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THE DEPENDENCE OF BIOMASS ON RICHNES OF SOILS IN THE BEECH FOREST OF THE EASTERN CARPATHIANS

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ABSTRACT. The main aim of our studies was to estimate the change of biomass and productivity of beech forests with richnes of soils. The paper presents results of studies the structure and productivity of 97-98 years old forest on poor and rich soils. The reaction of the beech stands to aggravation of soil conditions is manifested in the form of increased accumulation of branches, leaves and root mass, leaves and root surface and a simplification of the horizontal structure. Total biomass reserve decreased from 617.1 $t \cdot ha^{-1}$ in forest with rich soil to 235.2 $t \cdot ha^{-1}$ in forest with poor soil, but the reserve of branches, leaves and thin roots increased. The annual increment of biomass is rather high (from 10.4 in poor to 15.4 $t \cdot ha^{-1}$ $year^{-1}$ in rich soil). The annual increment of stems was 45% in forest with rich soil and 33% in forest with poor soil. The percentage of increment of leaves increased from 18.8% in the forest with rich soil to 27.3% in the forest with poor soil. For roots the increment of biomass varied from 16.6% to 21.2% accordingly. The surface of branches and leaves are slightly reduced but the stem surfaces are sharply reduced (from 11.1 to 2.8 $m^2 \cdot ha^{-1}$).

KEY WORDS: biomass, productivity, beech forest, soil, Eastern Carpathians

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INTRODUCTION

The climatic conditions in the Eastern Carpathians in the late Holocene period were optimal for development of beech forests. Under these favourable conditions (average temperature 5.0-7.1°C and precipitation 900-1250 mm) beech formed a wide vegetation belt from 400 to 1300 m a.s.l.

Eastern Carpathians occupy parts of Ukraine, Poland and Slovakia. Forests with dominating beech take up 55% of the area of the native forest cover in the Ukrainian Carpathians (GOLUBETS 1978). However, together with progressive activity of humans the area of natural beech forests in the Ukrainian Carpathians decreases. Spruce plantations have replaced primary beech forests. At present beech forests constituted only 33% of the total forest area of the Ukrainian Carpathians. Much stronger reduction of natural beech forests area from 42 to 15% occurred at the North Slope of the Carpathians range as compared to the South slope (from 73 to 58%). The end of 18th century and in the first half of 19th century were the period of intensive destruction of beech forests. At that time the forest management was oriented on cultivation of spruce. Beech forests as "less productive" were cut down. Since World War II included in the USSR Ukrainian part of the Eastern Carpathians became the object of Soviet political and economic system. Industry, craft, and trade were completely nationalised, agriculture become collectivised in a drastic way. Anthropopression increased due to an extremely intensive exploitation of forests. For example in the Beskid Mountains (near Poland, west part of the north slope of Ukrainian Carpathians) the present area of beech forests decreased to 4.3% of total area (19.6% in year 1939).

The situation is similar in the region of the Slovak Republic. In that country the species composition of stands changes strongly in favour of spruce monocultures which replaced broad-leaved and mixed stands (KODRIK 1998, KLIMO 1998).

In Poland, after World War II, Bieszczady and Beskid Niski mountains (Eastern Carpathians) became depopulated. In abandoned territory, secondary succession occurred on unprecedented scale in large areas of former fields and meadows (AUGUSTYN and KOZAK 1997). After several years of virtual isolation of the area, some of former agriculture land has been converted into large, extensive monocultures managed by state farms, while the other gradually reforested with pine, spruce, and larch, making a part of state forest (PERZANOWSKI 1997). The spruce forests of the coniferous altitudinal belt, in spite of their differentiated age, grow generally as one-storey stands. This is a cause of their weak stability (JAWORSKI 1997).

The main aim of our studies was to estimate the change of biomass and productivity of beech forests with riches of soils. We try to show that beech forest in the Eastern Carpathians has also an important ecological role among forests of this region. We know that foresters have measured forest production for many years. In general they tend to concentrate upon the economic product, mainly the stem wood. For us the forest primary production and biomass have somewhat different connotations than for foresters. We are rather concerned with total primary production and biomass of a forest, whereas foresters, at least in the past, were concerned only with primary production of the merchantable portion of the forest. The total dry matter production is considered to be a measure of the forest efficiency to fix energy in all components of the ecosystem. Total dry matter production is also a measure of total energy input to the system with its subsequent dissipation by respiring organisms. To maximise primary production and biomass accretion for plant production, it is logical to consider all energy pathways of the ecosystem.

The objective of this paper is to assess biomass, net primary production, and litter fall in 97 years old natural beech forests on rich and in 98 years old natural beech forests on poor soils.

STUDY AREA AND METHODS

Beech forests dominated by European beech (*Fagus sylvatica* L.) were studied in the Central part of Eastern Carpathians in Beskids (Ukraine). Sampling areas were situated in Scole forest region at the altitude of 600-650 m a.s.l. Brown soils (cambisoils) over the Carpathians flish were typical for all sampling areas. The areas were located in 97 years old beech forest on rich soil and in 98 years old beech forest on poor soil conditions.

The analyses were performed inside the 2000 m^2 (40 m $\times$ 50 m) sampling areas. The number of trees was determined within each sampling area. Every tree was numbered for easy identification. The breast height (1.3 m above-ground on the uphill side of the tree) was permanently marked around each trunk with a point. The trunk diameter at breast height (DBH) was measured.

Eighteen test trees were chosen to represent the range of different diameters and heights for each sampling area (plots). Those trees were cut down at the end of vegetation period (August-September) in the close neighbourhood of the plots. The stem was divided into 1-m logs, which were weighed. Test discs 5 cm thick, were cut at the base of each log for annual ring analysis. Different fractions of above-ground mass were analysed according to UTKIN (1975).

The determination of below-ground mass was carried out on trees of different diameters from each sampling area (LOHMUS and OJA 1983). Roots were dug out and collected in groups of the diameter of below 0.5, 0.5-1.0, 1.0-5.0, 5.0-10.0, and over 10.0 mm. Roots of ground flora, were sampled from 20 pits 50 $\times$ 50 $\times$ 60 cm, giving the fine root mass.

The litter fall on the sampling plots was collected in 25 litter traps (50 $\times$ 50 $\times$ 30, placed 25 cm above the ground surface). The traps were emptied once a month. The mass of the ground vegetation layer was estimated on 20 plots of 1 m^2

within each sampling plot. Values of particular mass fraction varied within 2-10 per cent of the mean.

RESULTS

Total dry biomass of beech forests varied between 235.2 $\pm$11.2 t $\cdot$ ha^{-1} in forest with poor soil and 617.1 $\pm$21.2 t $\cdot$ ha^{-1} in forest with rich soil conditions (Fig. 1). The above-ground mass was 167.4 $\pm$9.3 t $\cdot$ ha^{-1} (71% of the total biomass) in poor and 489.8 $\pm$18.2 t $\cdot$ ha^{-1} (79%) in rich soil. The below-ground mass reached 67.8 $\pm$2.4 t $\cdot$ ha^{-1} (28.8%) in poor and 127.3 $\pm$5.3 t $\cdot$ ha^{-1} (20.6%) in rich soil.

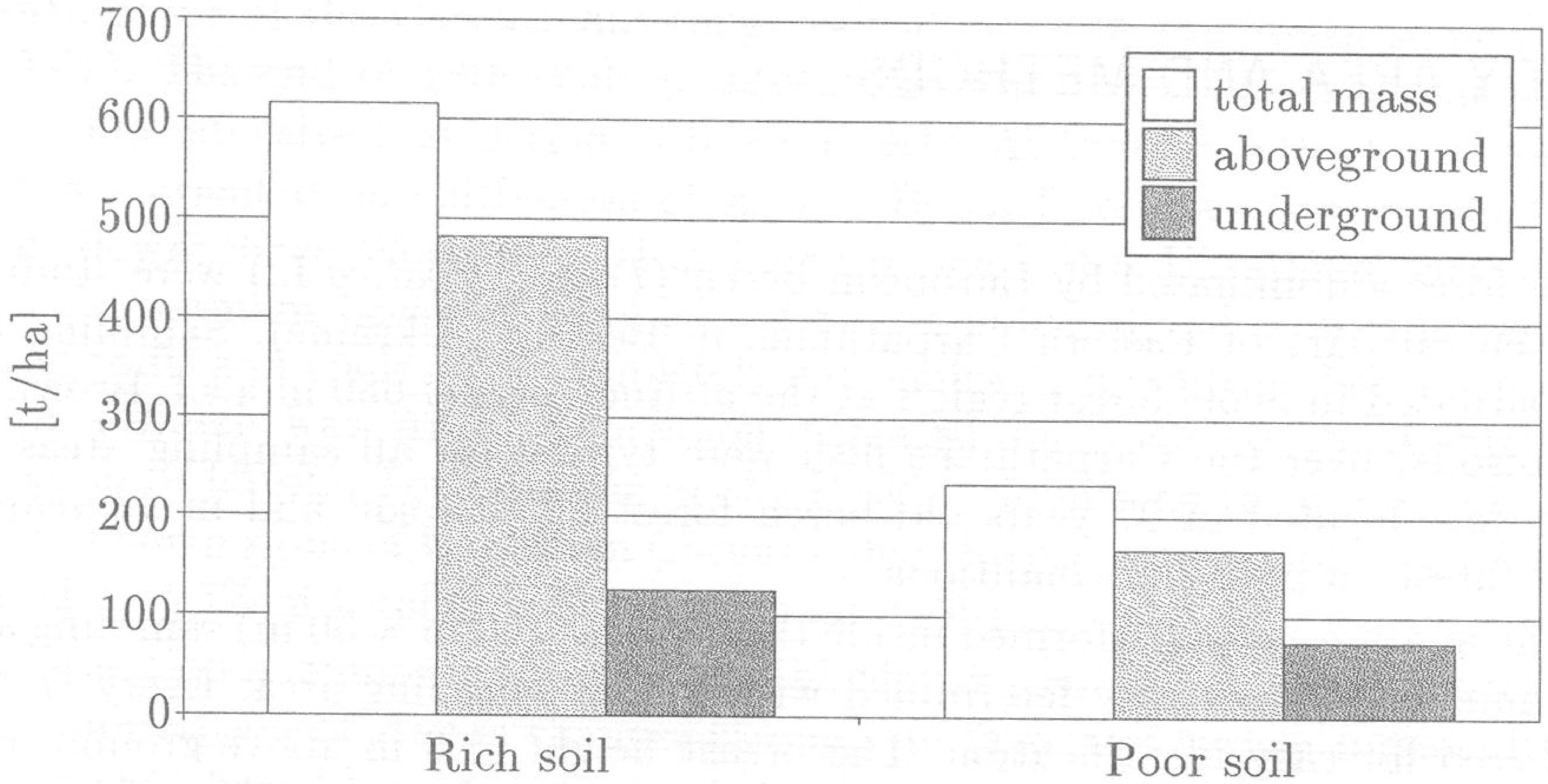

Fig. 1. Biomass of beech forests in sampling plots

The main part of the biomass was accumulated in stems. The mass of stems changed from 123.5 $\pm$4.7 t $\cdot$ ha^{-1} (52.5%) in the poor soil to 444.6 $\pm$16.8 t $\cdot$ ha^{-1} (72.1%) in the rich soil. The bark was 24.0 $\pm$1.3 t $\cdot$ ha^{-1} (7%) in the poor soil and 8.2 $\pm$0.4 t $\cdot$ ha^{-1} (4%) in the rich soil.

The proportion of branches leaves and roots increased as a sense of deterioration of soil conditions (Fig. 2). Mass of branches was 6.9%, mass of leaves – 0.4% and mass of roots – 20.6% of total biomass in the rich soil. In the poor soil conditions mass of branches, leaves and roots were 17.6%, 1.1% and 28.8% accordingly.

The mass of thin roots increased with deterioration of soil conditions. Thin roots to 0.5 mm reached 1.1% of the total biomass in rich and 2.6% in poor soil conditions. The relation of mass of leaves to mass of thin roots was 1.9 in rich and 1.5 in poor soil conditions.

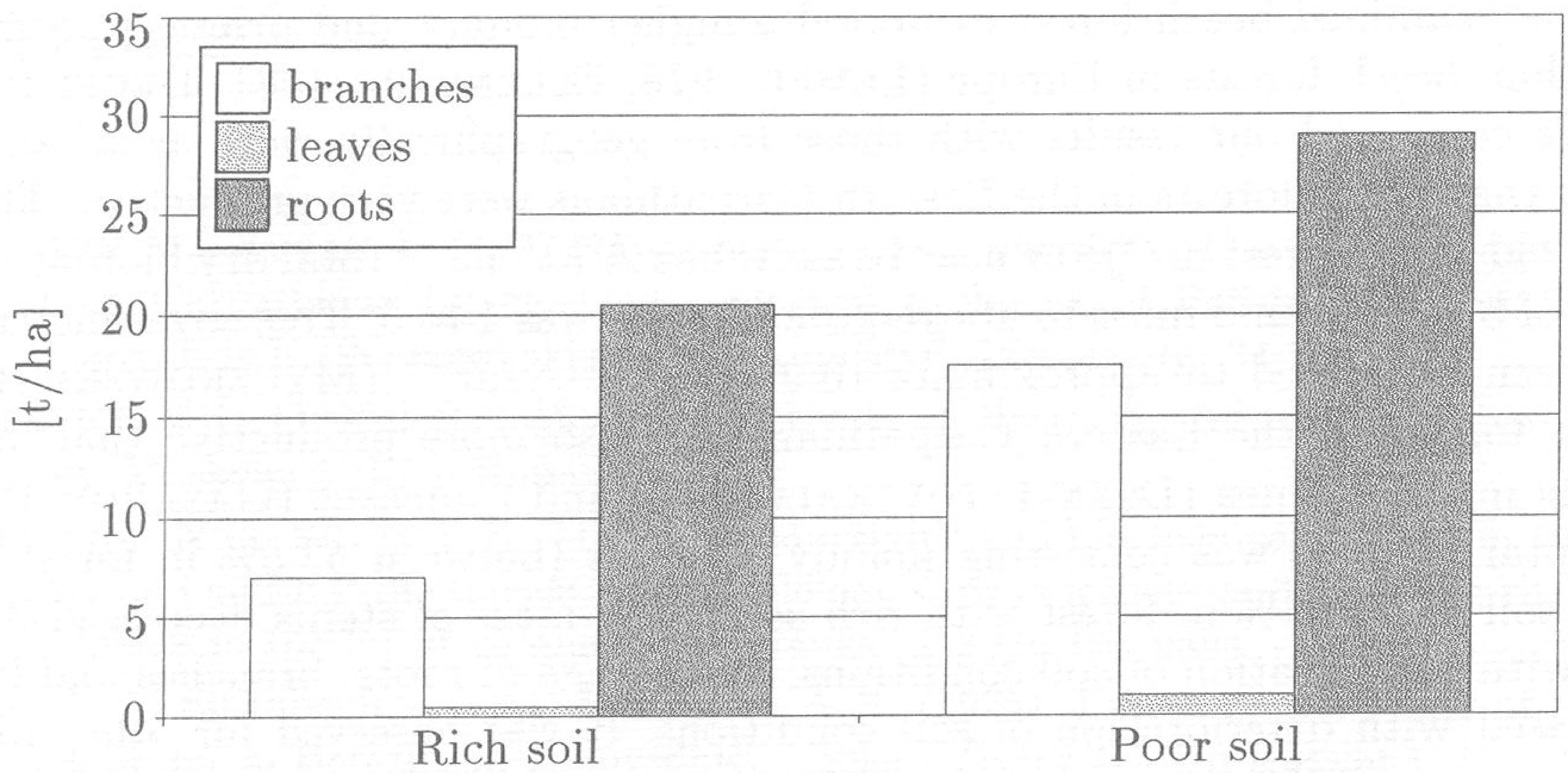

Fig. 2. Biomass of branches, leaves, and roots in sampling plots

The surface of plants was in the range 9.8-16.5 ha · ha^{-1}. It seams to be important for functioning of the beech forest ecosystems. The surface of leaves was high (81-88%). The index of the leaf surface was 5.7 in rich and 4.3 in poor soil conditions in the beech forest ecosystems. This result was the highest among deciduous forests (UITTEKER 1980).

The annual increment of biomass changed from 15.4 in the rich soil to 10.4 t · ha^{-1} in the poor soil. The distribution of annual increment among different fractions of biomass depended on deterioration of forest-soil conditions. The increment of stems was 45% in the forest with rich soil and 33% in the forest with poor soil. The percentage of the increment of leaves increased from 18.8% in the forest with rich soil to 27.3% in the forest with poor soil. The proportion of roots increased from 16.6% to 21.2% accordingly.

An amount of plant falling matter in studied areas was 4.0 and 3.3 t · ha^{-1} dry matter for forests with rich and poor soils respectively. The mass of the died organic matter increased from 11.1 t · ha^{-1} in the forest with rich soil to 19.6 t · ha^{-1} in the forest with poor soil. The litter constituted the main part (48-78%) of the total mortmas.

DISCUSSION

The collected data confirms that beech forest of the Eastern Carpathians accumulated the large part of the biomass (617 t · ha^{-1} in the age 100 years). This biomass may be estimated using the score X according to BAZILEVICH and RODIN (1975). This was the highest result for mountain forests in Northern Eurasia (BAZILEVICH 1993).

The examined beech forest exhibited a higher biomass and primary productivity than beech forests in Europe (LEMEE 1978, ELLENBERG 1981, DECEI 1981).

We compared our results with those from geographically close areas and we found that beech forests in the Eastern Carpathians were very productive. The 75 years old beech forest in Ojców near Kraków has 297 t $\cdot$ ha^{-1} total dry biomass. The ratio of below-ground mass to above-ground mass was 1 to 5. Tree cover increment has been estimated to approximate 10.9 t $\cdot$ ha$^{-1}\cdot$ year^{-1} (MYCZKOWSKI 1967). Beech forests in the Eastern Carpathians are also more productive than beech forests in the Crimea (DZEN-LITOVSKAIA 1960) and Caucasus (GASANOV 1980).

Total biomass was consisting mainly of stems (between 52.5% in forest with poor soil and 72.1% in forest with rich soil). The mass of stems decreased 3.6 times with deterioration of soil conditions. Percentage of roots, branches and leaves increased with deterioration of soil conditions. It was observed for other forests (MIAKUCHKO 1978, BOJKO et al. 1975, GOLUBETZ and POLOVNIKOV 1975, ROMANOV et al. 1976, KUCHKO 1977, RIABUCHA 1977, KAZIMIROV et al. 1978). The adaptation of forests to the changing conditions of site was observed. The proportion of thin roots was high in the forest with poor soil. That convinced us that beech trees could hardly assimilate the chemical elements from soil in poor soil conditions.

According to PASTERNAK (1967) the quantity of litter was 6.6 t $\cdot$ ha^{-1} in May and 13.3 t $\cdot$ ha^{-1} in June in the beech forests of Carpathians. The mass of litter was the similar in the beech forests in different regions.

The ratio of mass of litter to the mass of annual litter fall was 1.87 in forest with rich soil and 3.98 in forest with poor soil. The decomposition in the beech forest stand was very fast and fast (KORNEV 1966) in rich and in poor soil conditions.

CONCLUSIONS

In the forest with rich soil conditions the accumulation of biomass in beech ecosystems was the highest among forest ecosystems of Eastern Carpathians and Europe.

The present data confirms, that beech forests of the Eastern Carpathians has high accumulation of organic matter in stems. With deterioration of soil conditions the total mass of beech forest and mass of stems decreased. The mass of branches, leaves and thin roots increased.

Annual increment of total biomass and increment of stems were decreased with deterioration of soil conditions, but the proportion of leaves and roots increased.

With deterioration of soil conditions increased the died organic matter on the soil surface, litter and litter fall coefficient. Therefore we conclude that decomposition of organic matter decreased in the poor soil conditions.

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