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EVALUATING OF ECOSYSTEM SERVICES: CARBON STORAGE IN THE FOREST ECOSYSTEMS OF BELGRADE

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Abstract

The amount of carbon stored in Belgrade's urban forests is detailed as follows: 1,143,686 t/ha in above-ground biomass, 185,094 t/ha in underground biomass, 57,184 t/ha in dead wood biomass, 391,816 t/ha in forest floor, and 2,537,519 t/ha in soil, totaling 4,315,299 t/ha (Ratknić T et al., 2022). Satellite imagery was employed for measurements, facilitating automation and daily change monitoring. Wood has varying prints depending on its use, such as paper production, building materials, furniture, fuel, or biomass (pellets). It is necessary to develop a circular economy-based certification concept. Projected net-zero greenhouse gas emissions by 2050 underscore the need for incentivizing private forest involvement in carbon sequestration through storage or afforestation. This calls for a new management system ensuring the permanent fixation of carbon within the forest.

Key words: *ecosystem services, bound carbon, urban forests, City of Belgrade.*

Introduction

Forest ecosystems play a significant role in the global carbon cycle. This component modifies climate characteristics in the context of global warming. Concentrations of carbon dioxide, methane, and nitrous oxide are currently at an all-time high in the last 800,000 years. According to the latest IPCC Report (2023), the average global surface temperature was 1.09 [0.95 to 1.20]°C

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higher in 2011–2020 than in 1850–1900, with larger increases over land (1.59 [1.34 to 1.83]°C) than oceans (0.88 [0.68 to 1.01]°C). Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10]°C higher than 1850–1900. Global surface temperature has risen faster since 1970 than in any other 50-year period over at least the last 2000 years (high confidence) (IPCC AR6 SYR, 2023). The concentration of carbon dioxide, the most important greenhouse gas, has increased by 50% compared to the pre-industrial period and is now at 415.7 parts per million (ppb). The concentration of methane has increased more than 2.5 times (1908 ppb), and the concentration of nitrogen compounds by 25% (334.5 ppb). According to the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement, the Republic of Serbia is obligated to reduce greenhouse gas emissions by 9.8% by 2030 compared to the reference year of 1990. This reduction represents the National Determined Contribution (NDC) to mitigating greenhouse gas emissions. Each Party to the Paris Agreement is required to establish the NDC and update it periodically.

Forestry (alongside agriculture) plays a crucial role in climate change mitigation. Vegetation accounts for nearly 30% of bound carbon globally (IPCC, 2014), contributing significantly to climate change mitigation. This sector proves cost-effective compared to other sectors and aligns with sustainable development goals. The carbon bound in forest ecosystems serves as a vital economic parameter within the concept of ecosystem services. The carbon market should function as an incentive for agriculture and forestry to reduce greenhouse gas (GHG) emissions. This market operates through "carbon credits, a standard amount of GHG reduced or sequestrated, that can be bought and sold" (USDA, October 2023). They are one of the crucial ecosystem services enabling farmers and forest landowners to generate additional income.

While carbon markets have already been established in some countries, they are in their infancy in our region, largely due to the lack of relevant information about actual quantities present on agricultural and forest land, as well as in forest ecosystems. This study aims to determine the actual stocks of bound carbon in the urban forests of the City of Belgrade.

Material and methods

The quantity of sequestered carbon was determined based on data from forest management plans of all forest managers in the Belgrade area, along with information on areas covered by private forests. The forest growing stock data was processed based on landscape types using data from forest management units. In cases where forest management units spanned two or more landscape types, appropriate recalculations were performed to allocate the data to the corresponding type.

The research area was divided into the following 11 types based on the "Landscape Typology of Belgrade developed for the application of the European Landscape Convention" (Cvejić et al., 2008). The spatial database included information on area, tree species, canopy, tree mixture, developmental stages, age classes, volume, and volume increment. A Geographic Information System (GIS), enabling spatial analysis and spatial representation of biomass, was used to estimate the quantity of bound carbon. Carbon reserves were calculated for living biomass (encompassing aboveground and belowground biomass), dead organic matter (including dead wood and litter), and soil (soil organic matter) (Dimitijević et al., 2022). The estimation of carbon reserves followed the guidelines provided by the Intergovernmental Panel on Climate Change (IPCC) (2003, 2015). The results of carbon production are presented for the years 2030 and 2050, considering three scenarios: no increment increase, a 10% increment increase, and a 30% increment increase.

Results and discussion

Carbon reserves in the forests of the City of Belgrade for the period 1990-2050 are presented in Tables 1-7. The total carbon reserve in the forests of the City of Belgrade amounts to 4,315,301 tons, distributed as follows: above-ground biomass: 1,143,687 tons, below-ground biomass: 185,094 tons, dead wood biomass: 57,185 tons, forest litter: 391,816 tons, soil: 2,537,519 tons.

In the "Strategy for Addressing the Impact of Climate Change on the Interaction of Ecosystem Services in the Use and Management of Forest Resources in Belgrade", carbon storage is included in the "Regulation and Maintenance" section, under the "Mediation of Waste, Toxins, and Other Disturbances" sector. Carbon storage has a strong impact on the "Maintenance of Physical, Chemical, and Biological Conditions" sector.

Table 1. Carbon Reserves in Aboveground Biomass (tons)

Landscape type	1990	2020	2030			2050		
			Scenario			Scenario		
			0%	+10%	+30%	0%	+10%	+30%
Type 1/1		107109	115135	123963	125569	183356	192185	193790
Type 1/2		43100	44976	47039	47415	60923	62987	63362
Type 2		62263	64425	66803	67236	82801	85179	85612
Type 3		76777	79268	82008	82507	100443	103184	103682
Type 4		16374	16899	17475	17580	21355	21931	22036
Type 5		39477	41468	43658	44056	58391	60581	60979
Type 6		29813	31060	32433	32683	41667	43040	43290
Type 7		113772	119045	124845	125900	163866	169666	170721
Type 8		45375	47813	50495	50983	68538	71220	71708
Type 9		441105	460981	482846	486821	629932	651796	655771
Type 10		144613	151998	160122	161599	214772	222895	224372
Type 11		23909	24868	25924	26116	33025	34080	34272
Total	550507	1143687	1197936	1257611	1268465	1659069	1718744	1729595

Table 2. Carbon Reserves in Belowground Biomass (tons)

Landscape type	1990	2020	2030			2050		
			Scenario			Scenario		
			0%	+10%	+30%	0%	+10%	+30%
Type 1/1		17334	18633	20062	20322	29674	31103	31363
Type 1/2		6975	7279	7613	7674	9860	10194	10255
Type 2		10077	10427	10811	10881	13401	13785	13855
Type 3		12426	12829	13272	13353	16256	16699	16780
Type 4		2650	2735	2828	2845	3456	3549	3566
Type 5		6389	6711	7066	7130	9450	9804	9869
Type 6		4825	5027	5249	5289	6743	6966	7006
Type 7		18413	19266	20205	20376	26520	27459	27629
Type 8		7344	7738	8172	8251	11092	11526	11605
Type 9		71388	74605	78144	78787	101948	105487	106130
Type 10		23404	24599	25914	26153	34759	36073	36312
Type 11		3869	4025	4195	4227	5345	5516	5547
Total	89094	185094	193874	203531	205288	268504	278161	279917

Given the increasing establishment of the carbon market, this ecosystem service could potentially be included in the “Provision” section, under the “Materials” sector in the near future. Carbon offsets are sold through various exchanges, online markets, and directly through carbon projects that reduce or eliminate emissions. The carbon prices as of November 17, 2023, in specific countries are provided in Table 7.

Table 3. Carbon Reserves in Dead Wood (tons)

Landscape type	1990	2020	2030			2050		
			Scenario			Scenario		
			0%	+10%	+30%	0%	+10%	+30%
Type 1/1		5355	5757	6198	6278	9168	9609	9689
Type 1/2		2155	2249	2352	2371	3046	3149	3168
Type 2		3113	3221	3340	3362	4140	4259	4281
Type 3		3839	3963	4100	4125	5022	5159	5184
Type 4		819	845	874	879	1068	1097	1102
Type 5		1974	2073	2183	2203	2920	3029	3049
Type 6		1491	1553	1622	1634	2083	2152	2164
Type 7		5689	5952	6242	6295	8193	8483	8536
Type 8		2269	2391	2525	2549	3427	3561	3585
Type 9		22055	23049	24142	24341	31497	32590	32789
Type 10		7231	7600	8006	8080	10739	11145	11219
Type 11		1195	1243	1296	1306	1651	1704	1714
Total	27525	57185	59896	62880	63423	82954	85937	86480

Manulife Investment Management, the world's largest manager of natural capital with nearly $15 billion in assets under management in timberland and agriculture combined has established the Forest Climate Fund (FCF). Launched in 2022, this fund is a strategy involving the generation of carbon credits through natural carbon sequestration. It is designed to provide American investors with an opportunity to contribute to climate change mitigation through sustainable forest management. Approximately 70% of the fund will be invested in carbon projects, aiming to prioritize carbon sequestration over timber harvesting. To date, the fund has raised around $224.5 million, with a target of reaching $500 million (https://carboncredits.com/manulifes-forest-carbon-credit-fund-closes-224-million/).

The Strategy for Addressing the Impact of Climate Change on the Interaction of Ecosystem Services in the Use and Management of Forest Resources in Belgrade includes, among other things, increasing carbon storage to mitigate climate change. The strategy also envisions the establishment of new forests through afforestation. The utilization of carbon credits in the future will also contribute to the restriction of forest logging.

Table 4. Carbon in Forest Litter (tons)

Landscape type	1990	2020	2030			2050		
			Scenario			Scenario		
			0%	+10%	+30%	0%	+10%	+30%
Type 1/1		33119	33119	36431	43055	33119	40074	55972
Type 1/2		22489	22489	24737	29235	22489	27211	38006
Type 2		12324	12324	13556	16021	12324	14912	20828
Type 3		13882	13882	15271	18047	13882	16798	23461
Type 4		4761	4761	5237	6189	4761	5761	8046
Type 5		16123	16123	17735	20960	16123	19509	27248
Type 6		8844	8844	9729	11498	8844	10702	14947
Type 7		42799	42799	47078	55638	42799	51786	72330
Type 8		12493	12493	13742	16241	12493	15117	21113
Type 9		146475	146475	161123	190418	146475	177235	247543
Топ 10		67579	67579	74337	87853	67579	81771	114209
Type 11		10928	10928	12021	14206	10928	13223	18468
Total	300672	391816	391816	430997	509361	391816	474099	662171

The following activities related to carbon storage are planned through the strategy:

1. Specific Goal: Conservation of existing forest areas and their expansion through preservation of biodiversity as a crucial component of ecosystem services.
   a) Valorization of private forests to determine the scope and methods of afforestation and land acquisition.

Table 5. Soil Organic Carbon (tons)

Landscape type	1990	2020	2030			2050		
			Scenario			Scenario		
			0%	+10%	+30%	0%	+10%	+30%
Type 1/1		214490	214490	235939	278837	214490	259533	362488
Type 1/2		145643	145643	160207	189336	145643	176228	246137
Type 2		79814	79814	87795	103758	79814	96575	134886
Type 3		89907	89907	98898	116879	89907	108787	151943
Type 4		30833	30833	33916	40083	30833	37308	52108
Type 5		104417	104417	114859	135742	104417	126345	176465
Type 6		57278	57278	63006	74461	57278	69306	96800
Type 7		277176	277176	304894	360329	277176	335383	468427
Type 8		80909	80909	89000	105182	80909	97900	136736
Type 9		948617	948617	1043479	1233202	948617	1147827	1603163
Type 10		437662	437662	481428	568961	437662	529571	739649
Type 11		70773	70773	77850	92005	70773	85635	119606
Total	1947240	2537519	2537519	2791271	3298775	2537519	3070398	4288408

Table 6. Total Carbon Reserves in Forest Ecosystems in the Belgrade Area in 2020 (tons)

Landscape type	Carbon in					
	aboveground biomass	belowground biomass	deadwood biomass	forest litter	soil	Total
Type 1/1	107109	17334	5355	33119	214490	377407
Type 1/2	43100	6975	2155	22489	145643	220362
Type 2	62263	10077	3113	12324	79814	167591
Type 3	76777	12426	3839	13882	89907	196831
Type 4	16374	2650	819	4761	30833	55437
Type 5	39477	6389	1974	16123	104417	168380
Type 6	29813	4825	1491	8844	57278	102251
Type 7	113772	18413	5689	42799	277176	457849
Type 8	45375	7344	2269	12493	80909	148390
Type 9	441105	71388	22055	146475	948617	1629640
Type 10	144613	23404	7231	67579	437662	680489
Type 11	23909	3869	1195	10928	70773	110674
Total	1143687	185094	57185	391816	2537519	4315301

2. Specific Goal: Integration of ecosystem services into forest management standards.

a) Development of methods to demonstrate the impact of forest management practices on the provision of ecosystem services and the introduction of the concept of the "Ecosystem Services Zone" as part of forest ecosystem protection.
b) Development of partnerships (public and private) for the utilization of ecosystem services in forest ecosystems.
c) Introduction of ecosystem services certification.
d) Creation of favorable market conditions for owners of forest ecosystem services certificates and the implementation of mechanisms for efficient payment for certified ecosystem services.
e) Development of market opportunities for ecosystem services.

3. Specific Goal: Adaptation and mitigation of the consequences of climate change on ecosystem services.

a) Development of a project on potential areas for the establishment of intensive plantations of forest tree species.
b) Promotion of the use of renewable energy sources.
c) Afforestation with tree species resilient to new climate conditions.

d) Strengthening the capacity of nursery production for the cultivation of species resilient to climate change.
e) Production of planting material for afforestation in areas of natural goods.

Table 7. Carbon Prices in Various Countries on November 17, 2023

Carbon Prices	Last	Change	YTD
Compliance Markets			
European Union	€78.05	−3.28%	−2.44%
UK	£42.53	+0.07%	−41.94%
California	$29.45	-	+1.31%
Australia (AUD)	$31.40	+1.29%	−7.10%
New Zealand (NZD)	$70.05	−0.07%	−8.34%
South Korea	$7.38	−3.54%	−40.31%
China	$10.05	−1.15%	+25.38%

Source: https://carboncredits.com/carbon-prices-today/

4. Specific Goal: Conservation, improvement, and sustainable use of the population of indigenous species and communities of hunting and fishing resources, as well as the protection of the biodiversity of bees, birds, wildlife, and fish.

a) Creating conditions to prevent degradation and fragmentation of habitats suitable for wildlife.
b) Developing a project on the formation of a coastal vegetation belt that contributes to creating favourable microclimatic conditions around fish hatcheries.
c) Developing a study on the UN REDD+ Program (Reducing Emissions from Deforestation and Forest Degradation) and biodiversity.

The financial success of carbon storage projects depends on predicting future carbon prices. Currently, 64 carbon pricing initiatives have been implemented across one supranational jurisdiction, 45 national, and 35 subnational jurisdictions covering over a fifth of global greenhouse gas emissions. The largest of these is the European Union Emissions Trading Scheme (EU ETS), which covers emissions from factories, power plants, and other installations in 30 countries (EU countries, Iceland, Liechtenstein, and Norway) and accounts for 40% of greenhouse gas emissions in the EU. Other national initiatives include ETS in Kazakhstan, New Zealand, Mexico, and China, as well as carbon taxes in South Africa, Chile, Argentina, and Canada.

California enacted carbon pricing systems in 2013, and Washington State introduced its own carbon pricing system in 2021. Eleven northeastern U.S. states participate in the Regional Greenhouse Gas Initiative, covering 18% of emissions in participating states (https://carboncredits.com/manulifes-forest-carbon-credit-fund-closes-224-million/).

Carbon prices are widely variable, ranging from $0.30 per ton in Ukraine to $75 per ton in the EU. In Sweden, companies pay $200 per ton of carbon emissions. Outside the European Union, prices are significantly lower, ranging from $20 to $5 per ton. The projected carbon price in 2030 is expected to be in the range of 56 to 152 EUR per ton (MBIE, 2016; IEA World Energy Outlook, 2015). This implies a potential value of carbon storage in forest ecosystems ranging from 21,997,809.00 to 59,648,322.00 EUR.

Funding for projects to increase carbon storage in the forests of the City of Belgrade will come from European Union funds, including: Instrument for Pre-accession Assistance (IPA); IPARD - Instrument for Pre-Accession in Rural Development; Western Balkan Investment Framework (WBIF); European Social Fund; Cohesion Fund; European Regional Development Fund; Horizon 2020; LIFE - Environment and Climate Action Program; Invest EU; Connecting Europe Facility; Modernization and Innovation Fund (within EU-ETS); EU Territorial Cooperation Programs (INTERREG); Action Plan: Financing Sustainable Development (COM (2018) 97).

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