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ADVANTAGES OF USING GNSS TECHNOLOGY AND QGIS SOFTWARE IN INVENTORY STANDS EXPLOITERS

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Abstract

The inventory of the production fund aims to determine its size, structure and growth, starting with the determination of the dendrometric characteristics of each component tree. This inventory is done both for the purpose of regulating the production and protection process and for controlling the production fund and its evolution. The inventory methodology is based on the application of the methods of mathematical statistics and especially on the application of selective methods, as well as by scientifically based dendrometric estimations. In the case of these inventories, will be determined: the average diameter, the average height, the specific composition, the number of trees per hectare (density), the density index, the current growth by species, classes of diameters and quality classes, the volume of the trees. The trees that have reached the age of exploitability must be inventoried to determine the volume. Stands with a consistency of more than 0.4 and a surface area greater than 4.0 ha will be inventoried by the 12.62 m radius of circle and a 500 m^2 area, uniformly located in the entire layout, and those with consistencies of less than 0.4 will be fully compiled by the forest district, as they will enter the first-ever decennial plan. The only condition is the existence of a digital layout map, which can be obtained from the parcel and parcel construction work with the redevelopment works in the Stereographic 70 projection, where the position of each circle can easily be materialized with Qgis software.

Key words: *QGIS software, forests maps, topographic details, inventory stands.*

INTRODUCTION

Over the last decades, Geographic Information Systems (GIS) have proved to be a very useful and effective tool for the knowledge, description and analysis of the environment. In particular, studies performed since the 1990s have shown how the powerful capabilities of GIS in terms of data management and processing, spatial analysis and mapping could be successfully applied to environment analysis (Tebano et al., 2017).

In latest years, free and open source GIS software have been largely developed and applied with the aim to offer the users the possibility to customize functions and tools and sharing solutions with the scientific community. This approach allows a continuous improvement and updating of GIS platforms thanks to the contribution of different scientists and users. In particular, applications to watersheds and stream networks analysis are reported. Among them, (Dorillo, 2010; (Jasiewicz and Metz, 2011) proposed processing toolsets, based on raster analysis of Digital Elevation Models (DEMs), running under GRASSGIS (Neteler et al., 2012): the first estimates main geomorphic parameters, while the latter focuses on the extraction and analysis of stream network according to different criteria. Abera et al., 2014 presented a specialized toolset for topographic, hydrologic and geomorphic analysis running under the using application framework. A discussion on the application of open-source GIS to Earth and environmental sciences, including watershed analysis, can be found in (Noti, 2014).

QGIS is an open source Geographic Information System, released under the GNU general public license (QGIS 2016). Initially conceived as a simple GIS-GNSS RTK data viewer, QGIS experienced a very rapid growth over the last years, and its built-in functions, plugins and processing tools are nowadays widely used in many fields. Besides native algorithms, third-party processing tools and functionalities as GRASS (Neteler et al., 2012) and SAGA (Conrad et al., 2015) tools are also

integrated in QGIS current releases (Tebano et al., 2017).
It is a cross-platform, thus it works on different Operating Systems (OS) like Windows, Mac, Linux as well as Android. It provides noteworthy data viewing, editing and analysis capabilities. It facilitates users to create maps with multiple layers using different map projections. QGIS allows maps to be composed of raster and vector layers. The raster layer consists mainly of images (Google Hybrid), while the vector data is composed of points, lines and polygon features (*limite ua, limite parcela, borne, drum forestier, drum public*), as illustrated in Figure 4.
Satellite data or images consist of those images of Earth or other planets that are collected by the satellite. Satellite images are widely used in the field of cartography, geology, metrology, agriculture, electric power system, fishing, biodiversity, forestry and many others. QGIS can be used to create a composite image of the entire planet or of a desired region on the surface of the planet. This scheme aims to provide free and high quality satellite images to researchers and students for non-commercial usage (Khanet al., 2015).
Topographic details represent certain "natural" details on the terrestrial surface (e.g., oceans, rivers, continents, etc.) or certain "man-made" details (e.g., roads, constructions, parcels, compartments, etc.) (Boja et al., 2016).
Attributes describe the details in a GIS, for example the attributes of the forest fund can be all the information found in the parcel description sheet. A GIS-GNSS RTK is a computerized system used to accomplish various functions based on geographical information. The components of the system are: Software for making maps; The database that stores and links the field details and attributes; Tools for the analysis, editing and manipulation of geographic data.
The forests of the country, like other real estate, need to be studied in terms of geographic location, their analysis and representation accurately on plans and maps must be a topical concern both for the private and public entities.
The actual planning of the forest areas was done expeditiously, but the methods of planning involved some well-established topo-cadastral techniques. The use of terminals, toponyms, boundary boundaries of plots and sub-plots by painting trees and using a uniform system of conventional signs is the basis of a well-organized arrangement (Boja et al., 2013; 2016; 2018; 2020; 2021).

MATERIALS AND METHODS

GPS-GNSS RTK determinations have produced major changes in geodesy, topography and cartography. GPS-GNSS RTK (Global Positioning System) is a technology that uses a complex of satellites to help determine the location of any point on the Earth's surface in a single reference system with the help of specific devices.
For real-time centimeter accuracy of point coordinates, GPS-GNSS RTK is need to receive corrections from ground-based stations, this is possible either by UHF radio from one base (this requires 2 bases and rover devices), or they use GSM modems to connect to the Internet to receive RTK corrections from permanent fixed stations existing in Many countries (ROMPOS for Romania). GSM modules work with GSM internet cards from local mobile operators.
The condition of the GPS-RTK measurements is that the controller software has implemented the WGS 84 coordinate system transcaling algorithm in the national coordinate system of each country (in the case of Romania - Transdat - for the transition and the Stereographic Projection 1970 as a national system).
Another condition is that in the area where the measurement is carried out is a GSM data signal strong enough to make the Internet connection, otherwise, for the RTK measurements, at least two devices are needed (base and rover) and the possibility of establishing the UHF radio connection among them. A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS). As of September 2020, the United States' Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System, and the European Union's Galileo are fully operational GNSSs. Japan's Quasi-Zenith Satellite System (QZSS) is a (US) GPS-GNSS RTK satellite-based augmentation system to enhance the accuracy

of GPS-GNSS RTK, with satellite navigation independent of GPS-GNSS RTK scheduled for 2023. The Indian Regional Navigation Satellite System (IRNSS) plans to expand to a global version in the long term.

The S8 GNSS Stonex® (Figure 1) receiver is a high-precision equipment typically used to determine the outline of the property, using equipment that can be used with higher efficiency indoors. S8 is able to receive both GPS signal frequency and satellite signals. The S8 general unit includes the GNSS antenna, the GNSS module, the UHF radio, the receiving radio antenna, the GSM/GPRS modem, the Bluetooth device and the battery. S8 is fully integrated, which makes the topographer just start the device for measurements.

The forest fund covered by the present study belongs to Forest District Codrii Cămării, Management Unit I Dobrești.

For exploitable stands that have a consistency of more than 0.4 and have an area of more than 4 hectares, their inventory is made in circles of 500 m^2 with a radius of 12.62 m.

Figure 1. S8 GNSS Stonex Receiver ®10

The number of circles and the distance between them are established with the help of Technical Norms V for Forest Management Planning (Table 1).

Table 1. Determining the number of circles and the distance between them (Technical Norms V for Forest Management Planning), Tolerance 10%, Coverage probability 90%, The size of the test site 500 m^2

Surface, ha	**n**	**Coefficients of variation**																			
	d	15	20	21	25	28	**30**	35	36	40	**41**	43	45	49	50	54	55	56	60	65	70
4	n	6	10	11	14	17	**19**	23	24	28	**29**	30	32	36	37	39	40	41	44	47	50
	d	84	65	63	54	49	**46**	41	40	38	**37**	36	35	33	33	31	31	31	30	29	28
5	n	6	10	11	14	18	**20**	25	26	30	**31**	33	35	39	40	44	45	46	49	53	57
	d	93	72	69	59	54	**51**	45	44	41	**40**	39	38	36	35	33	33	33	32	31	30
6	n	6	10	11	15	18	**20**	26	27	32	**33**	36	38	42	43	48	49	50	54	49	63
	d	102	78	75	64	58	**54**	48	47	43	**42**	41	40	38	37	35	35	35	33	32	32
7	n	6	10	11	15	19	**21**	27	28	33	**34**	37	39	45	46	51	52	53	57	63	68
	d	110	84	81	68	62	**58**	51	50	46	**45**	44	42	40	39	37	37	37	35	33	32
8	n	6	10	11	15	19	**21**	27	28	34	**35**	38	41	47	48	53	54	55	61	67	72
	d	117	89	86	72	66	**62**	54	53	48	**47**	46	44	42	41	39	38	38	36	35	33
9	n	6	10	11	15	19	**21**	28	29	35	**36**	39	42	48	49	55	56	57	63	70	76
	d	124	94	90	76	69	**65**	57	56	51	**50**	48	46	44	43	41	40	40	38	36	34
10	n	6	10	11	16	20	**22**	28	30	36	**37**	40	43	49	51	57	58	59	65	73	80
	d	130	99	95	80	73	**68**	59	58	53	**52**	50	48	45	44	42	42	41	39	37	35
15	n	6	10	11	16	20	**23**	30	32	38	**40**	43	46	53	55	62	64	66	73	83	92
	d	159	120	115	97	88	**82**	71	69	63	**62**	59	57	53	52	49	48	47	45	43	40
20	n	6	11	12	16	20	**23**	31	33	39	**41**	44	48	56	58	66	68	70	78	89	99
	d	183	138	133	111	100	**93**	81	79	72	**70**	67	64	60	59	55	54	53	51	47	45
25	n	6	11	12	16	20	**23**	31	33	40	**42**	45	49	58	60	68	70	72	81	93	105
	d	204	154	148	124	112	**104**	90	88	79	**77**	74	71	66	65	61	60	59	55	52	49
30	n	6	11	12	16	20	**23**	31	33	40	**42**	46	50	59	61	70	72	74	84	96	108
	d	223	168	161	135	122	**113**	98	96	86	**84**	81	77	71	70	66	65	64	60	56	53
35	n	6	11	12	16	21	**24**	32	34	41	**43**	47	51	60	62	71	73	75	85	98	111
	d	241	181	174	146	132	**122**	105	103	93	**91**	87	83	77	75	70	69	68	64	60	56
40	n	6	11	12	17	21	**24**	32	34	41	**43**	47	51	60	62	72	74	77	87	100	114
	d	257	194	186	155	140	**130**	112	109	99	**97**	92	88	82	80	74	73	72	68	63	59
50	n	6	11	12	17	21	**24**	32	34	41	**43**	48	52	61	63	73	76	79	89	102	117
	d	288	216	207	173	156	**145**	125	122	110	**108**	103	98	91	89	83	81	80	75	70	65

Crown density of the stand	Stand structure					
	Even-aged			Uneven-aged		
	Homogeneity class					
	I	**II**	III	I	**II**	III
>=0,8	21	**30**	41	25	**36**	49
0,5-0,7	28	**41**	54	30	**43**	56

By GPS-GNSS RTK measurements, the coordinates of the points used later were calculated as routing heads and orientations, the location of these points being chosen so that the measurements are possible. Precision topographic elevation in forest sector required for the cadastre can not only be done with GPS-GNSS RTK technology because this type of measurement can only take place in uncovered terrain or where the free horizon can be reached up to 15º without obstacles.
Also, the measurement area must have GSM coverage to receive ROMPOS corrections through data transfer. In the case of the study, it was necessary to use the rover base system. The base was installed in a GSM signal area, and the transmission between the base and the rover was possible by using an external radio.

RESULTS AND DISCUSSIONS

The operation of circulating in the field is quite expensive, thanks to the GPS-GNSS RTK technique and the QGIS software, this operation can be done very easily and with very high precision.
In order to begin this operation, we need to have a digital map, and for example we have chosen the Forest District Codrii Cămării, Management Unit I Dobrești (Figure 2).

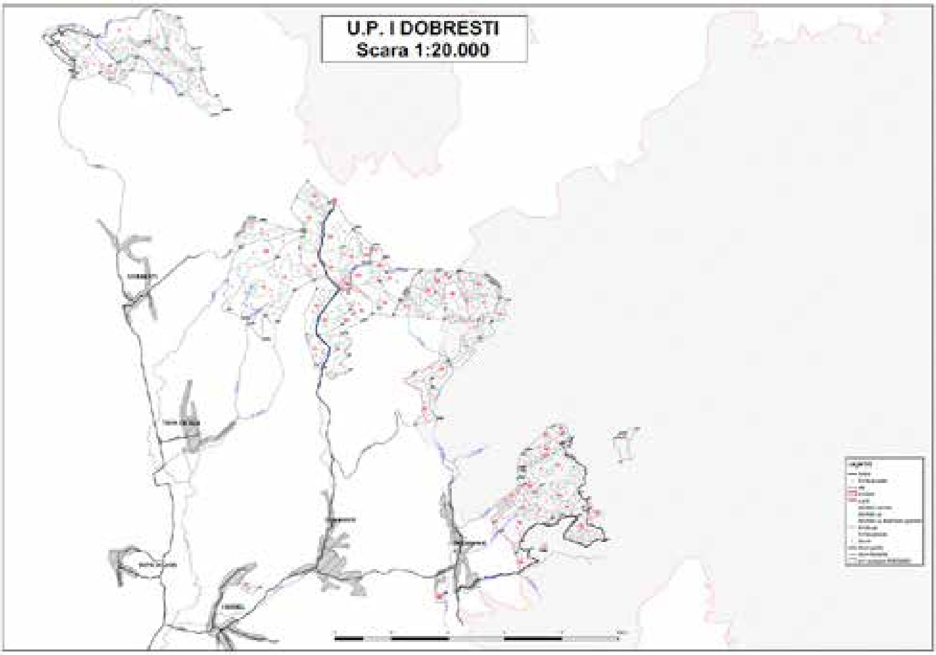


Figure 2. Forest District Codrii Cămării, Management Unit I Dobrești

In this management unit, the exploitable stands to be enumerated through the circles are: 10B, 14B, 15A, 19A, 34A, 40A and 41A. For example, we have chosen the forest compartments 41A, Figure 3.

To be able to materialize the position of each circle on the surface of the QGIS layout, it is necessary to install the Feature Grid Creator plug-in from the Plugins - Manage and Install Plugins menu.

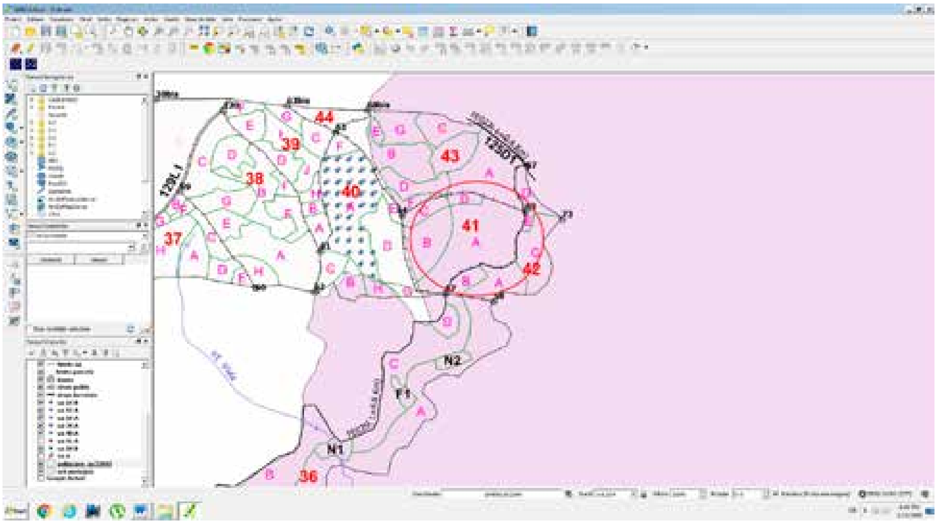


Figure 3. Forest compartments 41 A

The next step is to select the polygon layer that contains the forest compartment, select compartment in which the circles are to be created, and click the button created by the Feature Grid Creator plugging in to insert the distance between the circles (the same on x and y) according to the technical norms. In the case of the forest compartment 41 A the distance between the circles is **55** m and the number of circles is **37**, according to Figures 4-9.

The program creates a temporary layer called "holes" that contains the inventory circles but will be lost after closing QGIS so it must be saved with the username of forest compartment but it must be saved as a vector layer to which the forest compartment name will be entered because it will be inserted into the GPS-GNSS RTK along with the digital map. The advantage of using the QGIS software is that all the map elements, in our case the materialized circles (the vector layers that comprise the circles) are in Stereographic Coordinates 70.

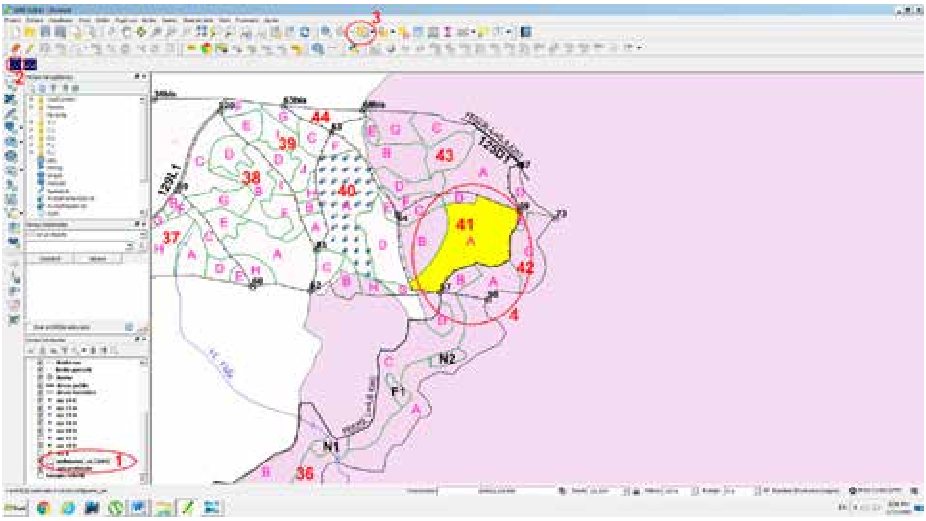


Figure 4. Selecting the forest compartment 41 A

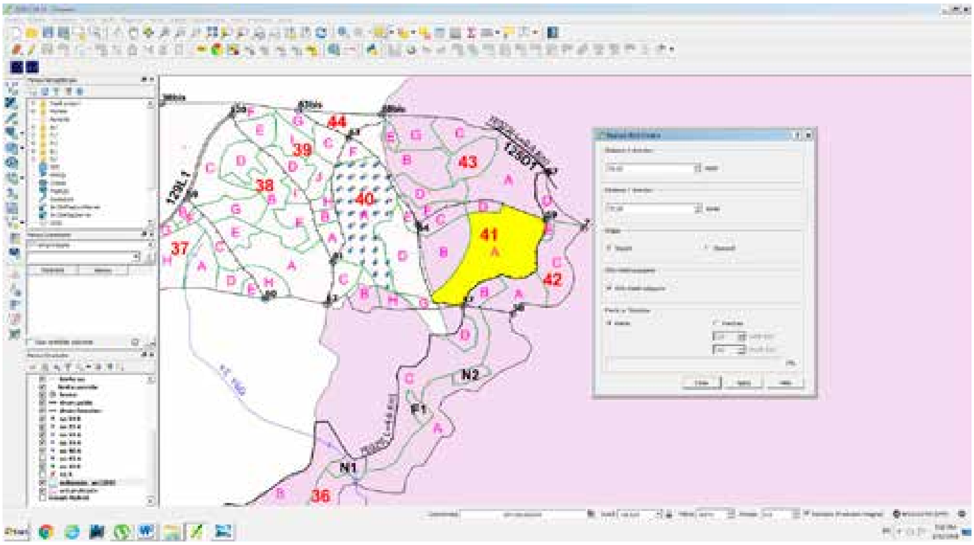


Figure 5. Entering the distances between circles

In the Layers panel, the new layer with the name of forest compartment will appear, and the following settings will be made: properties - labels - show labels for this layer - are tagged with - code, and then the attribute table and layer editing at code, enter the formula @row_number and then complete the update. At this point, the software assigns an automatic numbering to all circles, which is extremely important because the center of each circle must also materialize in the field, and the inventory of the trees must be done individually on each circle.

It is recommended that in the case of circles that fall very close to the compartment or parcel limits they are eliminated from the start because there is a risk that the radius of the circle will fall into another forest compartment or more severely in another parcel.

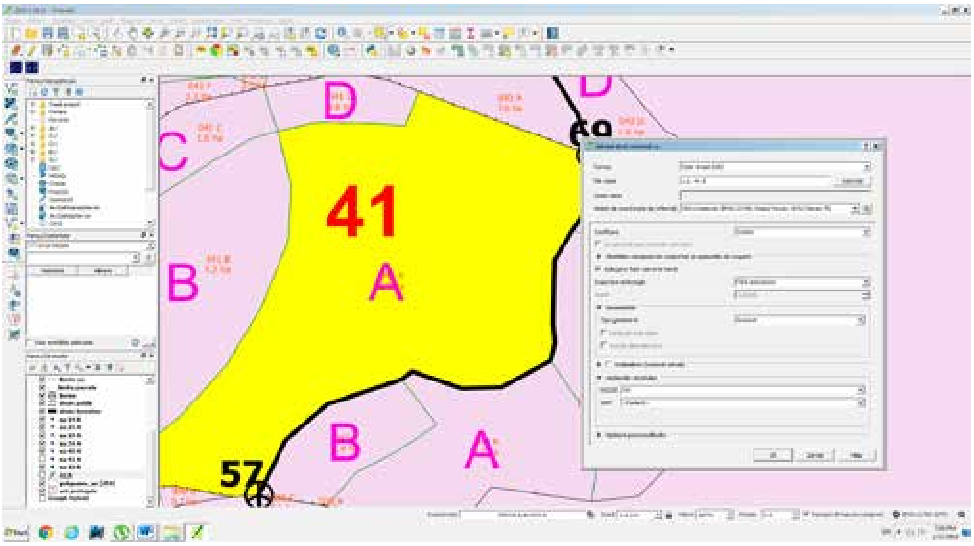


Figure 6. Saving circles as a vector layer

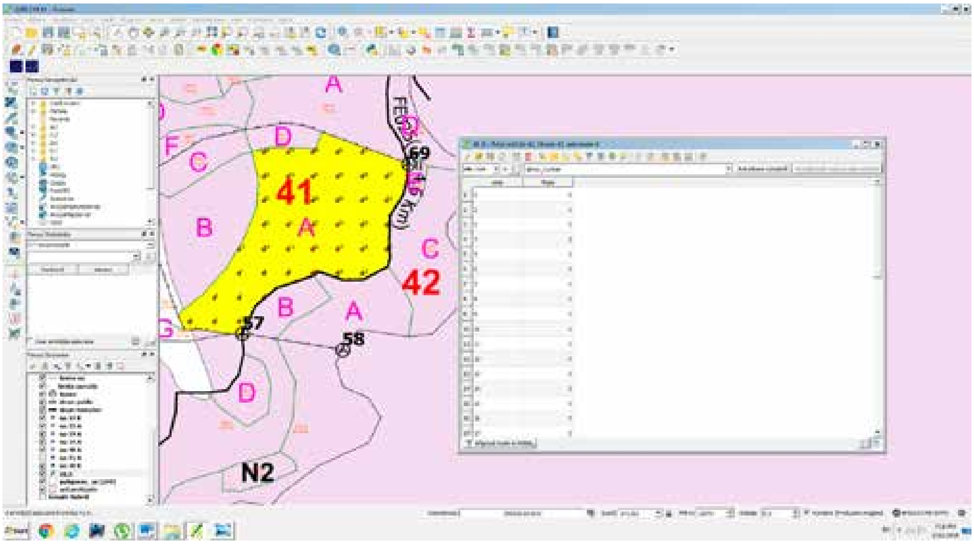


Figure 7. Numbering circles

After completing the QGIS drawing circle, this map can be loaded into the GPS-GNSS RTK, with each circle being found in the field based on GPS-GNSS RTK precision. The GPS-GNSS RTK identifies the Stereographic coordinates of the center of the circle, which is to be materialized on the nearest tree, and all trees falling within the range of 12.62 m are to be inventoried (mean species diameter and mean height). The following are the score sheets and the cubic sheet for the 41 A forest compartment. These records provide evidence of the species and average diameters and mean heights of all the trees in each inventory circle.

According to the interpretation of the cubic sheet, the composition of the tree stands: **5CA** (*Carpinus betulus*) **3FA** (*Fagus sylvatica*) **1CE** (*Quercus cerris*) **1ST** (*Quercus robur*) and the volume per hectare is 180 m^3, broken down by species: CA 84 m^3, FA 62 m^3, CE 18 m^3, ST 16 m^3, and the consistency of the tree is 0.51. A number of 371 trees with a total volume of 287.47 m^3 were inventoried in this forest compartment.

The average number of trees in the 37 circles is 8.83, even if there are circles without any tree.

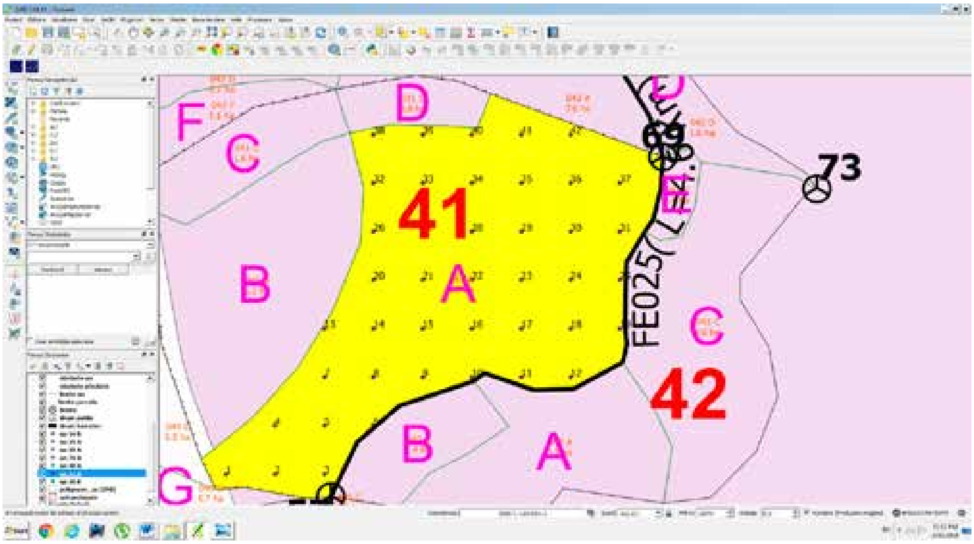


Figure 8. Finish placement of circles in forest compartment 41 A

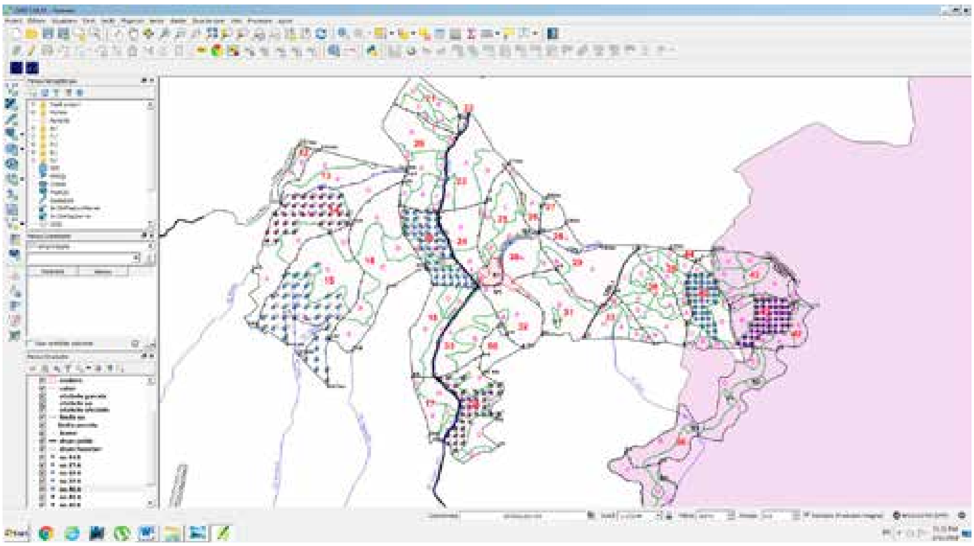
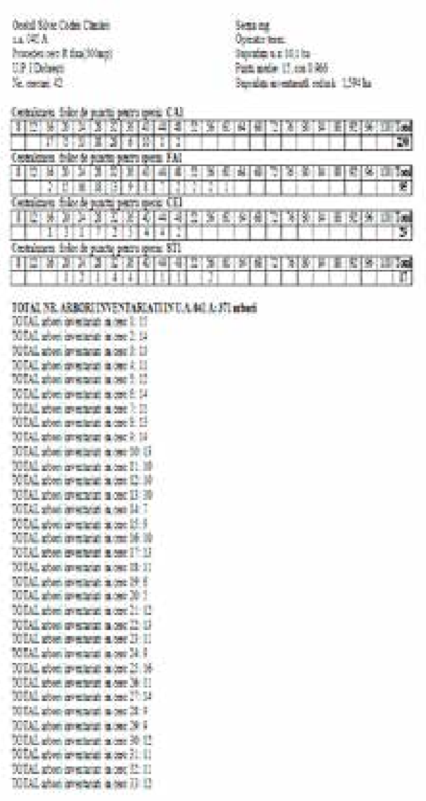


Figure 9. Location of circles in Management Unit I Dobrești

Table 2. Scoring sheet summary



Ocolul Silvic Codrii Cîmlări
u.a. 041 A
Procedeu: cerc R fixa(500mp)
U.P. I Dobreşti
Nr. cercuri: 42

Suprafaţa u.a.: 10,1 ha
Panta medie: 15, cos 0,966
Suprafaţa inventariată redusă: 1,594 ha

Centralizare fişă de punctaj pentru specia: CA1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		17	75	55	38	28	6	10	1	2														230

Centralizare fişă de punctaj pentru specia: FA1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]											[illegible]

Centralizare fişă de punctaj pentru specia: CE1

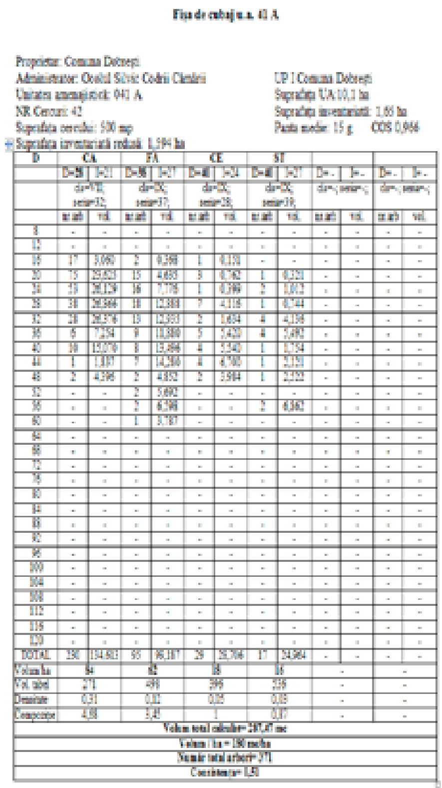
8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		1	3	1	7	2	5	4	4	2														29

Centralizare fişă de punctaj pentru specia: ST1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]												17

TOTAL NR. ARBORI INVENTARIATI IN U.A. 041 A: 371 arbori
TOTAL arbori inventariati in cerc 1: 11
TOTAL arbori inventariati in cerc 2: 14
TOTAL arbori inventariati in cerc 3: 13
TOTAL arbori inventariati in cerc 4: 11
TOTAL arbori inventariati in cerc 5: 12
TOTAL arbori inventariati in cerc 6: 14
TOTAL arbori inventariati in cerc 7: 11
TOTAL arbori inventariati in cerc 8: 13
TOTAL arbori inventariati in cerc 9: 14
TOTAL arbori inventariati in cerc 10: 13
TOTAL arbori inventariati in cerc 11: 10
TOTAL arbori inventariati in cerc 12: 10
TOTAL arbori inventariati in cerc 13: 10
TOTAL arbori inventariati in cerc 14: 7
TOTAL arbori inventariati in cerc 15: 9
TOTAL arbori inventariati in cerc 16: 10
TOTAL arbori inventariati in cerc 17: 13
TOTAL arbori inventariati in cerc 18: 11
TOTAL arbori inventariati in cerc 19: 8
TOTAL arbori inventariati in cerc 20: 7
TOTAL arbori inventariati in cerc 21: 12
TOTAL arbori inventariati in cerc 22: 13
TOTAL arbori inventariati in cerc 23: 11
TOTAL arbori inventariati in cerc 24: 8
TOTAL arbori inventariati in cerc 25: 16
TOTAL arbori inventariati in cerc 26: 11
TOTAL arbori inventariati in cerc 27: 14
TOTAL arbori inventariati in cerc 28: 9
TOTAL arbori inventariati in cerc 29: 9
TOTAL arbori inventariati in cerc 30: 12
TOTAL arbori inventariati in cerc 31: 11
TOTAL arbori inventariati in cerc 32: 11
TOTAL arbori inventariati in cerc 33: 12

Table 3. Log measurement sheet



Fişa de cubaj u.a. 41 A

Proprietar: Comuna Dobreşti
Administrator: Ocolul Silvic Codrii Cîmlări
Unitatea amenajistică: 041 A
NR Cercuri: 42
Suprafaţa cercului: 500 mp
Suprafaţa inventariată redusă: 1,594 ha

UP I Comuna Dobreşti
Suprafaţa UA:10,1 ha
Suprafaţa inventariată: 1,65 ha
Panta medie: 15 g   COS 0,966

D	CA		FA		CE		ST					
	D=[illegible]	I=21	D=[illegible]	I=27	D=[illegible]	I=24	D=[illegible]	I=27	D=..	I=..	D=..	I=..
	cls=VII; serie=32;		cls=IX; serie=37;		cls=IX; serie=28;		cls=IX; serie=19;		cls=; serie=;		cls=; serie=;	
	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.
8	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-
16	17	3,060	2	0,398	1	0,131	-	-	-	-	-	-
20	75	25,025	13	4,685	3	0,762	1	0,221	-	-	-	-
24	55	20,129	16	7,776	1	0,399	2	1,012	-	-	-	-
28	38	26,566	18	12,888	7	4,318	1	0,744	-	-	-	-
32	28	28,376	13	12,933	2	1,654	4	4,138	-	-	-	-
36	6	7,254	9	11,880	5	5,420	4	5,492	-	-	-	-
40	10	15,070	8	13,864	4	5,540	1	1,734	-	-	-	-
44	1	1,837	7	14,200	4	6,700	1	2,151	-	-	-	-
48	2	4,398	2	4,852	2	3,984	1	2,222	-	-	-	-
52	-	-	2	5,692	-	-	-	-	-	-	-	-
56	-	-	2	6,398	-	-	2	6,362	-	-	-	-
60	-	-	1	3,787	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-	-	-	-	-
88	-	-	-	-	-	-	-	-	-	-	-	-
92	-	-	-	-	-	-	-	-	-	-	-	-
96	-	-	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-
104	-	-	-	-	-	-	-	-	-	-	-	-
108	-	-	-	-	-	-	-	-	-	-	-	-
112	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-
120	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	230	134,803	[illegible]	96,187	29	28,706	17	24,064	-	-	-	-
Volum/ha	84		62		18		16		-		-	
Vol. tabel	271		498		396		336		-		-	
Desimea	0,31		0,12		0,05		0,05		-		-	
Compoziţie	4,58		3,45		1		0,87		-		-	
Volum total calculat= 287,47 mc												
Volum / ha = 180 mc/ha												
Număr total arbori= 371												
Consistenţa= 0,91												

CONCLUSIONS

For exploitable stands that have a consistency of more than 0.4 and have an area of more than 4 hectares, their inventory is made in circles of 500 m^2 with a radius of 12.62 m. The number of circles and the distance between them are established with the help of Technical Norms V for Forest Management Planning. This operation is carried out in the framework of the forest management planning.

With this method, the QGIS software and GPS-GNSS RTK technology, the center of the circles can be spotted very easily and in a very short time with the help of the GPS-GNSS RTK, and it is not necessary to measure the distances between circles in the field with the help of the forest ribbon, which is extremely expensive operation.

Thus obtaining a GIS, maps with all the information held can be easily generated: the parcels volumes, the consistency of the tree, the number of trees, etc.

The only condition is the existence of a digital layout map, which can be obtained from the parcel and forest compartment construction work with the redevelopment works in the Stereographic 70 projection, where the position of each circle can easily be materialized with QGIS software.

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