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CRIMEAN PINE-TREE AT GROUND PHYTOMASS AND CARBON DEPOSITED IN IT IN CRIMEA

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Results of the development of normative and information support for estimating quantitative characteristics of at-ground Crimean pine-tree stands phytomass in Autonomous Republic of Crimea are presented. The algorithm for making standard and reference tables are suggested, that represent the phytomass of such components as tree overbark, trunk wood, a tree foliage, wood and bark of tree top branches. This algorithm is founded on the results of mathematical modeling of quantitative format and weight characteristics and assess of their qualitative indexes. Developed in the research mature standards allow estimating phytomass format and carbon dioxide deposited therein for Crimean pine-tree and substantiating integrated use of forest resources of Crimea scientifically, silviculturally and ecologically

Key words: at-ground phytomass, Crimean pine-tree, a model, temporary experimental places, test trees, standards, carbon dioxide.

The current phase of human civilization functioning is characterized by dynamic changes of qualitative and quantitative nature that have caused reconsideration public attitude to the environment. Intensive development of science and techniques is responsible for the activation of all economic processes, at the same time, leading to the growth of man-induced impact on the environment and in effect to the appearance of major ecological problems. More specifically, a dynamic growth of carbon dioxide concentration in the planetary atmosphere has reasoned global climate changes and destabilized Earth's atmosphere. Highly important atground carbon dioxide absorber is forest with its natural capacity to balance carbon concentration.

The research of an ongoing use of forest resources under conditions of global climate change is a currently essential problem, scientists of many prominent research centres in the area of forestry throughout the world are trying to solve. Currently, considerable progress in this sphere has been made internationally. This is verified by a

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number of fundamental scientific works [1, 5, 6]. Although, together with an enormous number of descriptive data and general assessment of the subject of researches, a complex of adequate standard and reference materials available to estimate different aspects of forests bio productivity in practice is necessary. For the time being, its complex assessment will enable us to answer questions about the search of alternative sources of excess carbon depositing and oxygen producing, assessment of energy potential of forests and their productivity enhancement as well as to determine the level of forest ecosystem influence upon global carbon cycle in the context of expected climate changes.

Research Outline is to work out an algorithm, mathematical models and standard and informative support for estimating quantitative format of components of at-ground phytomass and carbon deposited in it for Crimean pine tree species which prevails in forests of Crimea.

Material and methodology of the research. Experimental data were collected during field work by professor P.I.Lakyda’s methodology from 2006 to 2010 [2]. They were used to study the at-ground phytomass components of Crimean pine tree growing on the territory of Crimea. 18 temporary sampling plots were used as experimental material which represent planted Crimean pine tree stands, ages 7 to 72 years old, having productivity of the 2nd, 3rd, 4th and 5th bonitet classes and relative density from 0,27 to 1,13. The study of the phytomass components of Crimean pine trees includes performing field forest resource management on temporary sampling places as well as laboratory scientific researches in defining some qualitative at-ground phytomass of trees [3, 4]. The process of investigating at-ground phytomass of trees consisted of the following steps; 1 – studying the history of trees at-ground phytomass assessment; 2 – experimental data collecting, processing and analyzing ; 3 – mathematical modeling of trees at-ground phytomass components and examining the adequacy of these samples; 4 – working out the algorithm and standard and reference tables that show quantitative indexes of trees phytomass components; 5 – verifying the worked out standards.

The quantitative assessment of experimental data of components Crimean pine trees phytomass is shown in Table 1.

1. Quantitative assessment of experimental data of components of Crimean pine trees phytomass

Age-old groups of sample trees, years	Number, items							
	Sample trees with phytomass assessment	Experimental cuts			Crown samples			Total
		Total	including		total	including		
			stand	branches		Tree leaves	Pine needles	
Up to 20	16	36	24	2	32	20	2	68
21-40	16	45	30	5	32	20	2	77
41-60	22	72	48	4	64	40	4	136
61-80	3	9	6	3	8	5	3	17
Total	57	162	108	4	136	85	1	298

Detailed mensuration characteristics of Crimean pine tree stands was received after processing the primary data taken from temporary sample plots with the help of programme PERTA, worked out by A.Z. Shvydenko and Ya. A. Yudytskyi, members of the department of forest mensuration and forest inventory of NULES of Ukraine in 1984. Calculation of qualitative indexes of phytomass components of a stand and head was done with the help of applied programmes GIL, ZRIZ and PLOT worked out by P.I. Lakyda [1]. It is necessary to mention that collected and processed experimental data appropriately describe Crimean pine tree stands available in forest fund of Autonomous Republic of Crimea and enable us to solve a number of problems put within the work being done.

Research Results. One of the main contemporary methods of research is mathematical modelling. Generally modeling is a research process of a real system which includes model constructing, its investigating and transferring of tangible results on the investigated system.

Indexes of phytomass components of Crimean pine trees were modeled in two directions:

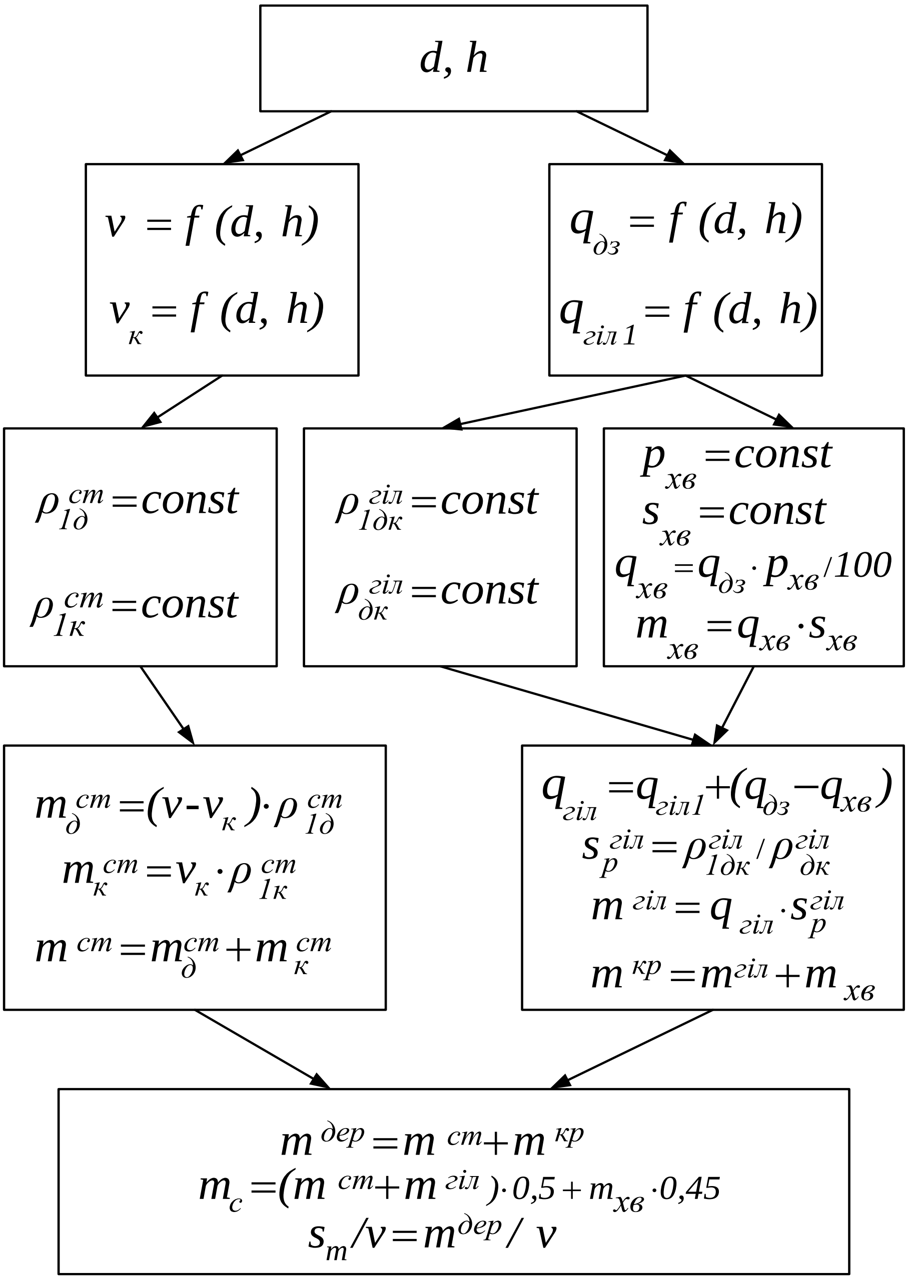
а) modelling the size of a trunk with the bark and the size of the bark;

б) modeling the phytomass components of the head of a pine tree (branches with the bark, pine tree needles).

While selecting different modeling combinations for an equation there were put the indexes which greatly influenced dependent variable at the 5^{th} % significance level. Thus the preference was given to more practical equations in which taxation features could be easily seen while full-scaling reviewing and estimating a tree with the help of unsophisticated equipment.

Modelling the at-ground phytomass components of Crimean pine tree was performed using the data that characterize main mensuration indexes of sample trees. While doing the regressive analysis it was revealed that the best model of main at-ground phytomass components depends on such mensuration features as the tree diameter at height of 1,3 m (*d*) and tree height (*h*). This model is two-component one. Other taxation features of trees and tree trunks such as age, head diameter, head length, etc were tested as well, however they are not analyzed in this article. For Crimean pine-tree species the received mathematical dependences serve as a basis of the algorithm for calculating the components of at-ground phytomass and carbon deposited in it. For this algorithm elaboration the following signs were used: d – tree with bark diameter at breast height, cm; h – tree height, m; v – trunk with bark size, m^3; $v_к$ – tree bark size, $м^3$; $q_{дз}$ –ДЗ phytomass in freshly cut state, kg; $q_{гіл1}$ – top branches phytomass without ДЗ fraction in freshly cut state, kg; $q_{гіл}$ – tree top branches phytomass in freshly cut state, kg; $q_{хв}$ – tree top needles phytomass in freshly cut state, kg; $\rho_{1д}^{ст}$ – basic trunk wood density, $kg\cdot(m^3)^{-1}$; $\rho_{1к}^{ст}$ – basic trunk bark density, $kg\cdot(м^3)^{-1}$; $\rho_{1дк}^{ст.}$ – basic trunk wood with bark density, $kg\cdot(м^3)^{-1}$; $\rho_{дк}^{гіл}$ – natural branch wood with bark density, $kg\cdot(м^3)^{-1}$; $\rho_{1дк}^{гіл}$ – basic branch wood with bark density, $kg\cdot(м^3)^{-1}$; $s_\rho^{гіл}$ – the content of absolutely dry substance in branches with bark; $p_{хв}$ – per cent of needles in tree foliage, %; $s_{хв}$ – the content of absolutely dry substance in fresh pine needles; $m^{гіл}$ – branches wood with bark phytomass in absolutely dry state, kg; $m_{хв}$ – pine needles in absolutely dry state, kg; $m^{кр}$ – tree top phytomass in absolutely dry state, kg; $m^{дер}$ – a tree at-ground phytomass on absolutely dry state, kg; m_C – dioxide deposited in at-ground tree phytomass, kg.

Layout view of the given algorithm and received mathematical models of main components of at-ground Crimean pine tree phytomass are shown in Picture. 1. and in Table 2.



Pic. 1 – the pattern of the algorithm for calculating Crimean pine tree at-ground phytomass components and carbon dioxide deposited in the phytomass

2. Models of assessment of Crimean pine tree at-ground phytomass in Crimea

Model Number	Model Type	R^2
1	$v = 5{,}600\text{ E-}05 \cdot d^{1{,}792} \cdot h^{1{,}160}$;	0,99

2	$v_{к} = 6{,}000\ E\text{-}06 \cdot d^{\,2{,}174} \cdot h^{\,0{,}801}$;	0,98
3	$q_{дз} = 0{,}372 \cdot d^{\,2{,}014} \cdot h^{\,-0{,}638}$;	0,86
4	$q_{гіл1} = 3{,}080\ E\text{-}03 \cdot d^{\,2{,}643} \cdot h^{\,0{,}452}$;	0,94

Theory and practice of scientific researches concerning the study of problems on biotic productivity of forests and developing regulatory support for assessment the components of tree stands phytomass prove that in fact it is almost impossible to avoid their qualitative indexes investigating, namely basic density of tree stand wood, stand bark, tree stand with bark, stand branches wood, stand branches bark and branches wood with bark. In addition, pine needles per cent in tree foliage and the content of absolutely dry substance in pine needles fraction were calculated. Qualitative features of Crimean pine tree phytomass was averaged, which were used to develop standards are shown in table 3.

3. Regulatory assessment of qualitative indexes of Crimean pine tree phytomass in Crimea

Tree stands wood and bark density, kg·(m³)⁻¹					
natural			basic		
wood	bark	wood+bark	wood	bark	wood+bark
916	563	839	451	343	427
Qualitative indexes of tree tops phytomass, kg·(m³)⁻¹					
wood	bark	wood+bark	wood	bark	wood+bark
946	900	930	472	460	464
The content of absolutely dry substance in pine tree needles				0,51	
The portion of pine tree needles in a tree foliage, %				58,8	

Thus, calculations resulted in standard and reference tables used to estimate a tree phytomass for such components as a tree stand phytomass, a tree stand bark phytomass, a tree stand with bark phytomass, a pine tree needles phytomass, a tree top branches with bark phytomass, a tree top phytomass, a tree at-ground phytomass, carbon dioxide deposited in at-ground tree phytomass, the ratio of a tree at-ground phytomass to the size of a stand with bark, a tree foliage phytomass.

Parts of the developed standards for estimating the Crimean pine tree at-ground phytomass in absolutely dry state is shown in table 4.

4. Crimean pine tree at-ground phytomass, kg

Absolutely dry state

Diameter, cm	Height, m											
	4	6	8	10	12	14	16	18	20	22	24	26
4	2,9	3,5	4,3	–	–	–	–	–	–	–	–	–
6	6,2	7,5	9,1	11	–	–	–	–	–	–	–	–
8	11	13	16	19	22	–	–	–	–	–	–	–
10	17	20	24	28	33	38	–	–	–	–	–	–
12	–	28	34	40	47	54	61	–	–	–	–	–
14	–	38	45	54	62	72	82	92	–	–	–	–
16	–	–	58	69	80	92	100	120	130	–	–	–
18	–	–	73	86	100	120	130	150	160	180	–	–
20	–	–	90	110	120	140	160	180	200	220	240	–
22	–	–	110	130	150	170	190	210	240	260	290	310
24	–	–	–	150	170	200	220	250	280	310	340	360
26	–	–	–	170	200	230	260	290	320	360	390	420

The standards of Crimean pine tree general at-ground phytomass (table 4) reflect biological peculiarities of accumulation of all components of phytomass of a tree stand as well as of a tree top. For low degrees of thickness an essential impact on the formation of a tree top can be seen, though with increasing in diameter and a stand height its mass impact is fundamental.

Analyzing standards of assessment of Crimean pine tree needles phytomass (table 5) it should be noted that a tree needles mass increases with increasing options of a tree stand, though having the same stand diameter, the higher the tree is the smaller needles mass becomes as part of a tree foliage fraction thus confirming the peculiarity of forming a tree top indexes for other coniferous species.

5. Crimean pine tree needles phytomass, kg

Absolutely dry state

Diameter, cm	Height, m											
	4	6	8	10	12	14	16	18	20	22	24	26
4	0,8	0,6	0,5	–	–	–	–	–	–	–	–	–

6	1,7	1,3	1,1	0,9	–	–	–	–	–	–	–	–
8	3,0	2,3	2,0	1,7	1,5	–	–	–	–	–	–	–
10	4,8	3,7	3,1	2,7	2,4	2,1	–	–	–	–	–	–
12	–	5,3	4,4	3,8	3,4	3,1	2,8	–	–	–	–	–
14	–	7,2	6,0	5,2	4,7	4,2	3,9	3,6	–	–	–	–
16	–	–	7,9	6,8	6,1	5,5	5,1	4,7	4,4	–	–	–
18	–	–	10	8,7	7,7	7,0	6,4	6,0	5,6	5,2	–	–
20	–	–	12	11	9,5	8,6	7,9	7,4	6,9	6,5	6,1	–
22	–	–	15	13	12	10	9,6	8,9	8,3	7,9	7,4	7,1
24	–	–	–	15	14	12	11	11	9,9	9,4	8,9	8,4
26	–	–	–	18	16	15	13	12	12	11	10	9,9

In order to receive integrated characteristics of regulations for estimating the whole complex of taxation and ecological indexes of trees and trees stands in recent time special attention is paid to defining the content of carbon dioxide as in the main structural components of a tree phytomass so in planted trees in general (table 6).

6. Carbon dioxide deposited in at-ground tree phytomass, kg

Diameter, cm	Height, m											
	4	6	8	10	12	14	16	18	20	22	24	26
4	1,4	1,7	2,1	–	–	–	–	–	–	–	–	–
6	3,0	3,7	4,5	5,4	–	–	–	–	–	–	–	–
8	5,3	6,3	7,7	9,3	11	–	–	–	–	–	–	–
10	8,2	9,7	12	14	17	19	–	–	–	–	–	–
12	–	14	17	20	23	27	31	–	–	–	–	–
14	–	19	22	26	31	36	41	46	–	–	–	–
16	–	–	29	34	40	46	52	59	65	–	–	–
18	–	–	36	43	50	57	65	73	81	89	–	–
20	–	–	44	52	61	70	79	89	99	110	120	–
22	–	–	53	63	73	84	95	110	120	130	140	150
24	–	–	–	74	86	99	110	130	140	150	170	180
26	–	–	–	87	100	110	130	150	160	180	190	210

Conclusions. The worked out algorithm and the complex of mathematical models and standards and reference tables for qualitative assessment of indexes of Crimean pine tree at-ground phytomass is a significant supplement to the existing regulations of forestry in Autonomous Republic of Crimea. The suggested standards are basic for scientific, ecological, silvicultural and technical and economical substantiating the extended use of forest resources on the principles of sustainable development with a complex assessment of forest value.

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НАДЗЕМНАЯ ФИТОМАССА И ДЕПОНИРОВАННЫЙ УГЛЕРОД ДЕРЕВЬЕВ СОСНЫ КРЫМСКОЙ В КРЫМУ

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Приведены результаты разработки нормативно-информационного обеспечения для оценки количественных параметров надземной фитомассы деревьев сосны крымской в АР Крым. Предложен алгоритм создания нормативно-справочных таблиц, отражающих фитомассу таких компонентов как ствол в коре, древесина ствола, кора ствола, хвоя, древесина и кора ветвей короны, который базируется на результатах математического моделирования их количественных объемных и весовых параметров и оценки их качественных показателей. Разработанные в процессе работы нормативы позволяют осуществлять оценку объемов фитомассы и депонированного в ней углерода для деревьев сосны крымской и сформулировать научное лесоводственно-экологическое обоснование комплексного использования лесных ресурсов Крыма.

Ключевые слова: надземная фитомасса, сосна крымская, модель, временные пробные площади, модельные деревья, нормативы, углерод.

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