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Research article

Ecological functions of forest stands in urbanized environment of Moscow

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Abstract. In urban forests, stock production is not the main function of stands. Carbon sequestration, the release of oxygen and phytoncides, dust precipitation, and changing wind conditions et al. are the main environmental functions. Phyto-organic substances emitted by trees help to reduce the number of microorganisms in air make the air cleaner and fresher. The purpose of the study is to evaluate the ecological functions of forest stands based on long-term observations of the forest stands of the Forest Experimental District of the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy. The study used data about 7 permanent trial plots in natural pine stands, 7 — in pine plantations (planting density — 32 000 trees per 1 ha), 13 — in larch plantations (planting density — 700—4000 trees per 1 ha), 8 — in oak stands (natural stands and plantations) and 9 — in birch stands (natural stands and plantations). For a year, 1 ha of forest covered area produces 10 tons of oxygen, and the entire territory of the Forest Experimental District produces about 2.5 thousand tons of oxygen. In the year, the stands of the Forest Experimental District absorb about 3 thousand tons of carbon dioxide. The forest stands of the Forest Experimental District are capable of precipitating 135 tons of dust and they emit about 130 tons of phytoncides into the air during the growing season. Under urban conditions, forest stands are subject to the influence of negative factors: emissions from industrial enterprises and transport, recreational loads, disruption of natural conditions, and many others. Negative factors lead to a decrease in the performance of ecological functions. Therefore, in urban forests it is necessary to carry out silvicultural measures to increase the sustainability and productivity of stands.

Key words: urbanized environment, ecological functions, forest stands

Introduction

In urban forests, stock production is not the main function of stands. Carbon sequestration, the release of oxygen and phytoncides, dust precipitation, and changing wind conditions et al. are the main environmental functions. Phyto-organic substances emitted by trees help to reduce the number of microorganisms in the air, make the air cleaner and fresher. In addition, urban forests are the resting place of citizens. The numerical evaluation of the ecological functions of forest stands can be calculated using biological productivity data. Biological productivity is an integral indicator characterizing the intensity of biochemical processes occurring in trees.

In forest stands, the intensity of their ecological functions is changed with age. The long-term data of inventories of permanent trial plots show that the growth of forest stands does not take place according to the patterns that are reflected in numerous yield tables [1—5]. Therefore, the study of the dynamics of the ecological functions of forest stands on the basis of multiple observations on permanent trial plots is becoming especially important.

The purpose of the study was to evaluate the ecological functions of forest stands based on long-term observations of the forest stands of the Forest Experimental District of the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy.

Materials and methods

The materials for the study were the inventory data of the permanent trial plots of the Forest Experimental District of the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy. Forest Experimental District was located in the north of Moscow. According to the results of the forest inventory in 2009, the area of the Forest Experimental District was 248.7 ha, including 233.4 ha (93.8 %) covered with forests. Observations on permanent trial plot have been carried out for more than 100 years. The study used data about 7 permanent trial plots in natural pine stands, 7 — in pine plantations (planting density — 32 000 trees per 1 ha), 13 — in larch plantations (planting density — 700—4000 trees per 1 ha), 8 — in oak stands (natural stands and plantations) and 9 — in birch stands (natural stands and plantations).

Aligned rows of stands were used for the study [2, 3]. Average values for groups of permanent trial plots were given with a 95% confidence interval. The text for the average shows the standard error values. Oxygen productivity was determined from the calculation that the formation of 1 t of absolutely dry organic matter led to the release of 1393 kg of oxygen [6]. The amount of deposited carbon was calculated according to the conventional methods through a phytomass conversion factor of 0.5. The potential dust holding capacity was calculated through LAI [7] and data on the deposition of dust by the leaf surface of trees [8].

Results and discussion

Plants produce oxygen during the process of photosynthesis. Fig. 1 shows the production of oxygen by stands, calculated from the net primary production of phytomass. Natural pine stands (maximum 40 years — 10.9 ± 1.0 $t \cdot ha^{-1} \cdot yr^{-1}$) and birch stands (maximum 60 years — 10.3 ± 0.8 $t \cdot ha^{-1} \cdot yr^{-1}$) produce the least amount of oxygen. Pine plantations with a planting density of 32 000 plants per 1 ha produce more oxygen than natural pine stands. In pine plantations, the maximum value of oxygen production is reached at the age of 30 years (23.9 ± 0.6 $t \cdot ha^{-1} \cdot yr^{-1}$). Larch stands for 120 years of growing show quite high values of oxygen production — 16.0 ± 1.1 $t \cdot ha^{-1} \cdot yr^{-1}$.

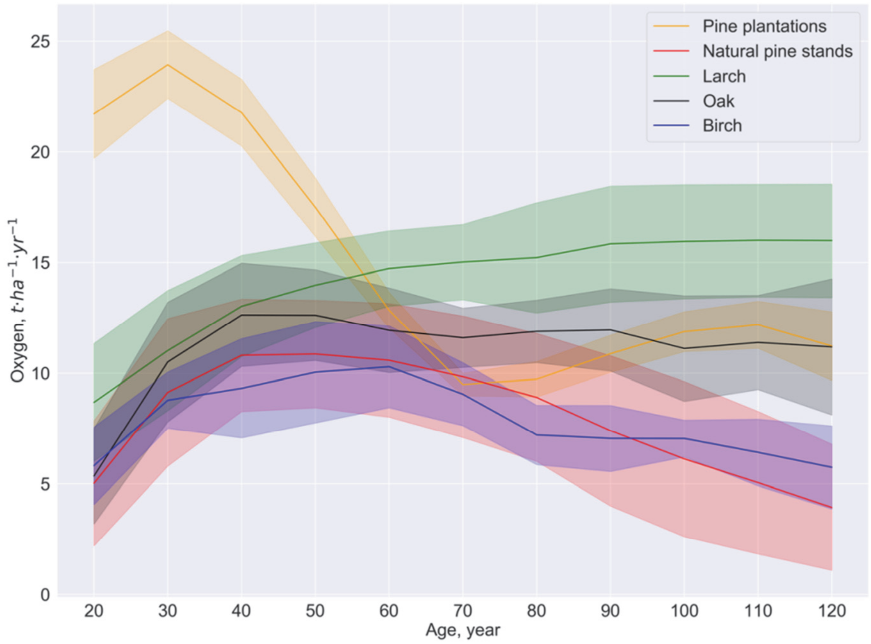

Fig. 1. Oxygen productivity of forest stands and 95 % confidence interval

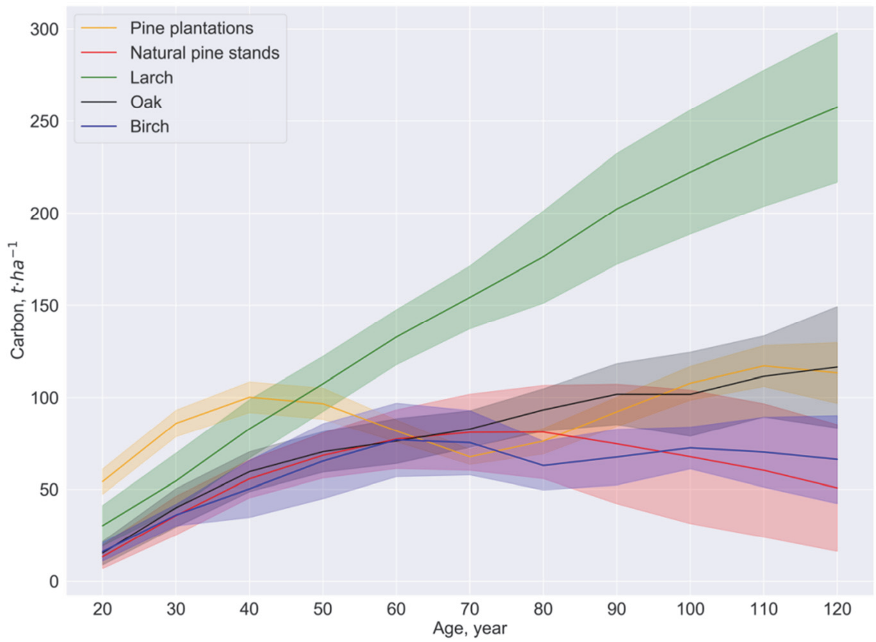

Fig. 2. Carbon sequestration in available phytomass and 95% confidence interval

Currently, the average daily value of oxygen production by the stands of the Forest Experimental District was 27 kg·ha^{-1}. Tree stands produced the maximum amount of oxygen on favorable summer days. In winter, the amount of oxygen produced was minimal. In general, for a year, 1 ha of forest covered area produced 10 tons of oxygen, and the entire territory of the Forest Experimental District produced about 2.5 thousand tons of oxygen.

In the process of photosynthesis, forest stands absorb atmospheric carbon dioxide. In conditions of increasing concentration of carbon dioxide in the atmosphere, the issue of carbon sequestration in the stands is important. In young stands, the largest amount of carbon is sequestered in pine plantations with a planting density of 32 000 trees per 1 ha (Fig. 2). Compared to other forest stands, larch stands sequester the largest amount of carbon. In 100 years available phytomass contains 222 ± 14 t·ha^{-1}. Least of all carbon stock in natural pine stands (maximum 80 years — 81.3 ± 10.7 t·ha^{-1}) and birch stands (maximum 60 years — 77.0 ± 8.7 t·ha^{-1}).

At present, on average, 80 tons of carbon are contained in stands for 1 ha of forest area. In total, the stands of the Forest Experimental District contain about 20 thousand tons of carbon. The average daily value of carbon dioxide uptake by trees is 35 kg·ha^{-1}. And in the year, the stands of the Forest Experimental District absorb about 3 thousand tons of carbon dioxide.

City air contains a large amount of dust and microorganisms. Crowns of trees contribute to the reduction of dust in the air. For example, dust content in Petrozavodsk squares is 300—500% less than the average in the city [9]. The dust holding capacity of trees depends on the leaf area and the morphological characteristics of the leaf. In the Forest Experimental District, up to 60—70 years, pine plantations with planting density 32 000 trees per 1 ha (maximum 30 years — 1375 ± 30 kg·ha^{-1}) and oak stands (maximum 40 years — 873±57 kg·ha^{-1}) had the greatest potential dust holding capacity (Fig. 3). After 70—80 years, larch stands had the greatest dust holding capacity (in 100 years — 853 ± 57 kg·ha^{-1}).

Fig. 3. Potential dust holding capacity of forest stands and 95% confidence interval

On average, 1 ha of forest area of the Forest Experimental District is capable of precipitating 550 tons of dust. In general, forest stands of the Forest Experimental District are capable of precipitating 135 tons of dust, which is washed away with precipitation water into the soil.

In the conditions of cities, an important sanitary and hygienic indicator is the quantitative composition of air microflora. Forest stands emit phytoncides and are good regulators of air quality. The canopy of trees is a natural filter where dust particles and microorganisms linger. Under the action of volatile microorganisms die and the sediments are washed into the soil.

The volatile secretions of trees have a positive effect on the cardiovascular, respiratory, and nervous systems of humans, and contribute to an increase in immunity. There is extremely low percentage of people with respiratory diseases and nervous system disorders in conditions of forest area [10].

As a result of the enlarged assessment, the average daily release of phytoncides by forest stands of the Forest Experimental District is 3.7 $kg \cdot ha^{-1}$. The forest stands of the Forest Experimental District emit about 130 tons of phytoncides into the air during the growing season. This indicates a high antimicrobial activity of tree stands and their great importance for the local population.

Under urban conditions, forest stands are subject to the influence of negative factors: emissions from industrial enterprises and transport, recreational loads, disruption of natural conditions, and many others. Negative factors lead to a decrease in the performance of ecological functions. Therefore, it is necessary to carry out silvicultural measures in urban forests to increase the sustainability and productivity of stands.

Conclusions

The best oxygen-producing and carbon-sequestration functions were expressed in larch stands, which show high resistance to adverse factors in the conditions of the city. Least of all these functions were expressed in birch stands, which were characterized by a high decorative effect. In general, for a year, 1 ha of forest covered area produces 10 tons of oxygen, and the entire territory of the Forest Experimental District produced about 2.5 thousand tons of oxygen. During the year, the stands of the Forest Experimental District absorbed about 3 thousand tons of carbon dioxide.

Pine, oak and larch stands were characterized by a high dust holding capacity. In general, forest stands of the Forest Experimental District were capable of precipitating 135 tons of dust which was washed away with precipitation into the soil.

The forest stands of the Forest Experimental District emitted about 130 tons of phytoncides into the air during the growing season. This indicates a high antimicrobial activity of tree stands and their great importance for the local population.

Under urban conditions, forest stands are subject to the influence of negative factors: emissions from industrial enterprises and transport, recreational loads, disruption of natural conditions, and many others. Negative factors lead to a decrease in the performance of ecological functions. Therefore, it is necessary to carry out silvicultural measures in urban forests to increase the sustainability and productivity of stands.

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Научная статья

Экологические функции древостоев в условиях урбанизированной среды на примере города Москвы

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Аннотация. В городских лесах продуцирование запаса не является главной функцией древостоев. Депонирование углерода, выделение кислорода и фитонцидов, осаждение пыли, изменение ветрового режима и другие являются основными экологическими функциями. Фитоорганические вещества, выделяемые деревьями, способствуют снижению количества микроорганизмов в воздухе, делают его чище и свежее. Цель исследования — оценка экологических функций древостоев по материалам многолетних наблюдений за насаждениями Лесной опытной дачи Российского государственного аграрного университета — Московская сельскохозяйственная академия имени К.А. Тимирязева. В исследовании использовались данные о 7 постоянных пробных площадях в естественных сосновых насаждениях, 7 — в культурах сосны (густота посадки — 32 000 деревьев на 1 га), 13 — в культурах лиственницы (густота посадки — 700—4000 деревьев на 1 га), 8 — в дубовых насаждениях (естественного и искусственного происхождения) и 9 — на березовых насаждениях (естественного и искусственного происхождения). За год 1 га покрытой лесом площади производит 10 тонн кислорода, а вся территория Лесной опытной дачи — около 2,5 тысяч тонн кислорода. В год древостои Лесной опытной дачи поглощают около 3 тысяч тонн углекислого газа. В целом древостои Лесной опытной дачи способны осаждать 135 тонн пыли и выделяют в воздух около 130 тонн фитонцидов в течение вегетационного периода. В городских условиях лесные насаждения подвержены влиянию негативных факторов: выбросов промышленных предприятий и транспорта, рекреационных нагрузок, нарушения природных условий и многих других. Негативные факторы приводят к снижению выполнения ими экологических функций. Поэтому в городских лесах необходимо проводить лесоводственные мероприятия для повышения устойчивости и продуктивности древостоев.

Ключевые слова: урбанизированная среда, экологические функции, древостои

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