

## Effects of Climate Change on Litter Production in a *Quercetum petraeae-cerris* Forest in Hungary

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**Abstract** – Climate change is a global problem. During the last century the increase of annual average temperature was 0.68°C, while the decrease of annual average of precipitation was 83 mm in Hungary. According to the long term meteorological data of Síkfőkút forest ILTER site the annual average temperature increased while average of yearly precipitation decreased, the forest climate became warmer and dryer. These processes could considerably contribute to forest decline, not only in the *Quercetum petraeae-cerris* stand of Síkfőkút, but everywhere in the country. Species composition and structure of the forest have changed considerably, as 68% of sessile oak (*Quercus petraea*) and 16% of Turkey oak (*Quercus cerris*) have died. Forest decline resulted in the breaking up of the formerly closed canopy, and consequently, in the formation of gaps in the forest. In the gaps, a secondary canopy developed with tree species of less forestry value. As a consequence, mass regeneration of field maple (*Acer campestre*) appeared in the gaps. The formation of gaps accelerated the warming and aridity of forests. In the article we answer the following question: how did climatic change and changing forest structure influence the leaf-litter production in the last four decades?

**oak forest / oak decline / Síkfőkút Project / litter production / climate change**

**Kivonat** – A klímaváltozás hatása egy Magyarországi cseres-tölgyes erdő avarprodukciónjára. Napjainkban a klímaváltozás egy globális probléma. Magyarországon az elmúlt évszázad folyamán az évi átlagos hőmérséklet 0,68 °C-ot emelkedett, az évi csapadék átlag 83 mm-t csökkent. A Síkfőkút Project korábbi, közel 20 éves meteorológiai adatai is bizonyítják a klímaváltozást, az erdő klímája melegebbé és szárazabbá vált. Mindezen folyamatok is hozzájárulhattak ahhoz a fapusztulási folyamatokhoz, amely nem csak a Síkfőkúti tölgyes állományt, de az ország számos állományát érintette. Az erdő fafaj összetétele és struktúrája jelentős mértékben megváltozott, a kocsánytalan tölgy 68%-a, a csertölgy 16%-a kipusztult. A fapusztulás következtében a korábbi zárt lombkorona felnyílt, az elpusztult fák helyén kisebb nagyobb lékek alakultak ki, amelyekben erdészeti szempontból kevésbé értékes fafajok nőttek fel és hozták létre a második lombkoronaszintet. Ennek köszönhető a mezei juhar tömeges megjelenése és térhódítása a lombkoronaszintben. A lékek kialakulása, a klímaváltozás hatását fokozva, felgyorsította az erdő felmelegedését és szárazodását. Jelen dolgozatunkban arra kerestük a választ, hogy a klímaváltozás, és ezen keresztül az erdő struktúrájának a változása hogyan befolyásolta az avarprodukción az elmúlt négy évtized folyamán.

**tölgyerdő / tölgypusztulás / Síkfőkút Project / avarprodukción / klímaváltozás**

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## 1 INTRODUCTION

Litter fall exerts a great influence on physical, chemical and biological characteristics of soil (Pande et al. 2002). Litter production in forest ecosystems is determined by climatic condition, species composition and successional stage (Haase 1999). Factors like climate, season, canopy architecture, timing of canopy gap formation and insect outbreaks govern the dynamics of the forests in terms of its structure and function of this ecosystem (Sukumar et al. 1992).

In Hungary, the annual average temperature increase was 0.68 °C, while the annual average of precipitation decrease was 83 mm during the last century (Szalai 2004, Jolánkai et al. 2004). During the last few decades the long-term meteorological data of the Síkfőkút Forest have followed the global climate change, the forest climate became dryer and warmer. Due to the climate change the forest structure and species composition have been changing dramatically. Since 1972 68% of *Quercus petraea* and 16% of *Q. cerris* trees died and in the gaps new tree species (*Acer campestre*, *A. tataricum*, *Cerasus avium*, *Carpinus betulus*) have grown up from the shrub layer into the canopy layer (Bowden et al. 2006, Kotroczó et al. 2007). The new species created a second canopy layer. Forest decline has been reported since the beginning of the 1970s in Central Europe as well as in North America (Siccama et al. 1982, Klein – Perkins 1987, Bruck – Robarge 1988). Subsequently, the extension of mortality became a chronic problem in the European oak forests (Gaertig et al. 2002, Thomas et al. 2002, Mátyás 2004, Helama et al. 2009, Mátyás 2010). Extensive decay of sessile oak has been reported in numerous European countries (Brasier et al. 1993, Chappelka – Freer-Smith 1995, Thomas – Büttner 1998).

At the Síkfőkút site (Hungary), decline affected both forest stand components (sessile oak – *Quercus petraea* and Turkey oak – *Q. cerris*) however, it affected sessile oak considerably stronger. In case of Turkey oak, higher vitality can be explained by its better adaptability to warming and drying climate. The adaptability is presumably connected to the higher water storage capacity which was pointed out inside the trunk of this submediterranean oak species (Béres et al. 1998). As compared to the survey which was carried out in 1973 (Jakucs 1985), no regeneration of oak appeared on the study area during the last few decades, although it may be suspected that game damage contributed to this situation. Mass regeneration and spreading of common maple characterizes the canopy level. Gaps in the canopy level accelerated the warming and aridification of the forest.

How the litter production is influenced by climate change, is still relatively unknown. Some authors (Tóth et al. 2007) predicted that although warming may increase litter production, aridity reduces litter production, and the combined effects of the two processes will determine the result of changes and the direction of the trend. Other authors explained these changes by shifts in species composition due to oak decay (Kotroczó et al. 2007). The litter production changes can also affect climate change due to drought-induced forest boundary shift towards the poles (Mátyás 2010). Clearly, litter production is controlled by climate as well as edaphic factors (Meentemeyer et al. 1982).

This study was aimed at quantifying litter production of a *Quercetum petraeae-cerris* forest. Considering the local environmental factors, the aim of our research was to examine the extent of changes in leaf litter production, under the effect of modifications in the tree species composition of the forest comparing the surveys of 1972–1976 and of 2003–2010.

## 2 METHODS

### 2.1 Area and project descriptions

Our research was carried out at the Síkfőkút site established in 1972 by Jakucs (1985) for the long-term study of forest ecosystems. The experimental site of 27 ha is located in the south part of the Bükk Mountains in North Eastern Hungary at 325 m altitude. GPS coordinates are N 47°55' E 20°28'. The forest has been protected since 1976, and it is part of the Bükk National Park at present. Annual precipitation amounts to 550 mm. According to the FAO Soil Classification, the type of soil is Cambisos (Fekete et al. 2011). The forest is a semi-natural stand (*Quercetum petraeae-cerris* community) without forest management. The Síkfőkút Project is the member of the Hungarian LTER (Long Term Ecological Research) and the ILTER (International Long Term Ecological Research) networks since 1995 (Kovács-Láng et al. 2000).

### 2.2 Measuring of litter production

The litter production of Síkfőkút Forest was continuously measured from 1972 to 1976 (Tóth et al. 1985). From 2003 to present we renewed these measurements to obtain information about the effect of climate change on the litter production. Litter inputs were measured by 30 plastic boxes of 55.5 × 36.5 cm (0.2 m<sup>2</sup>) size. The total surface of these boxes is 6 m<sup>2</sup>. The plastic boxes were placed randomly at the research site. The litter production was collected monthly and separated into the following parts: leaf litter (every species separately), branch litter and other debris. Fresh litter weights were converted to oven-dry weights (85 °C for 48 hours).

We used one-way ANOVA with the Tukey's HSD test as a post-hoc test if necessary to determine the significant differences among litter production of tree species. All statistical analysis were performed using PAST statistical software.

## 3 RESULTS AND DISCUSSION

### 3.1 Long-term changes of the litter production

Comparison of the earlier period (between 1972 and 1976) and the present term (between 2003 and 2010) showed that leaf-litter production of *Quercus petraea* is half of that measured during the former survey (*Figure 1*), and significantly higher between 1972 and 1976 than between 2003 and 2010 ( $F = 84.75$ ,  $p < 0.001$ ). This observation can be explained by the considerable mortality (68%) of sessile oak observed during the past forty years.

Despite of the 16% mortality of *Quercus cerris*, its leaf-litter production did not decrease in comparison with the survey between 1972 and 1976. Vigorous growth of *Quercus cerris* not only compensated but significantly surpassed its former leaf-litter production in years 2003–2010 ( $F = 11.29$ ,  $p = 0.006$ ) (*Figure 2*).

Leaf-litter production of *Acer campestre* is nearly five times as much as it was in the former period, and differences were significant ( $F = 18.06$ ,  $p = 0.001$ ). This can be explained by the fact that *Acer campestre* formerly occurred in the shrub layer, while presently it forms a part of canopy-layer, where it has become the second most common tree species, representing 28.17% of the total number of trees (*Figure 3*).

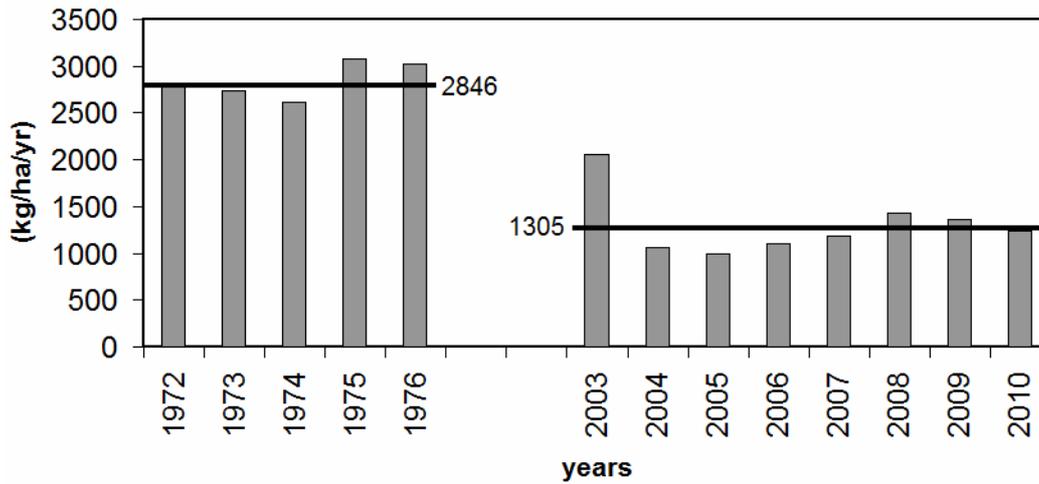


Figure 1. Annual litter production of *Quercus petraea* (with periodic averages) between 1972 and 2010 (kg/ha/yr)

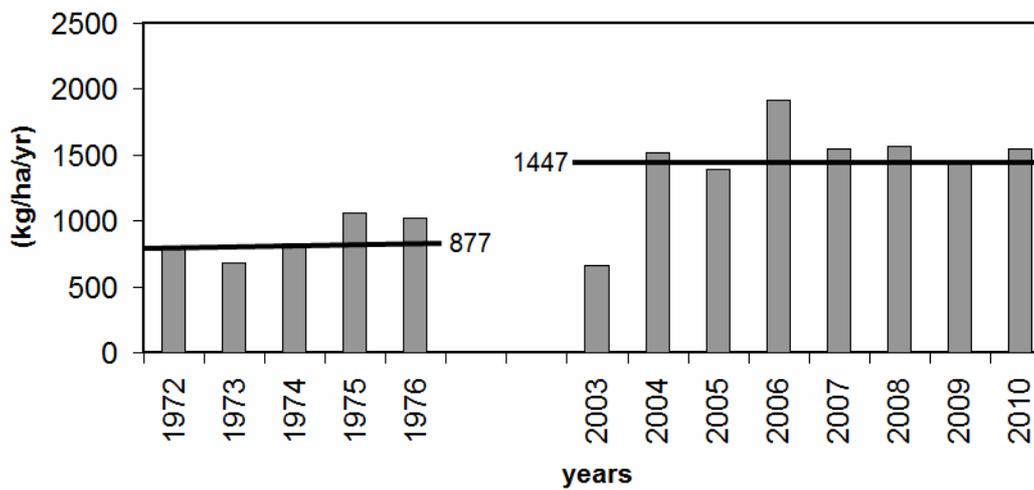


Figure 2. Annual litter production of *Quercus cerris* (with periodic averages) between 1972 and 2010 (kg/ha/yr)

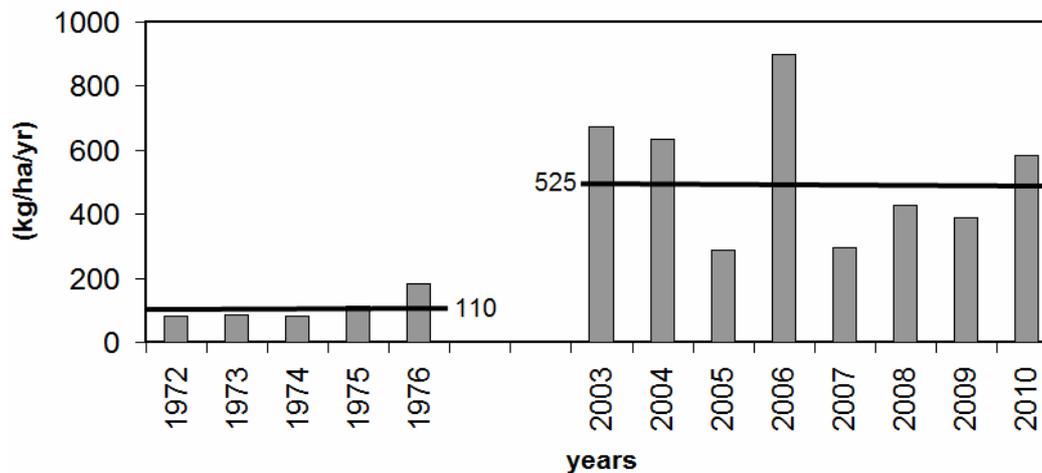


Figure 3. Litter production of *Acer campestre* (with the averages) between 1972 and 2010 (kg/ha/yr)

In Wisconsin, oaks have been more and more replaced by tree species (primarily maples) which are less sensitive to disturbance (Rogers et al. 2008). Increasing abundance and spread of the disturbance-tolerant sugar maple (*A. saccharum*) has been observed throughout the American sclerophyllous forests (Galbraith – Martin 2005). If these trends continue, disturbance-tolerating maples (*A. rubrum* and *A. saccharum*) may become the dominant species of the aforementioned forest associations (Galbraith – Martin 2005, Nowacki – Abrams 2008), because oaks cannot compete successfully against these species (McDonald et al. 2002, Zaczek et al. 2002).

Total leaf-litter production of Síkfőkút Project site (Figure 4) decreased as compared to the former period, differences between the two periods were less significant ( $F = 4.83$ ,  $p = 0.05$ ). The average leaf-litter production was  $3547 \text{ kg ha}^{-1}\text{year}^{-1}$  between 2003 and 2010 which is close to the average data ( $4063 \text{ kg ha}^{-1}\text{year}^{-1}$ ) of the years 1972–1976. Thus, a small decrease can be observed in the total leaf-litter production. *Quercus cerris* and *Acer campestre* could partly compensate the deficiency of leaf-litter production which resulted from the significant mortality of *Quercus petraea*.

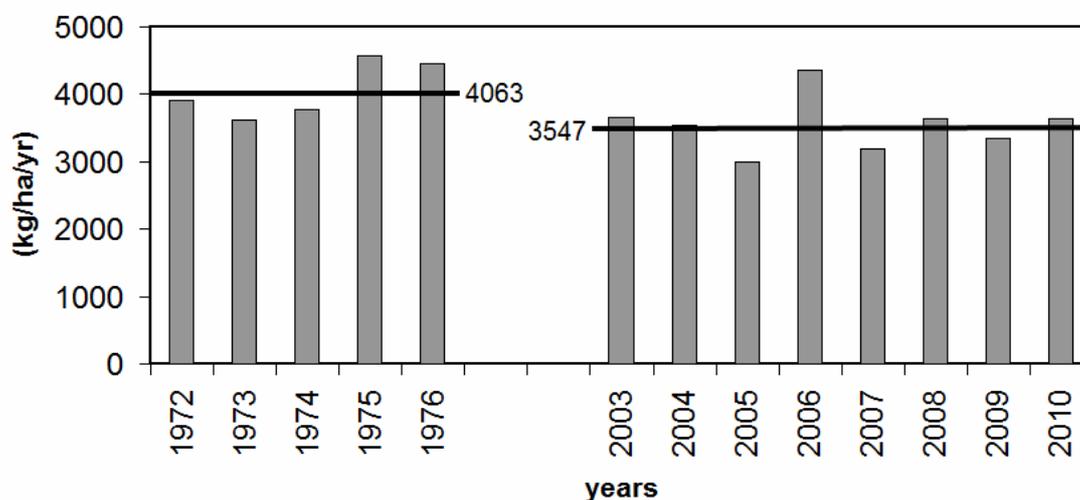


Figure 4. Total litter production of Síkfőkút Project (with the averages) between 1972 and 2010 (kg/ha/yr)

#### 4 CONCLUSIONS

In Hungary, temperature increase was in the average  $0.68 \text{ }^{\circ}\text{C}$ , while decrease of precipitation was  $83 \text{ mm}$  during the last century. As a consequence of climatic changes, the changes in structure and composition of the Síkfőkút forest are followed by the long-term changes of leaf-litter production. According to our examinations, leaf-litter production of *Quercus petraea* between 2003 and 2010 became less than a half of the amount which was measured in the earlier period (1972–1976). Leaf-litter production of *Quercus cerris* slightly increased, while leaf-litter production of *Acer campestre* multiplied. Total amount of leaf-litter production slightly decreased. In the long term, we could not detect a drastic change in the amount of leaf litter, however the qualitative composition changed. The question is whether the litter productivity will be maintained against further climatic changes, leading to further warming and aridification.

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