International Journal of Engineering & Technology, 7 (4.8) (2018) 214-220

International Journal of Engineering & Technology

Website:www.sciencepubco.com/index.php/IJET

Research paper

The Role of "Green Structures" in Reducing the Environmental Footprint of Urbocenoses

Tetiana Tkachenko[1]*, Olena Voloshkina[2]

[1]Kyiv National University of Construction and Architecture, Ukraine
[2]Kyiv National University of Construction and Architecture, Ukraine
**Corresponding author E-mail: tkachenkoknuba@gmail.com*

Abstract

The modern problem of urbocenoses is associated with an increase of the environmental footprint, the main indicator of which is the concentration of CO_2 in the atmosphere. One of the ways to reduce carbon emissions is to increase biomass through the «green structures». Nowadays, there are insufficient methods for calculating the accumulation of biomass and sequestration of CO_2. As a result, new methodological approaches are proposed.

Keywords: *biomass; carbon; dioxide; ecological imtprint; green structures.*

1. Introduction

The UN "Climate-Neutral Cities" report emphasizes the primary role of Urbotsenoz in mitigating climate change. According to experts, cities consume 75% of global energy and emit 80% of greenhouse gases [1]. The main contribution to the greenhouse effect is CO_2, which is an indicator of the ecological footprint of Urbocenoses. Despite the strong fluctuations in the concentration of CO_2 in the Earth's atmosphere over the past geological period, the natural cycle of CO_2 for the last several millennia as a whole has not changed. Anthropogenic activity violates this equilibrium by releasing CO_2 associated with such natural carbon stores as fossil fuels and green biomass. Since the beginning of the industrial era in the eighteenth century, the concentration of CO_2 in the atmosphere increased by almost a third. As a result of these actions during the last century there was a global increase in the average temperature, which was followed by the warming of the climate. Reduction of CO_2 emissions is the main mechanism for deceleration of climate change. In solving this problem, "green constructions" can be considered as promising technologies for reducing the ecological footprint due to biomass (trunk and branches, bark, leaves, roots) and substrate.

2. Literature analysis

According to the work [2], annually in the biosphere for about 250-400 billion tons of CO_2 bind in the photosynthesis reactions, which is equivalent to the formation of 160-200 billion tons of organic mass and 100-150 billion tons of O_2.
According to studies of Yanling Li and Roger Babcock [3], the trend of studying the binding of CO_2 to the phytomass in "green structures" is relatively new, but very promising. Therefore, there are still no clear validated methods for calculating the accumulation of carbon biomass on "green structures". According to the literature data, four methods for determining the amount of carbon in biomass can be distinguished: 1 – laboratory methods for dry residue of organic matter by roasting; 2 – field studies of CO_2 content in air by measuring devices; 3 - laboratory studies on the absorption of CO_2 by plants per time unit in an artificial chamber of climatron; 4 - GIS-modelling methods using well-known literary data.
The first group is known for the research by Kristin L. Getter et al. [4]. Two studies were conducted to quantitatively assess the carbon storage potential of "green roofs". Studies were conducted on eight roofs in Michigan and four roofs in Maryland. The age of plants on the roof varied from 1 to 6 years. All 12 "green roofs" consisted of species of the genus *Sedum*. Interest in these plants grew up because of the fact that they have CAM-metabolism, which contributes to limiting the loss of moisture during a hot period. As a result, in these plants, stomata are opened at night to absorb CO_2 and store it in the form of organic acid in vacuoles of cells. During the day stomata are closed. The organic acid decarboxylates again to CO_2.
The depth of the substrate ranged from 2.5 to 12.7 cm. Biomass and substrate were collected seven times during the spring and autumn seasons. The carbon content of the plant material varied by species: from 64 g C/m^2 in *S. acre* to 239 g/m^2 in *S. album*. The average carbon content in above-ground biomass was 168 g/m^2. Underground biomass (roots) also varied by species: from 37 g/m^2 in *S. acre* to 185 g/m^2 in *S. album*. The average content was 107 g/m^2. The average carbon content in the substrate was 913 g/m^2 without a specific effect. Specific effect is the rate of sequestration of 100 g of carbon per 1 m^2 over two years. It was found that the entire roof sequestered 375 g of carbon per m^2.
Salvador N. Lindquist, Richard K. Sutton [5] also investigated sequestration of carbon on succulent plants: *Sedum album* and *Bouteloua gracilis*. Plants were grown in 32 flat cells during six months. Then they were transplanted into trays of 30×20 cm filled with a 7.5 cm substrate. After that, the roots were washed and separated by scissors from the overhead mass. Then they were dried for three days at temperature of 100 °C in a dry oven. The accumulation of carbon in biomass and soil was studied. Soil studies on carbon accumulation were conducted on the basis of the

methodology of J. Sanderman and R. Amundson [6]. They took the upper (0-15cm) and deep (30-45 cm) ground layers. Ground samples were divided into fractions by sieving method. It has been found that *Bouteloua gracilis* gives a greater overhead (21.29±1.66g) and underground (14.84±1.32g) biomass, and therefore, it has more valuable binding of carbon compared to the *Sedum album*. The last one has 6.40±1.66 g of overhead biomass and 6.83±1.32 g of underground biomass. According to the authors, an increase in groundwater and underground biomass of plants indicates a large amount of sequestration of carbon.
The second and third groups of methods are described in work [7] by Jian-Feng Li, Onyx W.H. Wai, Y.S. Li, Jie-Min Zhan et al. The authors studied the effect of “green roofs” on the concentration of CO_2 in the ambient air. The roof was examined with plants and without plants in the size of 4×4 m. It was established that the concentration of CO_2 over the “green roof” was 4.3 mg/m^3 lower than the reference surface at daytime until 16 hours. At night, the CO_2 concentration through the breathing process was slightly higher. To further assess of the effect of “green roofs” on the concentration of CO_2 in the environment, the authors also measured the CO_2 in the chamber to construct the absorption rate curve. According to this curve, the authors simulated the effects of the “green roof” in urban areas. The simulation results showed that the CO_2 concentration around the “green roof” dropped significantly. It is noted that the concentration of CO_2 is influenced by the wind, which contributes to the mixing of air. In this case, the relative reduction in the concentration of CO_2 in the zone of “green roof” reached 9.3 %.
The fourth group of methods is covered in works [8,9]. The authors digitized the image of the area of “green roofs”, and then used the practical data of K. L. Getter [3]. The authors came to the conclusion that “green structures” are the effective modern way of reducing the concentration of CO_2 in the atmosphere. The most effective for reducing the concentration of CO_2 is the area of «green roofs» of 70 000 m^2. This area balances carbon emissions from 16 cars per year.
The purpose of the work is to calculate herbal biomass and carbon binding in “green structures”.

3. Methodological approaches for the experimental research

3.1. Experimental setup and measurements

In the non-destructive experiments, we use a laboratory model of green roof, which contains a box of 720×580×30 mm with lawn rolling of *Lolium perenne* on substrate (Fig. 1).

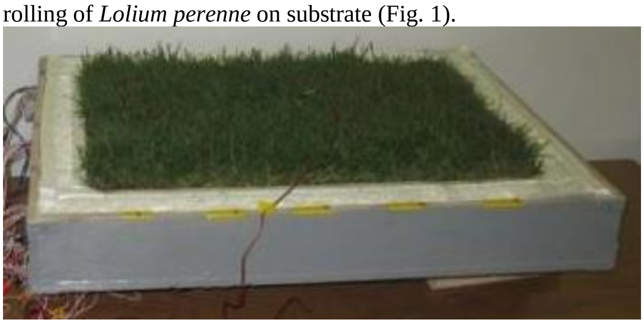

Fig. 1: Model of a “green roof”

One of the most important positive aspects of *Lolium perenne* is its high yield. Very comfortable is the property of the regress (*Lolium perenne*) for a long stay, because of the long life expectancy from 5 to 6 years [10].
The grass grows from 40 mm o 125 and 400 mm. In the lawn, we picked randomly parts 40×40 mm. In the parts, we calculated the number of blades of grass. The average number N was calculated and divided per area $A_0 = 0.04{\cdot}0.04 = 0.0016$ m^2. Thus, we obtained the average number of blades of grass per square meter $n = N/S$, m^{-2}.
After that, we chose randomly blades and measure them. Height and width was measured by an instrumental ruler with error of 0.1 mm between any points. Thickness was measured by a micrometer LIZ MR 0…25 mm, value of division 0,002 mm. The results are processed by standard statistical methods (Table 1).

Table 1: Results for measuring the biomass of *Lolium perenne*

Average thickness of the grass δ, mkm	Average grass width b, mm	An estimated height h, mm	An average number of blades of grass n, on the area $A_0 = 40 \times 40$ mm^2
170,8 ± 6,46	2,32 ± 0,11	40 та 125	26,5 ± 1,12

3.2. Biomass calculations

To calculate the biomass by formula (1), it is necessary to know the density ρ, kg/m^3, and the volume V, m^3/m^2:

$$V = \frac{\delta \cdot b \cdot h \cdot n}{10^6 \cdot 10^3 \cdot 10^3 \cdot A_0} = \frac{\delta \cdot b \cdot h \cdot n}{10^{12} A_0}. \tag{1}$$

The data of the mass of grass in a wet and dry state were taken by P. M. Mazurkin [11]: mass of dry hay or grass of air-dry state $m_{hay} = 248.199$ g/m^2; mass of the natural moisture in the grass sample $m_{moist.} = 656{,}388$ g/m^2; total mass of sample $m_{test} = 904{,}587$ g/m^2. Water density ρ_{water} is calculated at 20 °C: $\rho_{water} = 998.2$ g/m^2 [12]. According to [13], the density of dry small forest (or shrub) ρ_{dry} is about 319 kg/m^3. In the absence of data for dry grass without air cavities (not bulk hay), we accept the dry mass of the grass according to the data for the shrub.
The density of the live grass can be found by assuming that the density of dry mass and water in the living grass separately are the same as those described above. In this case,

$$V_{sample} = \frac{m_{hay}}{\rho_{hay}} + \frac{m_{moist.}}{\rho_{water}}. \tag{2}$$

The equation (2) allows estimating the density of the sample:

$$\rho_{sample} = \frac{m_{hay} + m_{moist}}{V_{sample}} = \frac{1}{\dfrac{\frac{m_{hay}}{m_{hay}+m_{moist}}}{\rho_{hay}} + \dfrac{\frac{m_{moist}}{m_{hay}+m_{moist}}}{\rho_{water}}}. \tag{3}$$

By the equation (3),

$$\rho_{sample} = \frac{1}{\dfrac{\frac{248.199}{248.199+656{,}388}}{319} + \dfrac{\frac{656{,}388}{248.199+656{,}388}}{998.2}} =$$
$$= 630.1\ \text{kg/m}^3.$$

When observing the growth of a lawn in an experimental plant for 0.5 years without a haircut, the maximum height of the grass $h_2 = 400$ mm was obtained. Initial height of the grass $h_1 = 40$ mm. During the next half of the year, the grass does not grow.

Calculate the biomass volume [m^3] V_1 and V_2 of the grass at the height h_1 and h_2 by the formula (1):

$$V_1 = \frac{170.8 \cdot 2.32 \cdot 40 \cdot 26.5}{0.0016 \cdot 10^{12}} = 2.625 \cdot 10^{-4}\ \text{м}^3/\text{м}^2.$$

$$V_2 = \frac{170.8 \cdot 2.32 \cdot 400 \cdot 26.5}{0.0016 \cdot 10^{12}} = 2.625 \cdot 10^{-3} \text{ м}^3/\text{м}^2.$$

The mass of the grass

$$m = V \cdot \rho_{sample}. \quad (4)$$

At the height [m] h_1 and h_2 of the grass, its mass is, correspondingly,

$$m_1 = V_1 \cdot \rho_{sample} = 2.625 \cdot 10^{-4} \cdot 630.1 = 0.1654 \text{ kg/m}^2;$$
$$m_2 = V_2 \cdot \rho_{sample} = 2.625 \cdot 10^{-3} \cdot 630.1 = 1.654 \text{ kg/m}^2;$$

For comparison, the average leaf-tree with a height of 3 m in diameter of a barrel of 15 cm (at a level of 1.3 m above ground or substrate), according to [14], has a total mass of above-ground part of 62.43 kg. This corresponds to the mass of grass in the planting area of the lawn at height [m] h_1 and h_2:

$$A_1 = \frac{62.43}{0.1654} = 377.4 \text{ m}^2;$$
$$A_1 = \frac{62.43}{1.654} = 37.74 \text{ m}^2;$$

Thus, dependent on the grass height [m], 37.74…377.4 m^2 of green roof with a lawn replaces one tree with a height of 3 m, with a diameter of 15 cm, for biomass.

3.3. Calculating the absorption of carbon by the biomass of the grass

For further calculations of carbon binding, we use the Belarusian method of absorbing carbon dioxide by phytomass [13]. Calculation of carbon deposits for a certain period of time is carried out by the formula.

$$C = V \cdot D \cdot BEF_2 \cdot (1+R) \cdot CF, \quad (4)$$

where D –average density of absolutely dry mass, [t/m^3]; V – total volume [m^3] depending on height of the plants [mm]; R – the relation between the mass of roots and trunks of trees, CF – part of carbon in dry substance; BEF_2 – phytomass coefficient for conversion of the total stock of plantings to the amount of phytomass of all components of the overhead part.
We make the calculation for the period of growth of the grass.
$D = \rho_{dry} / 1000 = 0{,}319$ t/m^3; $R = 0{,}3$; CF – 0,471 (Table 8 of the work [13] for "living surface layer"); $BEF_2 = 1$ because the grass does not have fractions.
By the equation (4), for initial h_1 and final h_2 height [mm]:

$$C_1 = 2.625 \cdot 10^{-4} \cdot 0.319 \cdot 1 \cdot (1+0.3) \cdot 0.471 = = 5.128 \cdot 10^{-5} \text{ t/m}^2 \text{ or } 0.05128 \text{ kg/m}^2.$$

$$C_2 = 2.625 \cdot 10^{-3} \cdot 0.319 \cdot 1 \cdot (1+0.3) \cdot 0.471 = = 5.128 \cdot 10^{-4} \text{ t/m}^2 \text{ or } 0.5128 \text{ kg/m}^2.$$

The difference in the deposit of carbon during the growth period of the grass

$$C_2 - C_1 = 0.5128 - 0.0513 = 0.4615 \text{ kg/(m}^2 \cdot \text{year)}. \quad (5)$$

The mass of carbon in CO_2 should be calculated by the following way. Molar mass of atomic carbon $M(C) = 12$ g/mol. Molar mass of atomic oxygen $M(O) = 16$ g/mol Molar mass of CO_2: $M(CO_2) = 12 + 16 \cdot 2 = 44$ g/mol; M(C) / M(CO2) = 12 / 44 = 3 / 11. The amount of CO_2 deposited during the growth period of the grass is calculated by the formula

$$M_{CO_2} = \frac{C_2 - C_1}{M(C)/M(CO_2)} = \frac{0.4615}{3/11} = 1.692 \text{ kg/(m}^2 \cdot \text{year)}. \quad (6)$$

Thus, we can say that during the period of the grass growth on extensive "green roofs" of 1 hectare (10000 m^2) there is deposit of 17 t CO_2 per year. According to [15], the daily CO_2 emission from a highway of Kiev is 1800 ... 2000 kg. Thus, one hectare of lawn per year consumes 1,692 · 10000/1900 = 8.9 daytime CO_2 emissions from the highway. This means the need of maximizing the use of «green structures», especially in poorly greened areas of cities to achieve maximum CO_2 absorption. At the green roofs, non-greened areas should be minimized. It is also necessary to maximize the use of intensive green roofs with trees, which have significantly higher biomass and greater CO_2 absorption potential.

3.4. The calculation of carbon sequestration by biomass of trees on an example of a "green roof" on the *Royal Tower* building

Applying similar methodological approaches, the calculation of CO_2 absorption for the tree assortment on the roof (Fig. 2-8) of Royal Tower (Kyiv) per year has been made. The area of green plantations on the roof becomes about 180 m^2. The trees (the height is 1…6 m) are: *Acer rubrum*, *A. rubrum "Scanlon"*, *A. platanoides "Globosum"*, *Amelanchier lamarckii*, *Carpinus*, *Malus multicaulus*, *Pinus sylvestris*, *P.mugo "Pumilio"*, *Quercus paludosus multicaulus*, *Q. rubra multicaulus*, *Thuja occidentalis 'Smaragd'*, *T. occidentalis "Brabant"*, *T. occidentalis "Danica"* та чагарниками висотою від 0,30 до 1,5 м: *Azalea rubra*, *Berberis thunbergii*, *Euónymus alátus*, *Hydrangea arborescens "Annabelle"*, *H. anomala "Petiolaris"*, *Ligustrum vulgare 'Globosum'*, *Parthenocíssus tricuspidáta*, *Physocarpus opulifolius 'Luteus'*, *Spiraea japonica "Golden Princess"*, *S. japonica "Goldflame"*, *S. japonica "Little Princess"*. One square meter of woody area absorbs 3.769 kg/(m^2·year) of CO_2, and one hectare of tree plantings per year absorbs CO_2 emissions from the highway for 19.8 days. The overall effect of absorbing CO_2 from trees and grass is 5.461 kg/(m^2·year), and one hectare of plantings annually absorbs emission from the highway for 28.7 days. The calculatios are in the Tables 2-4.

Fig.2: The general view of an intensive "green roof" on the *Royal Tower* residential complex (Kiev)

Fig.3: Location of expositions of deciduous tree plants

Fig.4: Location of expositions of deciduous tree plants

Fig.5: Location of exposition from wood and shrub plants

Fig.6: Location of exposition from wood and shrub plants

Fig.7: An example of placement of a hedge of bushes

Fig.8: An example of placement of a hedge of bushes

Table 2: Calculation of the relation between the mass of roots and trunks

Part	Species						
	Pi-nus	*Picea*	*Quercus*	*Betula*	*Al-nus*	*Ca-rex*	Others
Mass in dry condition m [t/(м^3 stem)] [13]							
Stem	0.535	0.465	0.68	0.6	0.55	0.445	0.274
Branches	0.095	0.066	0.268	0.091	0.116	0.052	0.074
Needles or leaves	0.023	0.072	0.053	0.054	0.055	0.039	0.033
The above-ground part m_o	0.653	0.603	1.001	0.745	0.721	0.536	0.381
Roots + stump	0.089	0.084	0.143	0.12	0.092	0.087	0.041
Juvenile + under-growth	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Live above-ground cover	0.009	0.003	0.012	0.01	0.003	0.001	0.017
Total	0.752	0.691	1.157	0.876	0.817	0.625	0.44
	The share of the above-ground part $R_i = m/m_o$						
Roots + stump	0.1363	0.1393	0.1429	0.1611	0.1276	0.1623	0.1076
Juvenile + - under-growth $\times 10^{-3}$	1.531	1.658	0.999	1.342	1.387	1.866	2.625
Live above-ground cover $\times 10^{-3}$	13.783	4.975	11.988	13.423	4.161	1.866	44.62

Table 3: Initial state of the plants

Plant species	Height, м	The share of the above-ground part R_i			Weight, kg									Carbon content, kg						
		roots + stump $\times10^{-4}$	juvenile +undergrowth $\times10^{-6}$	Live above-ground cover $\times10^{-5}$	bark	wood	branches	needles or leaves	the aboveground part	roots + stump	juvenile + undergrowth	live above-ground cover	total	stem wood	branches	needles or leaves	roots + stump	juvenile + undergrowth	live above-ground cover	total
Quercus paludosus	5	1429	999	1199	18.59	63.68	17.44	2.90	102.61	14.66	0.10	1.23	221.21	41.46	9.24	1.50	51.92	7.33	0.05	111.51
Quercus rubra	6	1429	999	1199	29.64	87.93	71.38	10.16	199.11	28.44	0.20	2.39	429.25	59.26	37.83	5.26	100.75	14.22	0.10	217.42
Malus	3	1076	2625	4462	1.77	6.01	1.97	6.06	15.81	1.70	0.04	0.71	34.07	3.91	0.99	2.94	7.81	0.85	0.02	16.52
Carpinus	3	1076	2625	4462	0.25	2.79	0.54	2.08	5.66	0.61	0.01	0.25	12.20	1.53	0.27	1.01	2.80	0.30	0.01	5.92
Pinus	6	1363	1531	1378	4.86	28.62	29.92	6.76	70.16	9.56	0.11	0.97	150.96	16.77	15.74	3.53	36.27	4.78	0.05	77.15
Amelanchier	3.5	1076	2625	4462	0.40	2.00	1.49	1.65	5.54	0.60	0.01	0.25	11.94	1.21	0.75	0.80	2.74	0.30	0.01	5.79
Acer platanoides	4.5	1076	2625	4462	7.20	21.31	13.70	2.87	45.08	4.85	0.12	2.01	97.14	14.34	6.85	1.39	22.27	2.43	0.06	47.33
Acer rubrum	5	1076	2625	4462	7.33	33.20	13.87	2.90	57.30	6.17	0.15	2.56	123.48	20.39	6.94	1.41	28.31	3.08	0.07	60.19
Ligustrum	1	1076	2625	4462	0.26	0.58	33.90	18.55	53.29	5.73	0.14	2.38	114.83	0.42	16.95	9.00	26.33	2.87	0.07	55.63
Thuja occidentalis	3	1076	2625	4462	1.26	4.14	10.68	11.80	27.88	3.00	0.07	1.24	60.08	2.72	5.34	5.72	13.77	1.50	0.03	29.09
Spiraea	0.35	1076	2625	4462	0.02	0.11	2.22	1.61	3.96	0.43	0.01	0.18	8.53	0.07	1.11	0.78	1.96	0.21	0.00	4.13
Berberis	0.45	1076	2625	4462	0.03	0.14	1.74	1.29	3.20	0.34	0.01	0.14	6.90	0.09	0.87	0.63	1.58	0.17	0.00	3.34
Euónymus	1.5	1076	2625	4462	0.34	0.77	45.20	24.70	71.01	7.64	0.19	3.17	153.02	0.56	22.60	11.98	35.08	3.82	0.09	74.13
Pinus mugo	1	1363	1531	1378	0.49	1.08	73.00	39.55	114.12	15.55	0.17	1.57	245.54	0.79	38.40	20.65	59.00	7.78	0.08	126.69
Hydrangea	0.8	1076	2625	4462	0.275	0.55	58.43	30.63	89.89	9.67	0.24	4.01	193.69	0.41	29.22	14.86	44.40	4.84	0.11	93.84
Azalea	0.5	1076	2625	4462	0.03	0.14	1.74	1.29	3.20	0.34	0.01	0.14	6.90	0.09	0.87	0.63	1.58	0.17	0.00	3.34
Parthenocíssus	1	1076	2625	4462	0.04	0.20	1.29	0.97	2.50	0.27	0.01	0.11	5.39	0.12	0.65	0.47	1.24	0.13	0.00	2.61
Physocarpus	0.8	1076	2625	4462	0.04	0.20	1.29	0.97	2.50	0.27	0.01	0.11	5.39	0.12	0.65	0.47	1.24	0.13	0.00	2.61
Total	—	—	—	—	72.83	253.45	379.80	166.74	872.82	109.84	1.60	23.42	1880.49	164.25	195.24	83.01	439.03	54.92	0.77	937.22

Table 4: Final state of the plants

Plant species	Height, м	The share of the above-ground part R_i			Weight, kg									Carbon content, kg						
		roots + stump $\times 10^{-4}$	juvenile + undergrowth $\times 10^{-6}$	live aboveground cover $\times 10^{-5}$	bark	wood	branches	needles or leaves	the above-ground part	roots + stump	juvenile + undergrowth	live ground cover	total	stem wood	branches	needles or leaves	roots + stump	Juvenile+ undergrowth	live aboveground cover	total
Quercus paludosus	5	1429	999	1199	20,66	70,76	19,38	2,56	113,36	16,19	0,11	1,36	244,39	46,08	10,27	1,33	57,36	8,10	0,06	123,19
Quercus rubra	6	1429	999	1199	32,33	95,92	77,87	11,09	217,21	31,03	0,22	2,60	468,27	64,64	41,27	5,74	109,91	15,52	0,11	237,19
Malus	3	1076	2625	4462	2,10	7,62	2,30	5,50	17,52	1,89	0,05	0,78	37,75	4,89	1,15	2,67	8,65	0,94	0,02	18,33
Carpinus	3	1076	2625	4462	0,30	3,35	0,65	2,50	6,80	0,73	0,02	0,30	14,65	1,84	0,33	1,21	3,36	0,37	0,01	7,11
Pinus	6	1363	1531	1378	4,95	29,11	30,43	6,89	71,38	9,73	0,11	0,98	153,58	17,06	16,01	3,60	36,90	4,86	0,05	78,49
Amelanchier	3.5	1076	2625	4462	0,44	2,22	1,25	1,40	5,31	0,57	0,01	0,24	11,44	1,34	0,63	0,68	2,62	0,29	0,01	5,56
Acer platanoides	4.5	1076	2625	4462	8,15	23,98	15,42	3,23	50,78	5,46	0,13	2,27	109,42	16,16	7,71	1,57	25,09	2,73	0,06	53,32
Acer rubrum	5	1076	2625	4462	8,15	36,89	15,42	3,23	63,69	6,85	0,17	2,84	137,24	22,66	7,71	1,57	31,46	3,43	0,08	66,90
Ligustrum	1	1076	2625	4462	0,51	1,15	67,80	37,10	106,56	11,47	0,28	4,75	229,62	0,83	33,90	17,99	52,64	5,73	0,13	111,23
Thuja occidentalis	3	1076	2625	4462	1,31	4,47	9,94	10,98	26,70	2,87	0,07	1,19	57,53	2,91	4,97	5,33	13,19	1,44	0,03	27,86
Spiraea	0.35	1076	2625	4462	0,35	0,16	1,59	1,19	3,29	0,35	0,01	0,15	7,09	0,26	0,80	0,58	1,63	0,18	0,00	3,44
Berberis	0.45	1076	2625	4462	0,45	0,19	1,37	1,03	3,04	0,33	0,01	0,14	6,55	0,32	0,69	0,50	1,50	0,16	0,00	3,18
Euónymus	1.5	1076	2625	4462	0,51	1,15	67,80	37,10	106,56	11,47	0,28	4,75	229,62	0,83	33,90	17,99	52,64	5,73	0,13	111,23
Pinus mugo	1	1363	1531	1378	0,51	1,15	67,80	37,10	106,56	14,52	0,16	1,47	229,28	0,83	35,66	19,37	55,09	7,26	0,08	118,29
Hydrangea	0.8	1076	2625	4462	0,44	0,88	93,49	49,01	143,82	15,48	0,38	6,42	309,91	0,66	46,75	23,77	71,05	7,74	0,18	150,14
Azalea	0.5	1076	2625	4462	0,04	0,20	1,29	0,97	2,50	0,27	0,01	0,11	5,39	0,12	0,65	0,47	1,24	0,13	0,00	2,61
Parthenocíssus	1	1076	2625	4462	0,07	0,33	0,86	0,67	1,93	0,21	0,01	0,09	4,16	0,20	0,43	0,32	0,95	0,10	0,00	2,02
Physocarpusк	0.8	1076	2625	4462	0,06	0,28	0,98	0,75	2,07	0,22	0,01	0,09	4,46	0,17	0,49	0,36	1,02	0,11	0,00	2,16
Total	—	—	—	—	81,33	279,81	475,64	212,30	1049,08	129,65	2,02	30,54	2260,36	181,80	243,29	105,04	526,30	64,82	0,97	1122,23

4. Conclusions

The methodical approaches for calculating the biomass of grass and depositing it with carbon dioxide on "green structures" are improved. Methods of calculation have been tested. It was established that on a "green roof" the mass of grass, depending on height, is 0,1654 ... 1,654 kg/m^2. That is, 37.74…377.4 m^2 of "green roof" with a lawn replaces one tree with height of 3 m and diameter of 15 cm. In this case, the period of growth of the grass deposits 1.692 kg/(m^2·year) of carbon dioxide. One hectare of the "green roof" binds 17 t CO_2. It consumes 8.9 days of CO_2 emissions from a highway of Kyiv. As a result, one square meter of woody area absorbs 3.769 kg/(m^2·year) of CO_2, and one hectare of tree plantings per year absorbs CO_2 emissions from the highway for 19.8 days. The overall effect of absorbing CO_2 from trees and grass is 5.461 kg/(m^2·year), and one hectare of plantings annually absorbs emission from the highway for 28.7 days. This means the need to maximize the use of «green structures», especially in poorly greened areas of cities to achieve maximum CO_2 absorption. It is also necessary to maximize the use of intensive green roofs with trees that have significantly higher biomass and greater CO_2 absorption potential.

Acknowledgement

Work performed under the state budget issues, state registration number 0117U003297.

References

[1] United Nations Economic Commission for Europe, "Climate neutral Cities", United Nations, (2011), pp. 71.

[2] Ilina N.A., Sergeeva N.V., Peritjatko A.I., "Fhyziologia i biochimija rastenyi", Uljanovsk-Saratov, (2013), pp. 335.

[3] Yanling Li, Roger W., Babcock Jr., "Green roofs against pollution and climate change. A review", *Agron. Sustain, Dev.*, (2014), 34, pp. 695–705., DOI. 10.1007/s13593-014-0230-9.

[4] Kristin L. Getter, D. Bradley Rowe, G. Philip Robertson, Bert M. Cregg, Jeffrey A. Andresen, (2009). "Carbon sequestration potential of extensive green roofs", *Environmental Science and Technology*, 43(19), pp. 7564-7570.

[5] Salvador N. Lindquist, Richard K. Sutton Storing, "Carbon in Green Roofs: Above- and Below-Ground Biomass of Blue Grama and White Stonecrop", University of Nebraska – Lincoln, (2015), pp.11, available online: http://digitalcommons.unl.edu/rurals/vol9/iss1/1, last visit: 21.09.2018.

[6] Sanderman, J., Amundson R., (2009), "A Comparative Study of Dissolved Organic Carbon Transport and Stabilization in California Forest and Grassland Soils", *Biogeochemistry*, Vol. 92, № 1/2, pp. 41-59, DOI 10.1007/s 10533-008-9249-9, available online: https://www.jstor.org/stable/25652592?seq=1#page_scan_tab_contents, last visit: 21.09.2018.

[7] Jian-feng Li, Onyx W.H. Wai, Li Y.S., Jie-min Zhan, Alexander Y.Ho, James Li, Eddie Lam, 2010),"Effect of green roof on ambient CO2 concentration", *Building and Environment*, 45, pp. 2644-2651.

[8] Nike Rosenström, Marko Scholze, "Quantification of the effect that Green Roofs have on ambient CO2 concentrations", Malmö, Lund University, Sweden,(2018), 27p., available online: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8950937&fileOId=8950942, last visit: 21.09.2018.

[9] Flake I, O'Donoghue D., (2011), "Green Roofs in the Saratoga Lake Watershed: Sedums of Change", 30 p., available online: https://www.skidmore.edu/wri/documents/flake_odonoghue.pdf , last visit: 21.09.2018.

[10] Mazurkin P.M., Michaylova C.I., (2010)., "Dinamika massy proby", available online: https://www.monographies.ru/en/book/section?id=3368, last visit: 21.09.2018.

[11] Analyticheskaya chimia, available online: http://www.novedu.ru/sprav/pl-h2o.htm, last visit: 21.09.2018.

[12] CHP Kolesnik, "Objomniy ves kustarnika i melkolesya (obyomnaya massa)", available online: http://kovka-dveri.com/metal_stroitelstvo0084qq0263.HTML, last visit: 21.09.2018.

[13] Shatravko A.V., Kriskevich E.L., (2017). "Sostavlenie uglerodnogo balansa lesov respubliki Belarus na osnovanii znacheniy koeffizientov vubrosov /poglochenia dioksida ugleroda ot nadzemnoy fitomassui, podgotovka prognoza uvelicheniya poglocheniya vuibrosov parnikovuich gazov lesami do 2030 i do 2050 godov, podgoyovka perechnya meropriyatiy po uvelicheniyu poglochenia parnikovuch gazov v lesnom chozaystve", Minsk, Belorus, p. 65 .

[14] Biomass and nutrients calculation, available online: https://apps-scf-cfs.rncan.gc.ca/calc/en/biomass-calculator, last visit: 21.09.2018.

[15] Bilyavskyi G.O., Furduiy R.S., Kostikov I.Y., "Osnovi nekologii", Kuiv (2005), p. 406.