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# BIOELECTRIC PARAMETERS OF *PINUS SILVESTRIS* FOREST ECOSYSTEMS

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**Abstract.** The article presents the study of the bioelectric potential of forest biotopes of *Pinus silvestris* to evaluate the possibility of their usage as a bioelectricity source. The increase of bioelectric potential in dry soils independent of moisture level was revealed. The positive effect of soil humidity on the generation of bioelectric potential was shown. Insignificant daily and seasonal fluctuations of bioelectric parameters of forest biotopes open their prospects as an important source of renewable energy.

**Keywords:** renewable energy; bioelectricity; electrode; biotope; rhizospheric microorganism; plant

## 1. Introduction

Obtaining bioelectricity from forest ecosystems by installing electrode systems is an innovative type of alternative and sustainable energetics and still a little-studied issue. Besides the direct climatic, geological, and recreational importance, forest ecosystems can serve as an ecological source of bioelectricity causing no damage to the environment ecosystems, which is typical of traditional energy sources. The essence of the method is collecting bioelectricity produced by rhizosphere microorganisms that develop in the root zone of plants by feeding on the plant photosynthesis products excreted by roots and degradation products of leaf litter (Strik et al., 2008; Kabutey et al., 2019).

The world's forest resources amount to 3.8 billion hectares, most of which are concentrated in the northern zone of Eurasia and North America with a predominance of conifers and in the southern zone of Central and South America, Equatorial Africa, South and Southeast Asia with deciduous trees (Index Mundi, 2019). In Europe, most forests are located in Scandinavia. The share of forests differs in each country, but occupies a significant part of the country's land, for example in Finland and Sweden, they cover up to 68.9–73.1 % according to data for 2016 (Index Mundi, 2019). Ukraine belongs to the forest-deficient states: afforestation of its territory is low, 16.7 % is the area of lands of the forest fund of Ukraine and coniferous plantations occupy 42.2 % of the total area of forested lands and 33 % of, them are pine trees (Index Mundi, 2019; Barvinskyi et al., 2015; Bodnar, 2016). Forests in Ukraine are unevenly distributed throughout the territory, and in Western Ukraine, in some regions, they account for 41.0–51.4 %. In neighbouring Poland, the total afforestation is equal to 30.9 %, but in some counties, forests cover up to 90 % of their territory (Fedoniuk et al., 2005).

The generation of bioelectricity in situ is mainly studied in wetland ecosystems of rice fields in Japan and Indonesia (Kaku et al., 2008; Takanezawa et al., 2010; Kouzuma et al., 2013; Ueoka et al., 2016; Sudirjo et al., 2019) and flooded forests of South Carolina, USA (Dai et al., 2015). Therefore, the study of the bioelectric potential of pine forests in the climatic conditions of Western Ukraine is of considerable interest. Considering these findings, the aim of the research was to assess in situ the prospects of biotopes of pine forest ecosystems in the Lviv region as an alternative source of renewable energy.

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## 2. Materials and Methods

The objects of research were the bioelectrical parameters of biotopes of forest ecosystems of *Pinus silvestris* L. of Lviv region, Western Ukraine. The subject of the research were daily, seasonal and dependent on environmental factors fluctuations of the bioelectric potential. The soil near the studied tree species was covered with a layer of fallen needles, moss or grass plants. The diameter of tree trunks averaged 0.47 m.

The monoelectrode system developed by us was used to register the bioelectric potential (Rusyn, Medvediev, 2016). Electrode systems were placed stationary in the soil, in the zone of association of plant roots and rhizospheric microorganisms, where electrons and protons are released at a depth of 0.3–0.4 m in the soil thickness, where the bulk of the root system of forest plants is concentrated. The results were processed statistically (Zinchenko et al., 2001; Crow, 2005; Eshel, Beeckman, 2012). Bioelectric potential was recorded using a digital multimeter in four different areas near a single object, as root systems may be asymmetric (Ganatsas, Spanos, 2005). The reported results were presented as the average of all replicate experiments and their standard errors (x ± SE). Significance of difference between average values was established using one-way analysis of variance and F-test for 95 % confidence level.

## 3. Results and Discussion

Biotopes of *P. silvestris* are characterized by rather high values of the bioelectric potential, which are averaged 1104.1 mV (Fig. 1). In (Rusyn, Hamkalo, 2019; Tou et al., 2019), the values of the average bioelectric potential ranged from 900 to 1100 mV. In contrast to the above-mentioned works with annual plants in laboratory conditions, forest plant-microbial bonds are stable and formed over many decades. An increased amount of isolated photosynthesis products in the soil is provided by a strong superficial root system with small roots and, usually with mycorrhiza (Munzenberger et al., 2004; Aucina et al., 2007; Raudaskoski, Salo, 2008). This creates optimal conditions for the development of rhizospheric microorganisms, which play a decisive role in the generation of bioelectric potential.

Fluctuations in the bioelectric potential of *P. silvestris* biotopes during a day were not significant (Fig. 2). The average daily difference between the maximum and minimum values was 50.2 mV in biotopes 1–7. As shown in Fig. 2 in biotopes 8–10 on some days the difference between morning and evening potential values was slightly higher and amounted to 90.5 mV, 110.2 mV, 106.9 mV, which was obviously due to the influence of environmental factors on the processes of bioelectricity generation. Recorded in some cases, higher values of the bioelectric potential in the morning can be explained by the active synthesis of organic compounds in the dark phase of photosynthesis and the active release of photosynthetants into the soil that feed rhizosphere microorganisms generating bioelectricity.

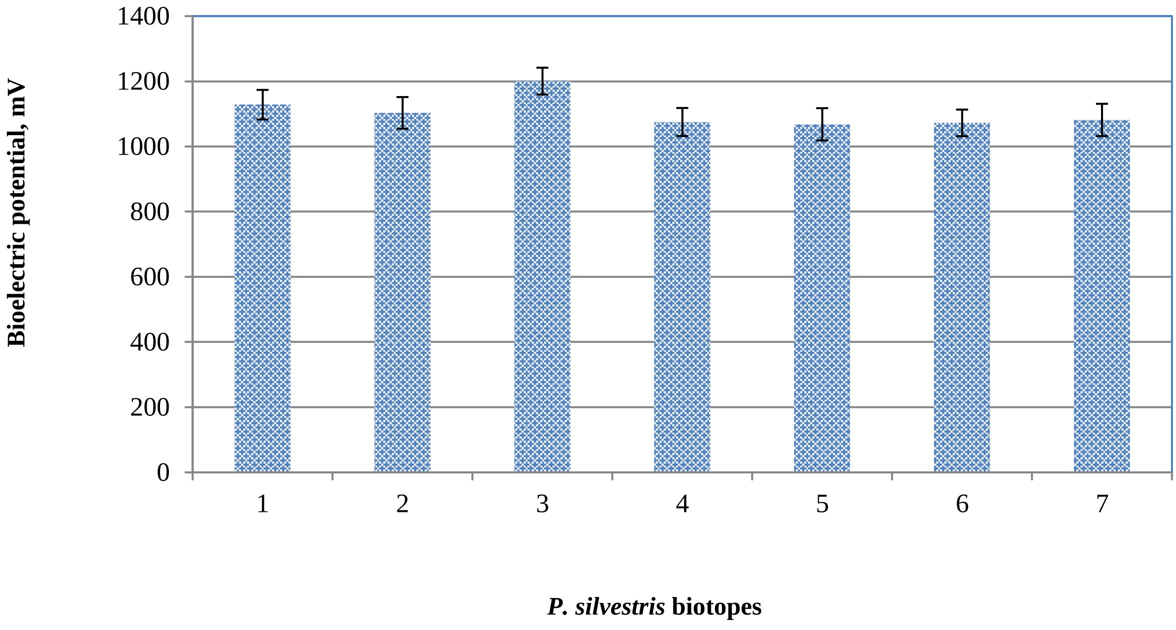


**Fig. 1.** Average bioelectric potential of *P. silvestris* biotopes in forest ecosystems (x ± SE, n = 10)

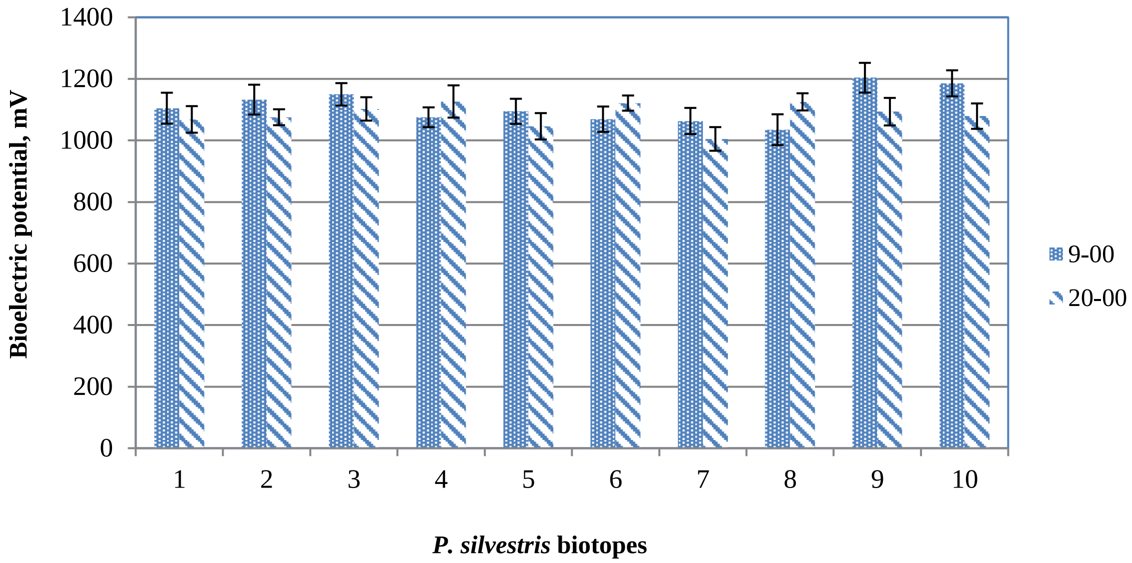


**Fig. 2.** Daily fluctuations of the bioelectric potential of *P. silvestris* biotopes in forest ecosystems during the 20th – 27th days of the experiment (x ± SE, n = 10)

Bioelectricity production in early summer and mid-autumn was almost at the same level (Fig. 3). The average bioelectric potential of *P. silvestris* biotopes of forest ecosystems in June and October was kept at the level of 1100.2–1106.5 mV. This fact of high and stable average values of bioelectric potential reveals their prospects as an important source of renewable energy.

The increase in humidity had a positive effect on the growth of bioelectricity of *P. silvestris* biotopes of forest ecosystems (Fig. 4). Thus, with an increase in humidity from 25 % to 45 %, the average bioelectric potential increased by 96.8–106.8 mV. Under humidifying conditions, optimal conditions are created both for the development of rhizospheric microorganisms and photosynthesis of plants, and for the collection of bioelectricity.

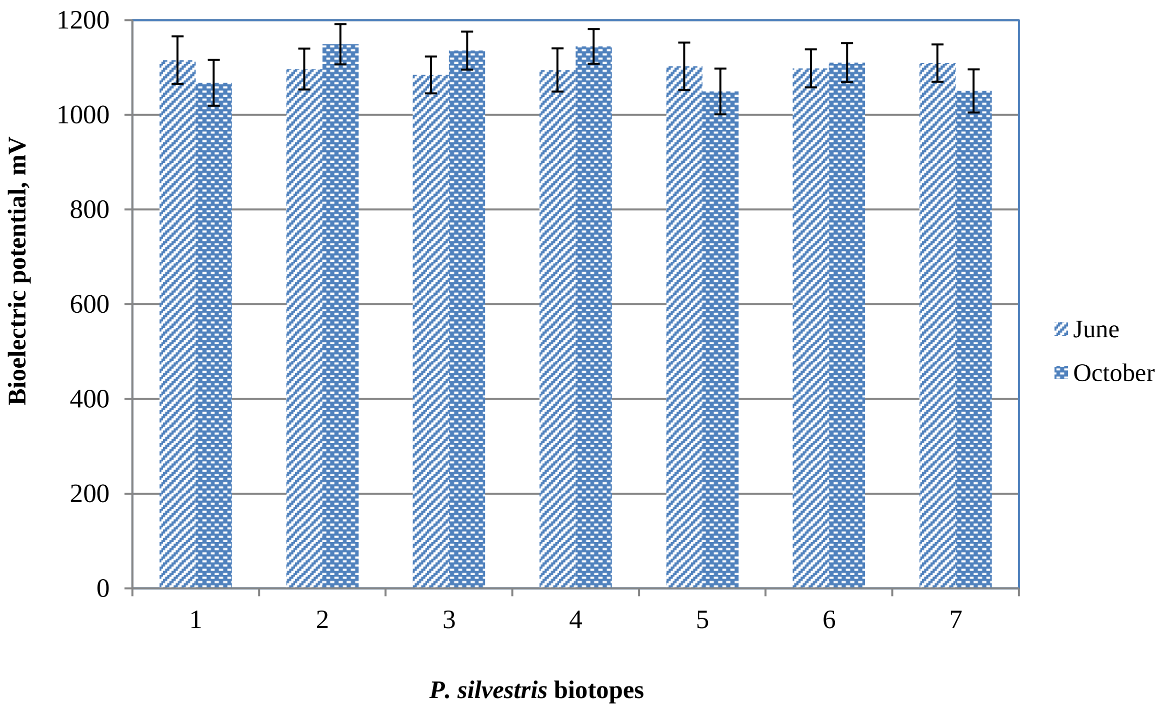


**Fig. 3.** Seasonal dynamics of bioelectric potential of *P. silvestris* biotopes in forest ecosystems (x ± SE, n = 10)

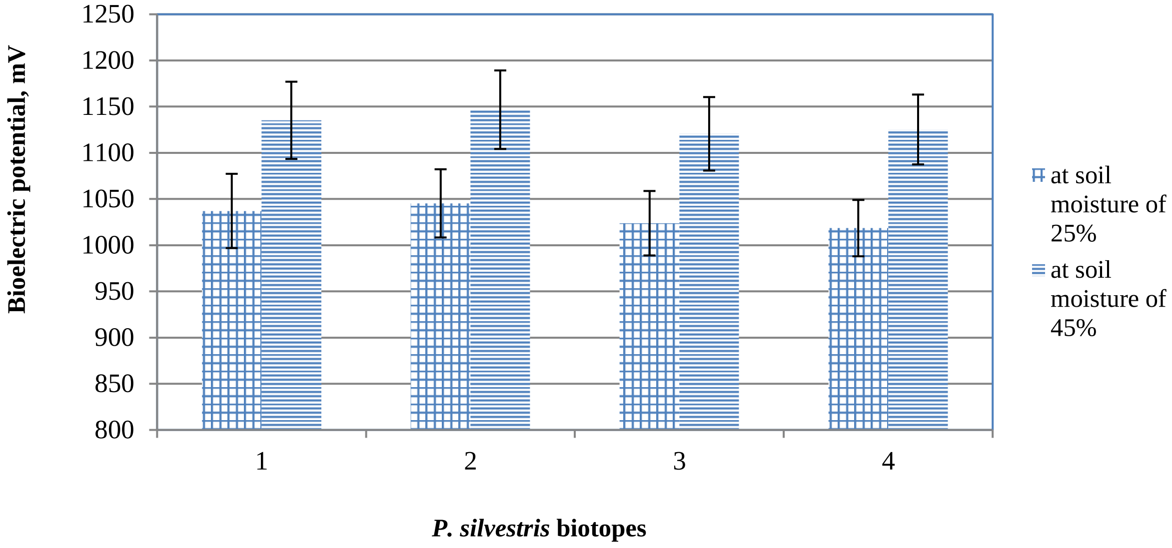


**Fig. 4.** Influence of soil moisture growth from 25 % to 45 % on the bioelectric potential of *P. silvestris* biotopes of forest ecosystems on the 50th and 52th day of the experiment (x ± SE, n = 10)

In the same samples of dry soil, at the same soil moisture, the bioelectric potential increased significantly over several days. For example, an intensive increase in the level of bioelectricity was observed in forest biotopes of *P. silvestris* at the same soil moisture content (20 %) during the 110th and 120th days of the experiment; the difference between the level of bioelectric potential was 127.8–169.2 mV (Fig. 5), despite the lack of changes in soil moisture.

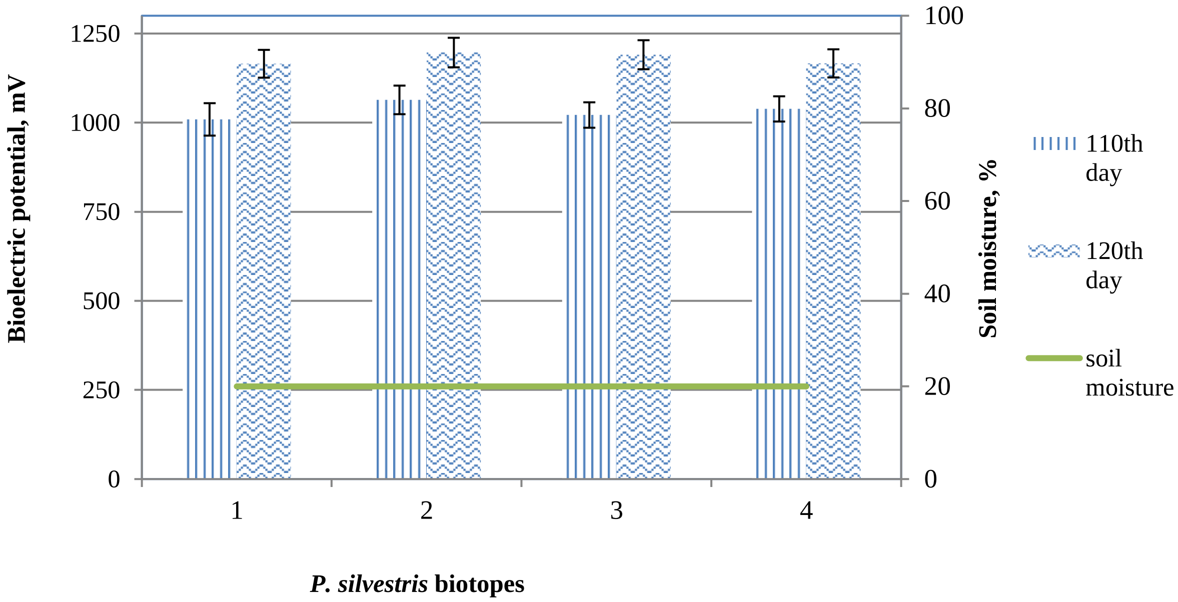


**Fig. 5.** Bioelectric potential of biotopes of *P. silvestris* forest ecosystems with soil moisture 20 % on the 110th and 120th day of the experiment (x ± SE, n = 10)

This fact of high bioelectricity of dry soils may be the result of active photosynthetants excretions through the roots and their concentration in the soil, and thus the intensive supply of nutrients to rhizospheric microorganisms that produce bioelectricity.

## 4. Conclusions

Natural biotops of *P. silvestris* forest ecosystems have the potential as a source of bioelectricity. Bioelectrotechnical systems installed in forests reveal the prospects for their use to feed the autonomous field systems of ecosystem monitoring. The application of forest ecosystems as a source of bioelectricity can be highly relevant, especially for the northern lowlands of Polissya and the regions of Western Ukraine, where forests make up quite a significant part.

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