UNIVERSITY OF SOPRON
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ROTH GYULA DOCTORAL SCHOOL FORESTRY AND WILDLIFE MANAGEMENT SCIENCES

Examination of the microclimate of forestry alley cropping systems and their mechanization possibilities

Doctoral (PhD) theses

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CURRENTITY OF THE RESEARCH

Climate change is a growing problem for the environment, economy and society. Solving this problem requires the use of technologies that enable the transition to a cleaner, more flexibly adaptable economy. These solutions do not only focus on mitigating climate change but serve a complete transformation in line with the goals of sustainable development. Agroforestry systems are successfully used in many parts of the world to adapt to climate change, combat desertification and soil erosion, and support biodiversity. Practical experience shows that the use of forestry alley cropping systems can help the climate adaptation of young forest stands with a well-chosen technology.

OBJECTIVES OF THE RESEARCH

The intercropping is currently used in several Hungarian state forestry areas in reforestation. The experience gained proves that the presence of intercrop helps to increase the effectiveness of forest regeneration, the health status and survival rate of seedlings. However, research supporting such positive experiences has not been conducted in Hungary so far, and in the international literature there are only a few results related to the issue - mostly focusing on soil improvement aspects and solving local food problems. Therefore, the main goal of the research is to examine what environmental changes occur in a forestry alley cropping system and which factors can play a role in these changes. The research was primarily aimed at measuring changes in the microclimate of the system, supplemented by the monetary side of maintaining the system, which of a significant part is mechanization.

The objectives of the research:

i) To examine the microclimate-modifying effects of intercropping on soil temperature, soil electrical conductivity, groundwater level, air temperature, relative humidity and wind speed by comparing intercropping reforestation (AE) and a control area without intercrops (KO) created under similar conditions.

ii) To examine what land equivalent ratio the AE systems have compared to the area utilized with homogeneous culture.

iii) To map the systems of this type in Hungary, then to assess their mechanization and other characteristics with a questionnaire, and then to propose more cost-effective technological solutions

RESEARCH METHODS

We used several methods to answer the research questions. The research was based on a review of domestic and international literature, an assessment and evaluation of the domestic situation and experiences of the examined technology. Following this, we created experimental areas under real operating conditions, each of which was divided into two units: a control area and an agroforestry area. In the experimental areas, we carried out field sampling and data collection for three years, which focused on the micro-climate change and technological aspects of the experimental systems. The soil samples required for the site inspection were evaluated after a laboratory test.

Microclimate tests

The microclimate tests will be carried out in 2020–2022. years, we measured 2-3 times a week in periods most prone to summer drought, which is dangerous for the stand. The measurements were made with mobile instruments, between 12:00 and 2:00 pm. The data collections are summarized in the table below.

Parameters	*Soil ·ature*	*Soil electrical conductivity*	*Air temperature*	*Air humidity*
Period	Jul. 01-Aug. 30	Jul. 01-Aug. 30	Jul. 01-Aug. 30	Jul. 01-Aug. 30
Measuring points	2 segments/ system 5 points/ segment	2 segments/ system 5 points/ segment	2 segments/ system 5 points/ segment	2 segments/ system 5 points/ segment
Height/ Depth	Surface, -10 cm	Surface, -10 cm	Surface, 1 m, 2m	Surface, 1 m, 2m

The wind speed was measured at 2 meters per segments in the tree rows and between the rows.

Growth parameters

In the experimental areas, noble aspen was planted. Seedlings were measured in June, August and September, in all three consecutive years. The measured parameters:

• Tree height

• Circumference at the surface

• Circumference at the breast height

The tree height values were recorded with an accuracy of 10 cm. To comply with the size and age restrictions, both the diameter at the head and the height at the breast were recorded with an accuracy of 0.5 centimetres. For the measurements, we used a tape measure and a measuring rod with an accuracy of 10 cm. In both the KO and AE systems, 3 measurement plots were designated in a parallel arrangement.

After the measurements, the TIBCO Statistica ™ version 13 program was used to evaluate the data. The results of the measurements of the same dependent variable microclimate of the statistical samples were classified into two independent groups (agroforestry and control areas). The averages of the obtained variables were compared. Statistical samples were taken from a normally distributed population.

Additional tests

The soil of each area was patterned. Mixed samples from the top 30 cm of the areas were collected and evaluated under laboratory conditions.

Groundwater level measurements were collected 2-3 times per week, similarly to the parameters mentioned above.

Economic Indicator (LER)

Regarding the land balance indicator related to the resource efficiency of land use, we established the relationship between the two systems based on a comparison of the parameters describing the development of standing trees in the agroforestry and control areas, as well as the yield of the intermediate plant and the national annual crop yields provided by KSH.

Technology data collection

During the data collection, a questionnaire survey was carried out in several steps: first, we assessed the occurrences of similar technologies used in domestic forestry practice, then the technology related to each area with the machines used. Based on the received data, machine work and the costs derived from it were established as our area and machine category based on the appendix of the publication " *Mezőgazdasági gépek költségei”.*

SUMMARY OF RESEARCH RESULTS

Agroforestry systems have a positive effect on their environment in many parts of the world and are therefore widely used forms of management. Forestry alley cropping systems, as agroforestry systems, are only spread in a very small circle and area of field-forest management practices. Their occurrence in Hungary is also like their distribution abroad. It is typically used in state forest areas, where the interests of afforestation come to the fore. The main goal of this additional management method during the research was to investigate the positive and negative effects of this type of design. Regarding the results, it can be said that the degree of positive effects was stronger than that of negative effects.

Regarding the soil temperature results, it can be unanimously described that the forestry alley cropping system has a favourable influence on the system. In the future, the question remains as to what extent it will be able to maintain this in the face of climate warming. The electrical conductivity of the soil is influenced by many factors, such as the amount of precipitation, the groundwater level, the density of the vegetation and thus the interception, as well as the evapotranspiration.

Regarding the AE system, it can be stated that it mostly reduces the air temperature to a small extent, but not significantly. However, this effect further helps to cool the soil, in other cases to warm it, and overall to create a much more balanced system.

The intercropping system gave higher relative humidity values, but a statistically significant difference was only seen in 2021 and 2022, at a height of 1 meter. As the intermediate plant grew, the surface roughness also increased, thereby significantly reducing the wind speed.

The system's use of groundwater was greatly influenced by the weather during the growing season, and the amount of water available for the vegetation was utilized accordingly. The yield of each precipitation event could be quantified at the next measurement occasion. The effect of vegetation on the groundwater level can be mapped in a similar way to the development of the electrical conductivity of the soil, so it was developed as a function of the monthly weather.

From the examination of the economic indicator, the conclusion can be drawn that in all cases when the agroforestry practice does not have a negative impact on the forest, it had favourable indicators. In all cases where wild animals do not damage the area 100%, it is profitable to establish and maintain a similar system.

As we have seen during the evaluation of the data, it is important to consider under which regional characteristics and environmental conditions we can apply forestry alley cropping systems, because a poorly chosen technology can also become a negative influencing factor for seedlings. At the same time, public cultivation carried out and operated in accordance with the conditions can have several favourable returns for the planted stand. Based on experience and measurements, it can be said that the applied agroforestry practice can increase the efficiency of afforestation and the use of land, and it also serves other purposes (ecosystem services, feeding). The cultivation of intercrops used in afforestation can thus be combined with resource efficiency and a better economic return, especially if the right machinery is used for its establishment and maintenance.

THESES

During the investigation, the most important scientific results are:

1. 1. As a result of three years of tests, it can be stated that the forest intercropping system consisting of poplar (Populus × euramericana cv. I-214) and maize (Zea mays L.) both on the soil surface (with an average of 7.26 °C in the rows , significantly reduced the soil temperature by 4.30 °C in the tree rows and at a depth of 10 cm in the soil (on average by 2.70 °C in the row intervals, by 1.69 °C in the tree rows), under similar growing site conditions compared to the control forest area. Based on the results of the electrical

conductivity of the soil, no significant difference can be established, however, based on the results of 3 years, it can be stated that the development of the electrical conductivity depends on the vegetation cover and the time area was able to preserve it better, the significance of which is that the system can thus mitigate the harmful effects of a possible atmospheric drought for a longer period of time. In a comparison of experimental plots with similar conditions, during the examination of the wind speed, it was shown that because of the surface roughness increaser of the AE system, the wind speed decreased significantly (on average by 0.19 m/s, i.e. by 31.7%) compared to the KO system 2 meters high.

2. In the comparison of experimental plots with similar conditions, during the examination of the wind speed, it was shown that at a height of 2 meters, due to the surface roughening effect of the agroforestry system, the wind speed decreased significantly (on average by 0.19 m/s, that is 31.7 %) compared to the control system.

3. Examining the air temperature at three heights, we found that in the row spaces (on average 1.31 °C on the ground surface of the row spaces, 0.61 °C in the tree rows; 0.90 °C in the row spaces at a height of 1 meter, in the tree rows by 0.39 °C; at a height of 2 meters by 0.48 °C in the tree rows) the AE system produced more favorable values. This was detectable against the control system in all three years. The agroforestry system also increases the relative humidity values, mainly at the 0-1 meter level above the soil surface. On average, 6.19% on the soil surface of the rows, 3.92% in the tree rows; at a height of 1 meter in the rows by 4.49%, in the tree rows by 5.27%; At a height of 2 meters, by 2.23% in the rows, and by 2.37% in the tree rows.

4. The presence of the intermediate plant did not adversely affect, in fact, it specifically promoted the development of

the tree seedlings. In terms of the growth vigor of the trees, in terms of capital girth, girth at breast height and growth in height, poplar /Populus × euramericana cv. The intercropping system consisting of I-214/ and maize (Zea mays L.) showed a more favorable picture. Based on the positional mean values, the perimeter values exceeded the values of the control area by an average of 1.0 cm and the height values by 0.5 meters. Thanks to this and the intermediate crop, the total biomass yield in the agroforestry system is higher than in artificial forest regeneration without intermediate crops. Due to the higher total biomass yield per area unit, the land equivalent ratio (LER value) of reforestation with intercropping was higher every year (≥2.14 in 2021; ≥2.47 in 2022) compared to reforestation without intercropping.

5. Based on the survey conducted among forest farms, it can be established that the proportion of artificial afforestation under public cultivation is very low compared to the total area of the national average annual afforestation. In the period 2010-2022, the share of public cultivation was 0.11%.

6. Based on my research, I found that the power and work machines suitable for creating and maintaining forest intercropping systems are common types in both forestry and agriculture, so these systems do not require the use of any specific machines. I also found that to increase the cost-effectiveness of these systems and to make them better manageable, there is a need for machine improvements to perform certain work operations.

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