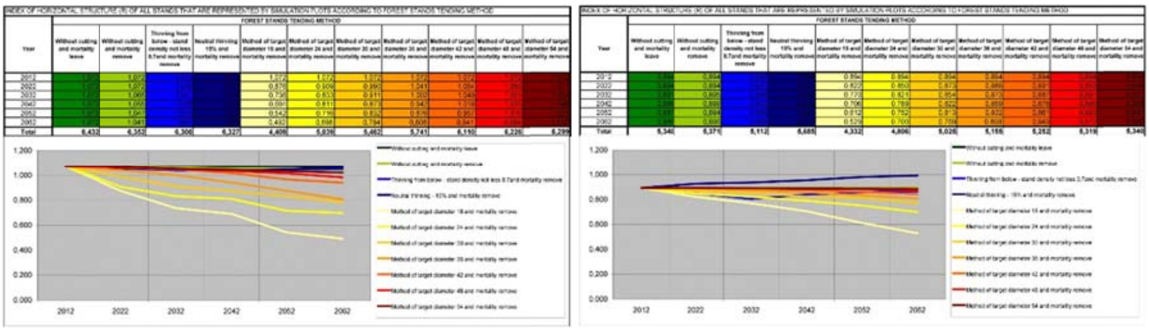


Figure 10: The dynamics of index of horizontal structure (R) according to forest stands tending method for Yundola (to the left) and for Teteven (on the right).

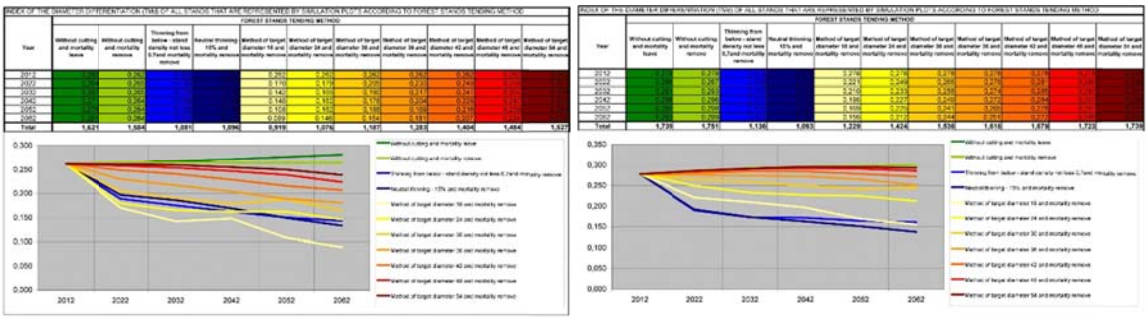


Figure 11: The dynamics of index of the diameter differentiation (TMd) according to forest stands tending method for Yundola (to the left) and for Teteven (on the right).

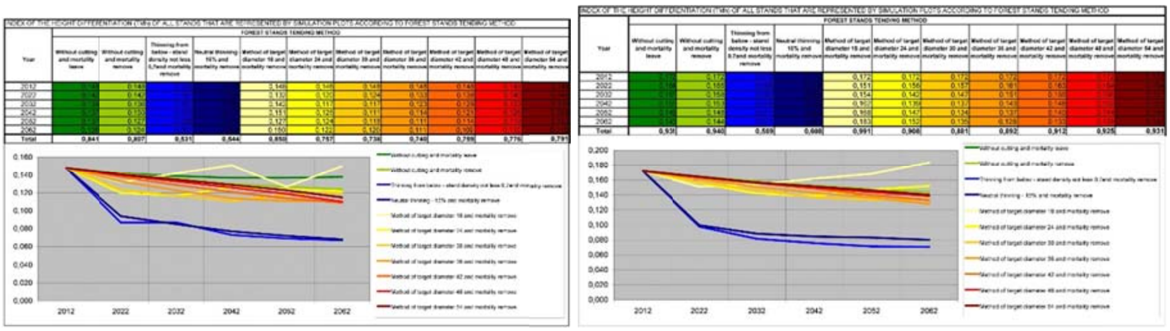


Figure 12: The dynamics of index of the height differentiation (TMh) according to forest stands tending method for Yundola (to the left) and for Teteven (on the right).

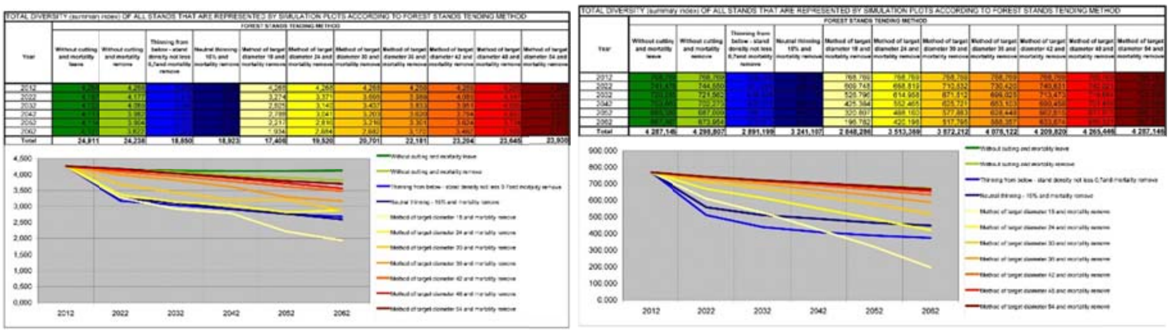


Figure 13: The dynamics of total diversity (summary index) according to forest stands tending method for Yundola (to the left) and for Teteven (on the right).

Figure 13 shows the dynamics of total diversity (summary index) according to forest stands tending method. Total diversity is the aggregation of partial components of diversity: tree species diversity, diversity of vertical structure, diversity of tree spatial distributions, and diversity of crown differentiations.

Total biomass production. Through simulation is traced dynamics (Fig. 14) of dry matter biomass (t) of the whole tree (includfing roots and stump, stem wood, stem bark, branches wood, branches bark and foliage – leaves or needles).

Figure 14: The dynamics of total diversity (summary index) according to forest stands tending method for Yundola (to the left) and for Teteven (on the right).

DISCUSSION

- Using no cutting model including mortality we observed clearly visible increase of all qualitative and quantitative indices of the Ecosystem Services.
- Using cutting model „Without cutting except mortality“ the increase is less than in the previous forest stand tending method.
- Using cutting models „Thinning from below“ and “Neutral thinning“ the values of the indices remain almost constant over the years and the line graph is almost horizontal. Such forestry practices can largely be treated as intermediate felling.
- Using cutting model „Method of target diameter 18 and mortality remove“ we get a maximum harvest but all of the qualitative and quantitative indices of the Ecosystem Services decrease dramatically. Such forestry practices can largely be treated as a final felling placed as now.
- Using the following cutting models where the diameter of the felling trees

gradually increased we observed gradually approach the values obtained in the intermediate fellings in varying degrees of intensity where the final fellings more or less take place at the end of the 50 year period.

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