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Ecological and economical impacts of climate change on Hungarian forestry practice

**Ernő Führer¹, Anikó Jagodics¹, István Juhász¹, György Marosi¹,
and László Horváth^{2*}**

¹*Hungarian Forest Research Institute, Paprét 17, 9400 Sopron, Hungary*

²*Hungarian Meteorological Service, Gilice tér 39, 1181 Budapest, Hungary,
and Plant Ecology Research Group of Hungarian Academy of Sciences
at Institute of Botany and Ecophysiology,
Szent István University, Páter K. utca 1, 2100 Gödöllő, Hungary*

**Correspondent author E-mail: horvath.l@met.hu*

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Abstract—As the result of the predicted climate change, not only the ecological circumstances but the profitability of forested areas will also change in the future in Hungary. The aim of this case study is to evaluate the expected ecological and economical impacts of a climate change scenario (REMO A1B) for three forest regions of Transdanubian Mountains (Bakony) for four climate indicator tree species (beech, hornbeam, sessile oak, and Turkey oak). According to this scenario, precipitation and air temperature increase by 5 percent and 1.3 °C, respectively in the spring months (March to May), while in summer (June to August) the precipitation decreases by 9 percent together with a higher temperature increase of 2.1 °C between the period of 2036 and 2065 compared to reference years (1961–2010). As a result of the forecasted climate change, a drift expected in forest climate classes towards the drier and warmer climate categories in Hungary, resulting in parallel decrease in production capacity of stands. We expect a significant area decrease in good forest yield classes together with an increase in poor categories. Hence, the annual revenues for the four indicator species will be lower by 9.4 percent compared to the reference period. The decrease in yield is caused by decrease of lumbered wood volume and more valuable wood assortments, as well. In case of the predicted climate scenario, the highest decay in production capacity will be expected for Turkey oak (12 percent), while the lowest for beech (7.5 percent).

Key-words: forest ecosystem, climate change, production capacity, forest yield classes, forest annual revenues

1. Introduction

The profitability of forestry practice is basically determined by ecological conditions beside the selection of tree species, the forestry practice applied, and the actual marketing circumstances (*Führer* and *Járó*, 1992). Namely, organic matter production of forests strongly depends on soil, hydrological, and climatic circumstances. While the quality of the first two site parameters can be considered as constant on short time basis, the climate, especially the magnitude and temporal variation of climate parameters show significant variability. Moreover, nowadays the change of climate can obviously be detected in Hungary, namely the climate becomes more and more warmer and drier as forecasted by *Bartholy et al.* (2009), *Faragó et al.* (2010), *Pieczka et al.* (2011), *Gálos et al.* (2007, 2012). In the forthcoming 50 years, frequency and strength of weather anomalies will be increasing. The evident, unfavorable changes in species composition, vitality, and growth of the forest ecosystems can be attributed to these changes according to numerous Hungarian forestry experts (*Berki et al.*, 2009; *Csóka*, 1996, 1997; *Csóka et al.*, 2007, 2009; *Czúcz et al.*, 2011; *Führer*, 1995; *Führer et al.*, 2011a,b; *Hirka* and *Csóka*, 2010; *Manninger*, 2004; *Mátyás*, 2010; *Mátyás* and *Czímber*, 2000, 2004; *Mátyás et al.*, 2010a,b, 2011; *Molnár* and *Lakatos*, 2009; *Solymos*, 2009; *Somogyi*, 2009; *Rasztovits et al.*, 2012).

Forestry, in practice, uses special climate categories represented by different tree species (*Járó*, 1972; *Führer*, 2010). These categories indicate different growing potential, therefore, any change in the area of climate categories accompanies with variation of organic matter production of the forest ecosystem (*Führer et al.*, 2011a,b). The forecasted warmer and drier climate in growing season would result in evident growth-loss of forest trees in Hungary; furthermore, a species composition change can also be expected on long-term time basis. The growth-loss can be indicated by the decrease in wood volume of an area unit. Considering that cost of logging are determined mainly by the actual marketing circumstances independently on climate change; final consequence of the loss in production will be the decrease of revenues and profitability of forestry practice.

The aim of this case study is to evaluate the expected ecological and economical impacts of a predicted climate change scenario for three forested regions of Transdanubian Mountains (Bakony) in Hungary (*Fig. 1*). In this work we investigate the climate of these state owned forests, the yield circumstances and potential revenues of climate indicator species, and the change of them as a result of climate change.

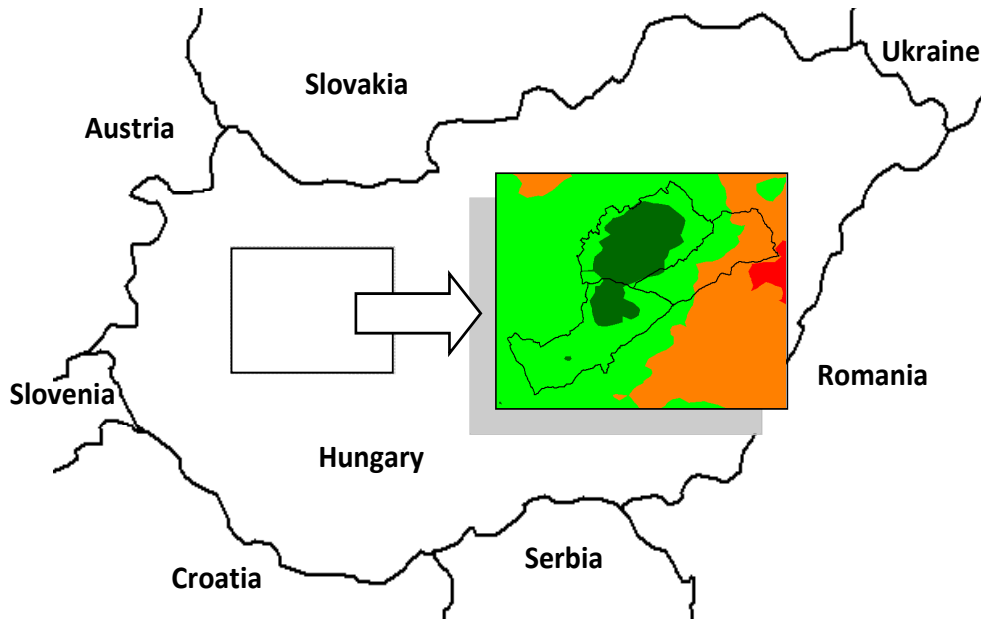


Fig. 1. Location of the three investigated forested regions in Hungary.

2. Methodology

The three forested test regions aimed in this study, in close connection each other, are the High-, South- and East-Bakony. Though these areas are part of the same geographical region (Mountains), they can be characterized by a variety of ecological (pedology, hydrology, climate) circumstances. Altitude of these areas varies within 150 and 700 meters above sea level influencing among others the climate.

In the High-Bakony, the ratio of forested area is 53 percent (35,711 ha). Ridges of High-Bakony heighten over 600 m above sea level, however, nearly 48 percent of forests are located between altitudes of 350–450 m. Rate of forests between 450–550 meters is 15 percent, and above 550 m only 3.5 percent of forest can be found. Rate of forests below the altitude of 350 m above sea level mostly lies between 250 and 350 m; below that the share of forest does not reach the 3 percent. Dominant species are: beech (39 percent), hornbeam (15 percent), Turkey oak (14 percent), and sessile oak (4 percent).

In South-Bakony, the ratio of forests is 48 percent (31,989 ha). Forests can dominantly be found between altitudes of 150 and 450 m. Altitude distribution of forests are as follows, 150–250 m: 29 percent, 250–350 m: 34 percent, 350–450 m: 33 percent, and >450 m: 4 percent. Dominant species are: beech (12 percent), hornbeam (12 percent), Turkey oak (40 percent), and sessile oak (5 percent).

In the lower East-Bakony, the ratio of forested area is only 38 percent (18,132 ha). 42 percent of the forests lie between 250 and 350 m, accordingly to the lower altitude of this region. The ratios of forests below 250 m and above 350 m are 22 and 36 percent, respectively. Dominant species are: beech (9 percent), hornbeam (7 percent), Turkey oak (29 percent), sessile oak (8 percent), downy oak (12 percent), and European black pine (11 percent).

These data clearly show that the share of climate sensitive test species (as beech, hornbeam, Turkey oak, and sessile oak) is the highest in High-Bakony (72 percent), while the ratios of these in South-Bakony and East-Bakony are only 69 and 53 percent, respectively. In latter forest region, drought tolerant tree species (as downy oak, European black pine) significantly appear. While the share of beech (preferring highland, cool, moist climate) is the highest in High-Bakony (39 percent) and lowest in lower East-Bakony (9 percent), the pattern of sessile oak (preferring hilly, warmer climate) is just the opposite.

Respecting that the three regions range from 150 m up to 700 m above sea level, climate categories are definitely separated, caused by vertical changes. In the first stage of our evaluation we have characterized the climate of the regions mentioned above and the stands according to forestry climate classification methods (Führer, 2010; Führer et al., 2011a, b) taking into account the growing circumstances of trees. The evaluation is based on precipitation and temperature data in those summer months when physiological processes are in intensive phase and 80–90 percent of organic matter production is realized (May to July) and in those (July, August) when growth of trees are limited by weather extremes. On the basis of meteorological data interpolated to the points of a Hungarian survey aiming the observation of forest stands growing (Kolozs, 2009) on a 2.8×2.8 km² grid, covering the regions, we have determined the distribution of different climate categories appeared in the examined forest regions by means of *forestry aridity index, FAI* (Führer, 2010; Führer et al., 2011a) calculated from meteorological parameters in main growth cycle (May–July) and in critical months (July–August). *FAI* can be derived as:

$$FAI = 100 \times \frac{t_{VII-VIII}}{(p_{V-VII} + p_{VII-VIII})} , \quad (1)$$

where $t_{VII-VIII}$ is the mean air temperature in critical months (July and August, °C), p_{V-VII} is the precipitation sum (mm) in the period from May to July, and $p_{VII-VIII}$ is the precipitation sum (mm) in the warmest (critical) months (July and August).

Then, we have collected the production capacities (from 1st to 6th forest yield classes) of state owned forests in different climate categories from the National Forest Database of Hungary, and we have evaluated the potential organic matter production in different climate categories. Test species

representing the forestry climate classes were involved in the evaluation, namely the beech (*Fagus sylvatica* L.), hornbeam (*Carpinus betulus* L.), sessile oak (*Quercus petraea* (Matt.) Liebl.), and Turkey oak (*Quercus cerris* L.).

Each forest yield class can be characterized by an annual average yield at the cutting age depending on tree species and actual marketing conditions. The change in yield of wood production and wood marketing is a suitable index for quantification of the economic impact of climate change. For this reason, in the economical evaluation we have determined the estimated yield of the test stands for each yield classes. Principle of the estimation was the yield of timber during wood harvesting operations in cutting cycle. Hence, revenues depend on the species, amount and quality of timber, and assortment composition. Respecting the available data for size and assortment composition of yield, separated for the target stands and for forest yield classes for the whole cutting cycle on the basis of previous investigations (Márkus and Mészáros, 2000; Marosi *et al.*, 2005), we have calculated the expected revenues. Annual rate of this parameter gives the mean revenues of the given yield class.

The economical influence of spatial realignment of the investigated stands, as a consequence of climate change, can be calculated by the method described above. Consequently, the product of the average annual yield of yield classes and area of the stand give the average yield of the given investigated forest stand.

We can estimate the change of this index in estimating the expected variation in area of different climate categories and the potential production capacity taking into account the climate scenarios. We have calculated with a climate change scenario, where the predicted changes in climate parameters to the reference climate period (1961–1990) are given for the period of 2036–2065. The scenario describes the expected changes in the investigated regions according to the A1B emission scenario of the REMO regional climate model (Gálos *et al.*, 2007). Hence, in the spring months (March to May) the precipitation and air temperature increase by 5 percent and 1.3 °C, respectively, while in summer (June to August) the precipitation decreases by 9 percent together with higher temperature increase of 2.1 °C compared to the period 1961–2010.

3. Results and discussion

3.1. Climate of studied forest stands

The Transdanubian Mountains (Bakony) have temperate cool and wet climate with prevailing wind of NW. In Hungary, forestry practice - depending highly on weather conditions - uses special climate classes; hence the different climate categories are represented by climate indicator test species. Accordingly, the coolest/most humid and warmest/most arid climates are represented by beech

and forest-steppe climate, respectively. In the middle there are hornbeam-oak climate close to *beech*, and sessile oak-Turkey oak close to forest-steppe climate. The yearly precipitation of originally treeless forest-steppe climate zones is not enough for production of native species, while sessile oak-Turkey oak climate is represented by these two species either together or separately. Precipitation and temperature characteristics of different climate categories are described in details by *Führer et al.* (2010, 2011a). On the basis of homogenized and interpolated meteorological data, the climate and the expected changes in different regions of Bakony can be characterized as follows.

In High-Bakony region the average yearly precipitation and the annual mean air temperature were 737 mm and 8.8 °C, respectively, between 1961 and 1990. Both are in the interval representative for beech climate (752±31 mm, 8.8±0.9 °C). The average temperature in the main growing period (16.1°C, May-July) and in critical months (18.0 °C, July-August) are lower than the averages of beech climate categories (16.6±0,8 and 18.5±0,8 °C). Precipitation amount for the same period (226 and 158 mm) are 10 and 5 percent lower than representative value for beech climate (259±13 and 167±9 mm). The main *FAI* for this region is 4.69 close to the upper limit of beech climate category ($FAI_B: \leq 4.75$). On the basis of *FAI* calculated for the climate reference period (1961–1990) a total of 59 percent of this region lies in beech climate, while remaining part can be represented by hornbeam-oak climate (*Fig. 2*). In case of climate change according to the predicted scenario, the mean of *FAI* increases up to 5.59 hence there will be no longer beech climate in that region, moreover, 13 percent of the High-Bakony will be represented by sessile oak-Turkey oak climate.

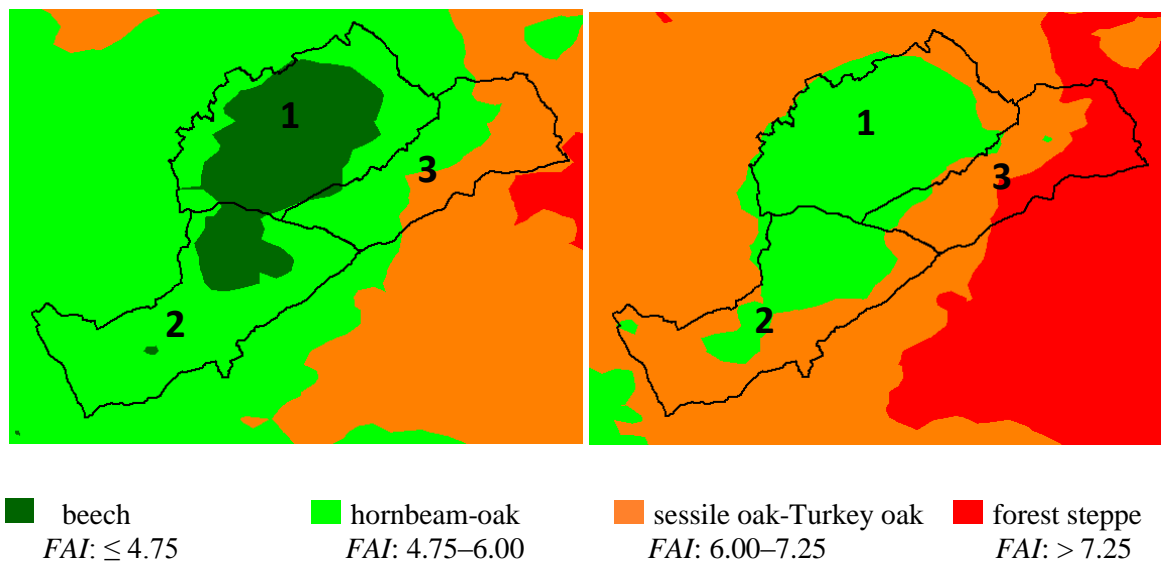


Fig. 2. Distribution of climate classes according to *FAI* in the examined forest regions; left: in the reference years (1961–1990), right: in case of the predicted scenario.

In the South-Bakony region, the average yearly precipitation and the annual mean air temperature were 693 mm and 9.4 °C, respectively, between 1961 and 1990 corresponding to the averages of hornbeam-oak climate (663 ± 55 mm, 9.4 ± 0.7 °C). Average temperature in the main growing period (May-July) is 16.7°C, while in the critical months it is 18.6 °C, i.e., temperature circumstances are representative rather for the cooler *beech* climate. However, precipitation data in the same period (219 and 150 mm) is representative again for hornbeam-oak climate (218 ± 15 and 139 ± 13 mm). For this region the *FAI*, as an overall index, is 5.03 referring to the hornbeam-oak climate (4.75–6.00). The share the climate classes here is 20 percent beech and 80 percent hornbeam-oak. In case of climate change scenario, the predicted average *FAI* increases up to 5.98, which is practically at the borderline between the hornbeam-oak and the sessile oak-Turkey oak climates. In this case, 44 percent of the region would be representative for hornbeam-oak and the remaining part to the sessile oak-Turkey oak climate. On the basis of this prediction, total extinction of beech zone is expected (*Fig. 2*).

In the East-Bakony region, the average yearly precipitation and the annual mean air temperature were 634 mm and 9.3 °C, respectively, between 1961 and 1990. These values are close to hornbeam-oak climate (663 ± 55 mm, 9.4 ± 0.7 °C), similarly to the average temperature in main growing period (17.3 °C) and in critical months (19.4 °C). On the other hand, the precipitation amount in these months are lower (198 and 132 mm) than favorable for hornbeam-oak climate (218 ± 15 and 139 ± 13 mm). Average *FAI* in this region is 5.88 close to the borderline between the hornbeam-oak and sessile oak-Turkey oak climates (6.00). The share of the beech, hornbeam-oak, and sessile oak-Turkey oak climates in this region is 2, 51, and 47 percent, respectively (*Fig. 2*). In case of the predicted climate scenario, the average *FAI* changes to 6.95 and the share of different climate categories would change to hornbeam oak: 9, sessile oak-Turkey oak: 51, and forest steppe: 9 percent ratios.

Average *FAI* for the total areas of the three regions (High-, South-, and East-Bakony) in the reference years is 5.09, lying in the favorable side of hornbeam-oak climate (close to the beech climate). This value would change to 6.05 (nearly by one *FAI* unit) in case of the predicted climate scenario. It means that, in the area of the three regions, 30 percent of beech climate would disappear, the share of hornbeam-oak climate would decrease from 58 to 52 percent; the ratio of sessile oak-Turkey oak climate would increase from 12 to 32 percent, while forest steppe climate would appear sharing 10 percent in the region.

The total surface area of the three Bakony regions is 179,621 ha; ratio of forested areas is 48 percent (85,752 ha). In our study only the state owned forests (64,957 ha) are involved, where the share of beech, hornbeam-oak, and sessile oak-Turkey oak climates are 36, 57, and 7 percent, respectively. Classification of the Forest Database (*MGSZH*, 2008) based on climate indicator

tree species differs from our results: the share of the climate is 41 percent beech, 33 percent hornbeam-oak, and 26 percent sessile oak-Turkey oak climate (*Table 1*).

Table 1. Distribution of forest yield classes according to the forest management plan and the *FAI* for state owned forests in the examined regions (in percent)

climate classes	High-Bakony		South-Bakony		East-Bakony		Bakony	
	plan	<i>FAI</i>	plan	<i>FAI</i>	plan	<i>FAI</i>	plan	<i>FAI</i>
beech	78	67	17	23	15	3	41	36
hornbeam-oak	21	33	44	77	36	70	33	57
sessile oak-Turkey oak	1	0	39	0	49	27	26	7

Regarding this distribution in lower scale, the differences are higher. In High-Bakony, 78 percent of the state owned forest are in beech zone, followed by hornbeam-oak climate (21 percent) and the ratio of sessile oak-Turkey oak climate is only 1 percent. In contrast in South-Bakony, hornbeam-oak climate is the dominant (44 percent), while ratio of sessile oak-Turkey oak and beech climates is 40 and 16 percent, respectively. In the East-Bakony region, the share of climate zones is: 49 percent of sessile oak-Turkey oak, 36 percent of hornbeam-oak, and only 15 percent of beech.

Classification according to forestry aridity index (*FAI*, Eq. 1) differs from figures above. Taking into account the period of 1961-1990 as reference, the ratio of the beech climate in High-Bakony, South-Bakony, and East-Bakony are 67, 21, and 2 percent respectively. The ratio of the hornbeam-oak climate is highest in South-Bakony (77 percent), a little lower in East-Bakony (71 percent), while in High-Bakony it is only 33 percent. Significant share of sessile oak-Turkey oak climate can be found in East-Bakony (27 percent).

It seems that the difference between the two classifications is lower for High-Bakony with cooler and wet climate, compared to the other two drier and warmer Bakony regions (*Table 1*). Remarkable, that for latter regions the sessile oak-Turkey oak climate shares significant areas according to the forest management classification plan (South-Bakony 39; East-Bakony 49 percent). Explanation for this is that in forestry practice, the sessile oak-Turkey oak climate was classified according solely to the Turkey oak species. In contrast, nowadays, owing to the appropriate forestry practice the majority of Turkey oak trees can be found in hornbeam-oak climate zones. Reasons can be traced back to the practice in the 19th and 20th centuries, when two of the main aims were to satisfy the rapidly increasing firewood demand and the utilization of rich acorn yield as mast (rearing of pigs).

The difference between the two classifications underlines the necessity that the data in Forest Database – possible subjects of modification according to the

actual species selection policy – must be supervised in the future. It is also important, since the reference basis in evaluation of impact of expected climate change in connection to tree species may have high influences to the outcome, i.e., the measure of changes.

3.2. Composition of production capacity of regions and its change according to the predicted climate scenario in state owned forests

3.2.1. Production capacity of tree species of different regions

Wood production capacity of a given site is characterized by the sum of annual average growth calculated up to the critical cutting age, and it can be classified into good (1st and 2nd), medium (3rd and 4th), and poor (5th and 6th) classes. On the basis of the Forest Database, the investigated regions can be characterized as follows, good: 24, medium: 40, and poor: 36 percent (MGSZH 2008) (Fig. 3). More favorable conditions are in High-Bakony, where share of classes 1st and 2nd is 46 percent, in contrast with other two regions where only 8–9 percent of trees are in the good classes. In East-Bakony, 65 percent of trees are in the poor category, where circumstances for production are less favorable mainly due to the unfavorable, climate for the given species composition. In South-Bakony, the majority of stand belongs to the medium (48 percent) and poor (43 percent) categories.

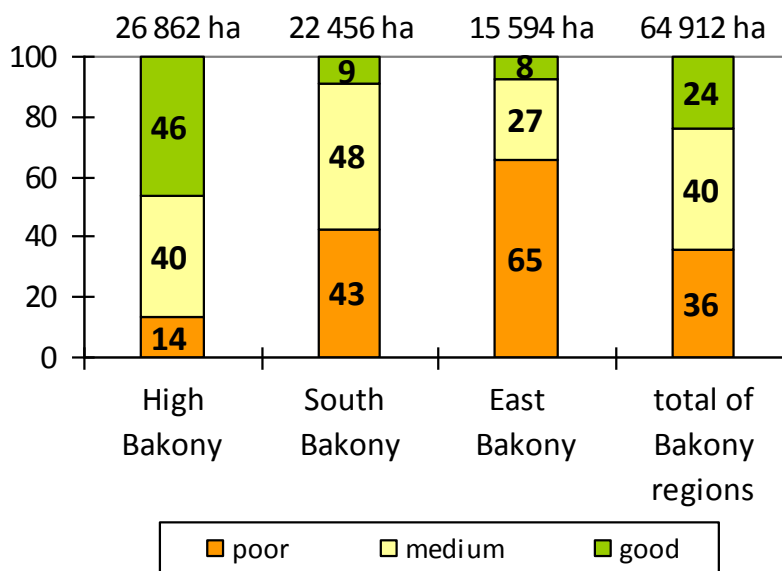


Fig. 3. Distribution of forest yield classes in the *Bakony* regions (in percent).

On the basis of distribution of forest yield classes (from 1st to 6th), the calculated average production capacity index (average of area weighted yield classes) in High-Bakony is 3.1, in South-Bakony its value is 4.2 due to the more unfavorable ecological conditions, and it is the worst in East-Bakony (4.9), as a

consequence of most unfavorable conditions in this region. It is evident, because the share of different climate categories differs for the different regions (Table 2), and the production capacities of climate categories are also different (beech climate: 2.9, hornbeam-oak climate: 4.3, and Turkey oak- sessile oak climate: 5.1).

Respecting the large differences among the climate conditions for the different investigated regions, we have examined whether these differences appear in production capacity of test species. Area covered by test species in the state owned forests is 44,884 ha, with largest share of Turkey oak (17,941 ha), followed by beech (15,459 ha), hornbeam (7,516 ha), and sessile oak (3,968 ha).

It is evident, that among the three regions the structure of forest yield classes of test species is most favorable in High-Bakony, where the share of good class is the highest, while poor categories represent the lowest area (Fig. 4). Conversely, the worst conditions are in East-Bakony. Average production capacity index for beech is 2.5, 3.1, and 3.3 in High-, South-, and East-Bakony, respectively. Difference among regions is higher in case of Turkey oak, where indices for the regions above are 3.3, 4.3, and 5.0. For all of four test species the difference is larger between High- and South-Bakony than between South- and East-Bakony, showing that climate of latter two regions are closer and highly differs from that of High-Bakony. Average tree production capacity index for the group of three regions is the lowest for beech (2.6), followed by hornbeam (3.5), sessile oak (4.0), and Turkey oak (4.2).

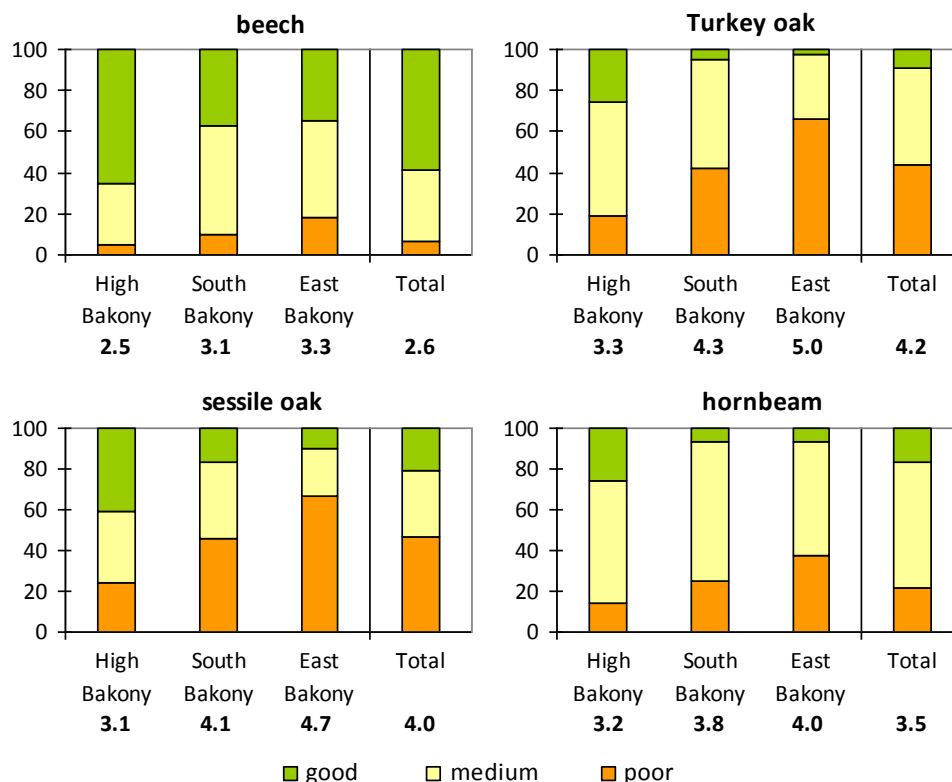


Fig. 4. Structure of forest yield classes in the examined regions (in percent).

3.2.2. Expected change in production capacity of test species for the examined regions

As it was mentioned above, four test species only in areas of state owned forests were involved in evaluating the change of area of climate classes according to the predicted climate scenario. Share of state owned forests in the three regions is 52 percent. On the basis of evaluation, the ratio of good yield classes decrease in the direction from beech to sessile oak-Turkey oak climate for four test species (Fig. 5). Ratio of stands in poor categories is considerably increased for hornbeam, sessile oak, and Turkey oak. For beech in Turkey oak climate, even the ratio of medium category remarkably increases as well. Certainly, the effect of climate involving the effectiveness of precipitation is influenced by the properties of underlying soil in high extent. E.g., there are stands in poor class in soils with thin organic layer or with wrong mechanical parameters even in favorable climate conditions; and vice versa, stands over deeper and better structured soils can utilize the precipitated water effectively, increasing the organic matter production.

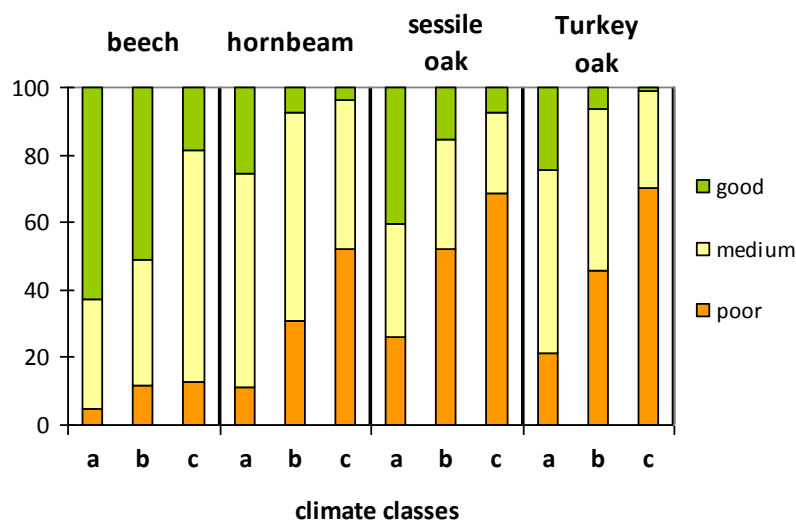


Fig. 5. Distribution of climate indicator tree species in the climate classes according to forest yield classes (in percent). Climate classes: a= beech, b=hornbeam-oak, c= sessile oak-Turkey oak.

By means of the aridity index (*FAI*), we can predict that majority of *beech* climate –calculated using the basic climate reference period (1961–1990) – will be moved to hornbeam-oak climate as a consequence of even a minor summer temperature increase at the examined three Bakony regions. According to the predicted scenario, when higher temperature increase and minor decrease in precipitation amount can be expected in summer season, the beech climate completely disappears, all of them will be moving towards hornbeam-oak climate. In turn, half area of former hornbeam-oak climate will be dominated by Turkey oak climate. Accordingly, the climate dependent tree production

capacity most likely changes; pattern of forest yield class of beech climate declines to hornbeam-oak, while latter declines to sessile oak-Turkey oak climate (*Fig. 6*). Namely, we can expect a decrease in production capacity of stands, even at constant soil properties; i.e., area of good production capacity decreases from 12,781 to 5,058 ha, together with an increase of poor area from 12,339 to 21,401 ha.

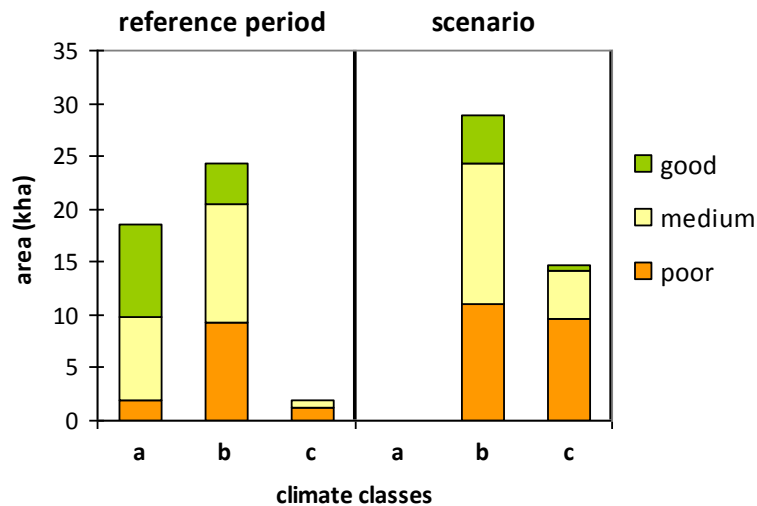


Fig. 6. Distribution of forest yield classes in climate classes in the reference period (1961–1990) and in case of predicted scenario. Climate classes: a= beech, b=hornbeam-oak, c=sessile oak-Turkey oak.

3.2.3. Yield indices of test species and their change in the investigated forest regions

It can be clearly seen from the specific revenues of forest yield classes calculated for the four climate indicator tree species (beech, hornbeam, Turkey oak, and sessile oak), that revenues for beech and sessile oak in good (1st and 2nd) classes is remarkably higher than that of for hornbeam and Turkey oak (*Marosi et al., 2005*) (*Table 2*).

Table 2. Average revenues of forest yield classes for each climate indicator tree species (in KHUF ha⁻¹ year⁻¹) (*Marosi et al., 2005*)

yield classes	beech	hornbeam	sessile oak	Turkey oak
1st	129	55	129	62
2nd	108	46	108	53
3rd	77	37	83	42
4th	62	29	68	35
5th	43	21	51	25
6th	29	16	37	19

From the point of view of wood industry, the beech and oak are much more valuable than the hornbeam and Turkey oak, however the difference is continuously decreasing to the direction of less favorable ecological circumstances, more in case of beech and less for sessile oak. As previous investigations in Hungary have shown, stands in poor yield classes (5th and 6th) still do not produce any profitability.

For the 45 kha of state owned forests in the three Bakony regions, based on revenues concerning to different yield classes, we have estimated the expected economical effect of the climate change according to the forecasted scenario. As it has already been demonstrated, the expected climate change reduces the production capacity of forests. In practice, it appears in the change of the ratio of different forest yield classes. Area of good classes significantly decreases with parallel increase of poor classes, hence, available revenues decreases accordingly, as lumbered wood volume and the ratio of more valuable wood assortments decrease as well (*Fig. 6*). Specific expenses of forest management do not change significantly hence the fewer revenues appear in the decrease of profitability. In this study we disregard the case when ecological changes require the change (replace) of tree species. Naturally, in this case as a consequence of further increase of expenses, profitability would be even less depending on kind of tree species and on the technology applied.

Referring the average change of revenues to ha unit, it is highest for sessile oak (7.893 kHUF ha⁻¹, followed by beech (6.941 kHUF ha⁻¹), hornbeam (4.098 kHUF ha⁻¹), and Turkey oak (3.920 kHUF ha⁻¹) (*Fig. 7*).

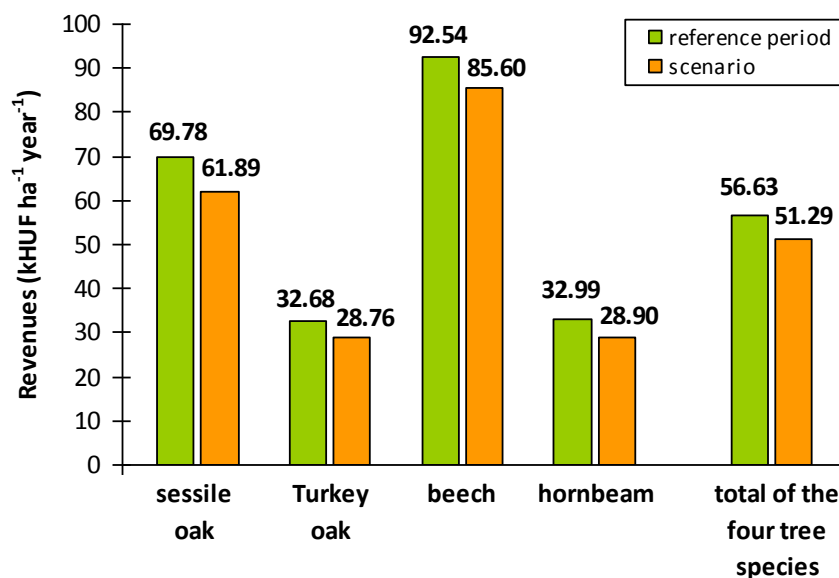


Fig. 7. Average annual revenues of test species in the examined forest regions in the reference period (1961–1990) and in case of the predicted scenario.

Calculating with the scenario predicted, the revenues will be lower by 9.4 percent for the four test species. It means that the state forest companies expect only 2.302 billion HUF (10.56 million USD) instead of 2.542 billion HUF (11.66 million USD) in the 45 kha area for the middle of this century, at the present price level. This rate of deficit may query the profitability of forest management. The four test species respond to the climate changes in different extent; highest deficit can be expected for Turkey oak and lowest for beech.

4. Conclusions

The predicted climate change probably influences the profitability of forest management besides the ecological circumstances of forested areas. We have estimated the expected changes to the A1B climate scenario for the case of test species locating in a group of Hungarian forest regions (High-, South-, and East-Bakony). The average measure of the predicted scenario between years of 2036–2065 compared to the reference period (1961–1990) is the follows: in the spring months (March-May) the precipitation decreases by 5 percent, the air temperature increases by 1.3 °C, while in the summer months (June-August) the precipitation decreases by 9 percent parallel with a dramatic temperature increase of 2.1 °C.

The average calculated forestry aridity index (*FAI*) for the three investigated Bakony regions in the reference period (1961–1990) is 5.09 favoring to hornbeam-oak climate. In these areas the dominating climate zones are *beech* (36 percent), hornbeam-oak (57 percent), and sessile oak-Turkey oak (7 percent) (*Fig. 2*).

On the basis of the predicted scenario, *FAI* increases to 6.05 extremely enlarging the share of sessile oak-Turkey oak zones dominating in East-Bakony, while hornbeam-oak climate will be representative in High-Bakony. In South-Bakony, hornbeam-oak and sessile oak climates will equally be characteristic.

As to the productivity we find the best conditions in High-Bakony (*Fig. 3*), where the ratio of good yield classes is higher, in contrast with the two other regions, where good classes share the lowest ratio of areas. Two-third of East-Bakony areas belong to the poor yield classes.

According to the assessment of climate, classes the ratio of good classes definitely decreases from beech to sessile oak climate in case of four climate indicator species (*Fig. 4*). At the same time, the share of poor yield classes significantly increases for hornbeam, sessile oak, and Turkey oak.

As a response to climate change – according to the scenario discussed – we expect a shift in climate classes resulting in decay in production capacity even at constant soil conditions, i.e., share of good classes decreases with parallel increase of poor classes.

For the four climate indicator tree species, the annual average revenues will be lower by 9.4 percent compared to the reference period in the forecasted interval (Fig. 7). There are two reasons of that, on one hand the volume of yield, and on the other, the ratio of valuable assortments will also be lower.

The respond of four species are different. In the case of predicted climate scenario, the highest decay in production capacity will be expected for Turkey oak (12 percent), while the lowest for the beech (7.5 percent).

Expected unfavorable ecological effect of climate change can be a high risk for forest management. Today, the conservation of forests can be financed exclusively by revenues of selling wood products on the market. If the revenues decrease as calculated above and there will not be other available sources to finance then the steady maintenance of forests will be questionable in lack of profitability of forest management.

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