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ISSUES RELATED TO THE IMPLEMENTATION OF GEOMATIC APPLICATIONS IN THE NATIONAL FORESTRY FUND

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Abstract

The development of various geomatic applications in the forest requires advanced technologies for collecting, transferring, and processing data from the field, related to the spatial positioning of various topographic details. Special software is also required to report the coordinates of detail points and obtain various graphical products. In the forestry sector, planning maps, in analogue and/or digital format as appropriate, are used for various practical applications. The exploitation of cartographic material in digital format, with high accuracy, involves a process of spatial transformation or georeferencing, for which a few at least four points of known coordinates, are required in the two working systems. The positioning of the points required for the georeferencing process is performed with Global Navigation Satellite System (G.N.S.S.) technology, with a G.P.S system and/or with total station (TS), as appropriate. The MapSys 10.0 software can be used to perform the spatial transformation process. The results obtained in this case study ensure that the georeferenced raster is used with optimal accuracy to solve various current problems in the forestry sector.

Key words: *forest fund, forest map, geomatic applications, GNSS technology, GPS system, MapSys 10 program.*

INTRODUCTION

Sustainable management and administration of forest resources, regardless of ownership, is one of the objectives of the forestry strategy at national level. For the successful implementation of the various current and future activities in the national forestry fund, it is necessary to create and use an appropriate infrastructure for the spatial positioning of topographical details on forest areas and their representation on plans and maps.

Giurescu (2004) mentions that the maps of the 18th and early 19th centuries, compared with those of today, are of the greatest use for the study of the evolution of the country's forest area. For decades, plans and maps in analogue format have been used for several research and production activities specific to forestry.

Nowadays, thanks to modern working technologies and state-of-the-art equipment related to the land measurement sector, new, efficient possibilities (opportunities) have been created to obtain graphical representations of forest details in digital format, allowing high flexibility in their use and exploitation. Consequently, the application of various positioning technologies - such as the Global Navigation Satellite System (G.N.S.S.), different satellite systems, conventional total stations, and combined positioning methods−has enabled more efficient spatial positioning of various details within the forest fund. As a result, the use of the Global Navigation Satellite System (G.N.S.S.), conventional technology represented by total stations, combined positioning technologies, has made it possible to spatially position various details of the forest fund with greater efficiency (Crainic, 2011). In this context, the logistical basis for collecting, recording, verifying, transferring, and processing field data has significantly enhanced the efficient production of diverse alphanumeric and graphical digital outputs (Tereşneu & Tereşneu, 2023).

In principle, the positioning of detailed topographic points, with the GPS, in the national forest fund, can be carried out using various methods and procedures of data acquisition and processing, each with many peculiarities related to the equipment and calculation algorithms used (Pica et al., 2022; Crainic et al., 2023). In this context, by considering some specific conditions of the forest sector frequently encountered, an attempt was made to analyse, by comparison, the opportunities offered by the various working procedures of GNSS technology.

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Only under these conditions can specific proposals for the forestry fund be formulated, ensuring adequate accuracy, higher yield, and increased efficiency of the national geodetic network (Crainic et al., 2011).

In this context, a new direction of activity has been outlined, concerning the acquisition and processing of data necessary for the spatial positioning of topographic details on forest areas, using specific state-of-the-art technologies, namely Forest Geomatics. As a result, Geomatics is a modern discipline that integrates the acquisition, processing, modeling, analysis, and management of geo-referenced spatial data, based on the scientific support of geodetic and terrestrial, aerial and satellite records (Boș, 2011). Thus, Geomatics provides specific (spatial) information related to an investigated area on the earth's crust.

Accordingly, forest geomatics is a component of general geomatics, whose objectives are the study and knowledge of forests in terms of their extent, geographical location, structure, condition etc. These objectives are achieved through the integrated use of modern geo-topo-photogrammetric, aerial and satellite remote sensing techniques (used for the acquisition, storage, transfer, and processing of spatial data) (Boș, 2011; Petrila et al., 2010), and the archiving of the final products obtained.

A series of remote sensing applications in the forestry sector have been aimed at studying forest habitat fragmentation and the effects of forest management practices. Analysis of environmental conditions in protected areas has also been successfully carried out using these high-performance technologies (Olariu et al., 2022; Sabău & Crainic, 2006a).

The use of forest maps in analog format is currently restricted in the forestry sector, but there are still several current activities where these special graphical representations are used. Scanning produces the digital conversion or raster of the analogue forestry map format, which is defined by a specific extension, jpg, tif, ecw etc. As a result, it is possible to use them in digital format, thus ensuring their efficient and rigorous exploitation (Crainic et al., 2021; Crainic et al., 2022).

For the use of forest maps in analogue and implicitly in digital format, and for their differentiated exploitation, a series of specific work steps are required, which are conditioned by the final product required. If the digital format of the landscape map is requested for exploitation and evaluation in the national reference system - Stereographic-1970, topographic points of known coordinates in this system are required. If the digital format map is intended for surface evaluations (to scale), the topographic points used for transformation do not need to be positioned within the national reference system (Crainic et al., 2021; Sabău, 2010).

MATERIALS AND METHODS

The case study was carried out in the forest fund of Sălard Commune, Bihor County, which is managed by the Production Unit (PU) I - Sălard, Săcuieni Forest District, under the Bihor County Forest Administration.

The area on which the research was carried out is approximately 120.70 ha and is represented by several 21 stands (plots), which are shown in Figure 1.

Figure 1. Location of the case study-Toros Forest (after the Forest Map of the U.P. I Sălard, 2015)

The objectives of the case study are: to carry out integrated geomatic applications in the forestry background; and differentiated exploitation of forestry maps in analogue and digital format, according to the requirements imposed by the activities in the forestry sector.

The integrated geomatic applications carried out in the forestry background concern: the determination of a regional datum from the geodetic points in the study area; its verification by repositioning known geodetic points, and the spatial positioning with the G.P.S. system of characteristic topographic points of detail, in the studied stands.

Two research and study options were approached for the differentiated exploitation of forest maps. In the first variant, the raster of the forest maps in analogue format at a scale of 1:20000 was georeferenced to a local coordinate system, represented by the corners of its rectangular A3 format (Cioflan et al., 2023). In the second variant, vector data was used for georeferencing, represented by the spatial coordinates, in the national reference system, of the characteristic points corresponding to the corners of the plots.

The research methods used are: bibliographic documentation, observation, pilot experiment, simulation, comparison, and analysis.

The bibliographic documentation involves the study and analysis of specialized treatises, research and scientific papers related to topographic applications in the forestry sector. Technical standards related to the land measurement sector were also analysed.

The observation was carried out in the field, on the route and at the stationary, when identifying the study location (Figure 2). The pilot experiment is a research method based on a preliminary experiment, whereby methods and techniques are tested.

Table 1. Inventory of coordinates of geodetic points used to obtain the regional datum, in STEREO 70 projection system and Black Sea 1975 coordinate system

Topographic point		X (m)	Y (m)	Z (m)
Code	Order			
7	IV	641,143.150	275,370.096	109.517
11	IV	641,359.879	287,730.401	138.411
41	IV	648,959.326	274,488.095	111.925
16401	II	648,424.902	285,780.343	218.360
42401	I	623,315.749	273,944.933	294.259
43101	I	613,159.578	258,199.448	132.740
52401	IV	674,298.698	284,124.563	145.516

As a result, methods for spatial positioning of topographic points in the forestry sector were tested and verified with modern working technologies.

To obtain the regional datum, the geodetic points in the working area were analysed, positioned, and spatially repositioned with the G.N.S.S. technology, G.P.S. system, using the traditional static method (Tables 1 and 2). The spatial coordinates of the geodetic points used for the experiment are shown in Tables 1 and 2 and Figure 2.

Table 2. Known geodetic points in the area positioned in the global geocentric system on the WGS-84 ellipsoid

Topographic point		X(m)	Y(m)	Z(m)
Code	Order			
7	IV	4022080.269	1627582.127	4659390.965
11	IV	4016997.393	1638839.045	4659866.580
41	IV	4017227.959	1624350.434	4664669.252
16401	II	4013124.326	1634882.839	4664668.344
42401	I	4034621.346	1631844.383	4647376.578
43101	I	4047548.519	1620516.059	4639923.201
52401	IV	3996465.545	1625304.068	4682066.904

Figure 2 shows the location of known geodetic points in the study area.

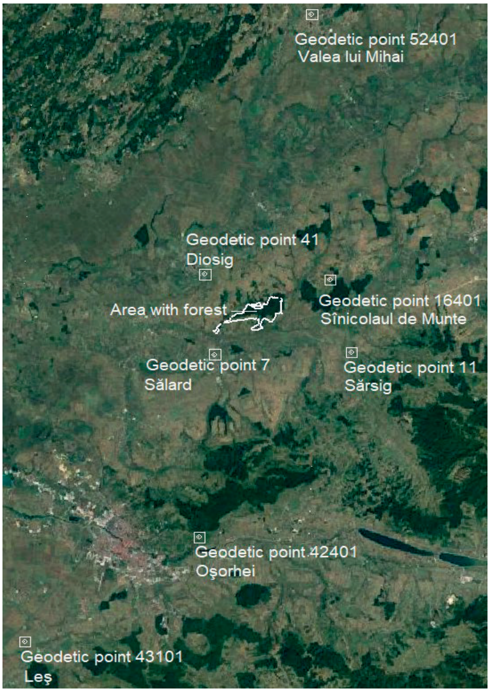


Figure 2. Location of known geodetic points in the study area

The analysis of the elements in Figure 2 shows that there are seven geodetic points in the working area. Simulation is a modern research tool. For the georeferencing of the raster related to the forest map, two working variants were simulated, with common transformation points in the national reference system and in the local system, respectively. In this context, the raster georeferencing process was carried out with the Mapsys 10.0 software. The software used is licensed.

For this process, transformation points in the local system and respectively points in the national reference system, Stereographic - 1970, were used.

The comparison contributes to a deeper study and knowledge of the methods of spatial positioning of details, georeferencing, as well as the accuracy and precision of the final products obtained. In this context, the spatial coordinates of some geodetic points that have been redetermined with the GPS system, using the regional datum, have been compared with those of the inventory of Cadastre and Real Estate Publicity Office Bihor. Also, the areas of vectorized stands on the two rasters (which were georeferenced using topographic points in different reference systems), were compared.

Content analysis was used to test and verify the working technologies and the quality of the results obtained. Consequently, the working methods and the results obtained were analysed to optimise the exploitation of the final products, and enhance the proposed technical solutions.

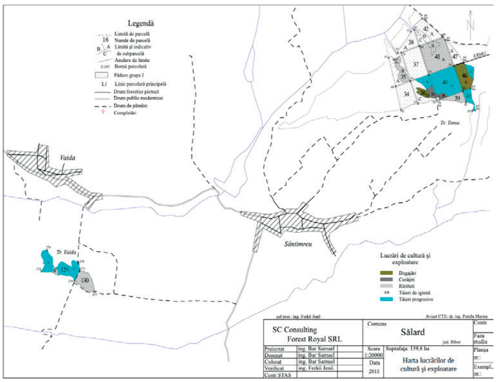


Figure 3. Forest Map of Production Unit (PU) I Sălard (2015)

The logistics used include analogue and rasterised landscape maps, Trimble R3 GPS receivers, A3 antennas, specialised software for data collection - RawDataEditor, and for data processing - Trimble Total Control (T.T.C.).

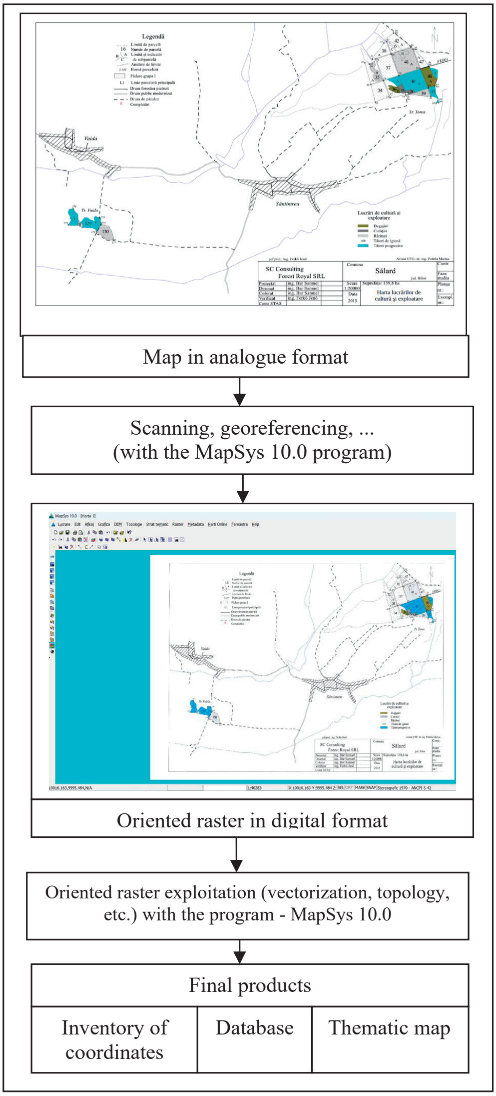


Figure 4. Work steps for exploiting cartographic material in digital format, with MapSys 10.0 software

MapSys 10 software was also used for: reporting the coordinates of the positioned points, georeferencing the raster, making the geographic information system and making the related database (Marton, 2007). For a complete analysis of the possibilities of exploitation of the cartographic material related to the forest background, the orthophoto plan of the study location was also used (Bodog & Crainic, 2016). The spatial coordinates of the characteristic points that represent the outline of the parcels were determined with G.N.S.S. technology, the G.P.S. system, using the fast static positioning method. To obtain the final coordinates, the regional datum was used, which was determined by a spatial transformation with seven parameters. The transformation parameters are a rotation and a translation on the three axes, OX, OY and OZ and respectively the scale factor (Figure 5).

This transformation relied on four geodetic points, accurately determined within the study location, and was then applied to the national reference system (Table 1). The planimetric standard deviation of the geodetic points is $s_{xy} \leq$ 5 cm.

The geodetic points 7 Sălard, 41 Diosig and 16401 Sînicolaul de Munte, 42401 Oşorhei, 43101 Leş and 52401 Valea lui Mihai are in a very good technical condition and point 11 Sărsig shows a 20% deterioration.

The georeferencing of the raster for the forest maps, in the two working variants, was carried out with the MapSys 10 program, using four common coordinate points in the two reference systems (local and national). Consequently, the stages presented in Figure 4 were completed for each variant.

RESULTS AND DISCUSSIONS

The results obtained in this case study are ranked and presented in turn, according to the stages completed.

Since 2001, research and studies conducted in the case study location (Crainic, 2011) have confirmed that using a regional datum for satellite positioning of various topographic details in the forestry sector, based on highly accurate geodetic points, achieves high accuracy. With the Trimble Total Control (T.T.C.) calculation system, the transformation of coordinates from the WGS 84 global reference system to national coordinates - planimetric and altimetric - was performed. In principle, this is carried out according to the conditions imposed by specific working algorithms.

The computation steps are: determination of the common points on which the transformation will be performed; implementation of the coordinates in the national reference system under the Control Coordinates option; selection of the type of transformation (planar or spatial); the processing of the selected transformation and obtaining the transformation parameters; analysis of the accuracy indicators of the performed transformation; implementation of the transformation parameters in the database of the computation system (Coordinate System Manager) related to the national datum.

The set of transformation parameters (Figure 5) that has been implemented in the database of the computing system - in the Coordinate System Manager section (Figure 6), together with the reference ellipsoid, the map projection system, the coordinate reference system, constitutes the regional datum for the working area. It is properly archived to keep and use (access) it, as needed, in the appropriate database (Figure 6).

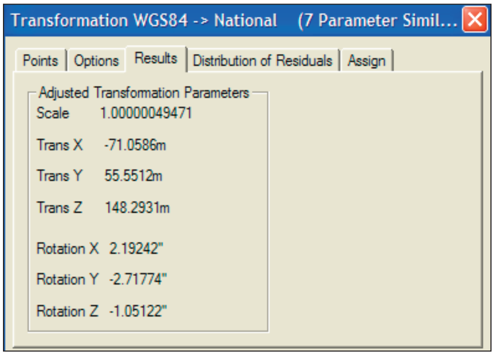


Figure 5. Set of transformation parameters on four known points obtained with the T.T.C. program

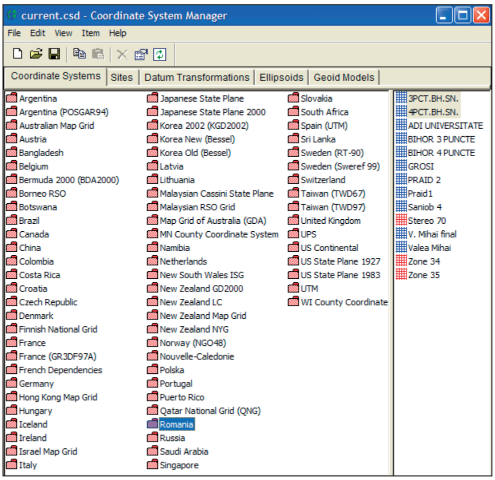
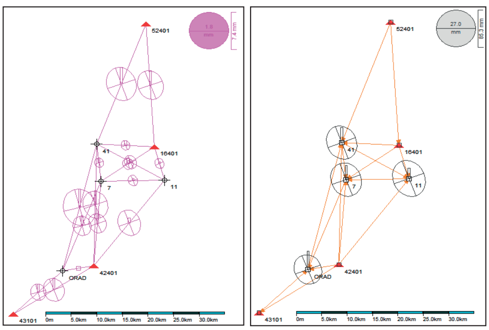


Figure 6. Database of datums related to the Trimble Total Control calculation system with the datums determined for the case study, implemented

As a result, in the Trimble Total Control calculation system, the regional datum can be used, by setting, to configure the worksheet for a new project.
Consequently, the use of the regional datum, (obtained from the transformation parameters shown Figure 5), when using the T.T.C. (program for processing satellite records), facilitates the obtaining of final coordinates, rigorously compensated in the national reference system. As a result, no further transformation in the national reference system will be necessary to obtain them.
Three geodetic points in the study area were repositioned to verify the datum. Processing of the recorded satellite data with the T.T.C. software, to obtain the final coordinates in the Stereographic 1970 system, involves the following steps: initialization of the program and opening of a new working project; setting of the corresponding processing parameters; transfer of the records into the computer system; primary verification and processing of the recorded data; verification of the triangle mismatches and the type of solution adopted; recalculation of the verified data and obtaining the provisional (3D) spatial coordinates; rigorous compensation of the provisional spatial coordinates and obtaining the final spatial coordinates with the related statistical accuracy indicators (Figure 7).



a.) b.)
Figure 7. Sketch of vectors processed for compensation, a) primary processing; b) rigorous compensation

In the preliminary operations, comprising the first five positions above, the possibility of checking the recorded data is ensured, including the elimination of some inappropriate ones, affected by disturbing factors, by deactivating certain intervals of records. Thus, in the case of records from the points to be repositioned, following the primary processing of the data, the inappropriate solutions, of the *float* type, will be eliminated and only the *fixed* type solutions will be kept. Fixed solutions result from the processing of primary data with a specific algorithm, and the results fall within an established tolerance. Consequently, positioning with centimeter precision is ensured.
From the analysis of the coordinates presented in Table 3, the planimetric standard deviations vary between 49 and 53 mm, and those for the elevations vary between 68 and 90 mm.

Table 3. Inventory of coordinates of geodetic points repositioned with regional datum, in 1970 Stereographic projection system and 1975 Black Sea coordinate system

Point	X (m)	Y (m)	s_{XY} (mm)	Z (m)	s_Z (mm)
7	641,143.200	275,370.173	50	109.202	86
11	641,359.990	287,730.395	53	138.188	68
41	648,959.360	274,488.137	49	111.554	90

s_{XY} - planimetric standard deviation, s_Z - altimetric standard deviation.

Consequently, geodetic points 7, 11, and 41 have been repositioned with high accuracy, using the regional datum.
In order to obtain the spatial coordinates of the characteristic points of detail, of the corners of the plots, successive stages of positioning with the GPS system were carried out (Crainic, 2011), aspects that are presented in the Figures 8-11.

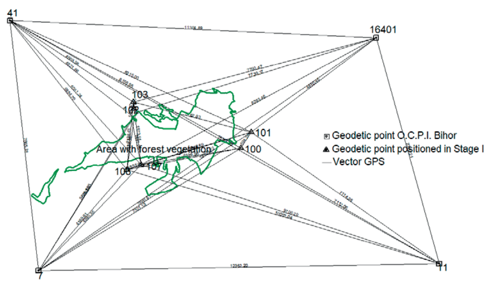


Figure 8. Stage I of the creation of the net of control points, from the case study location (Crainic, 2011)

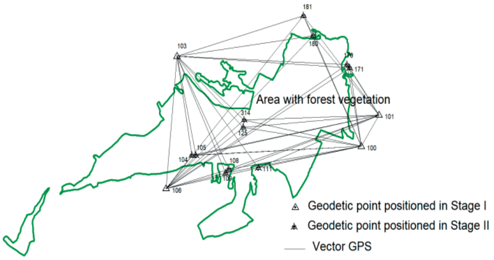


Figure 9. Phase II of the creation of the net of control points, from the case study location (Crainic, 2011)

As a result, point couplings were determined in the working area to optimise the satellite positioning process. In this context, within the framework of the fast static method, the prerequisites were created for reducing the positioning time and ensuring a higher accuracy (Crainic, 2011).

Satellite data recording in the field was performed by the fast static method, with TRIMBLE R3 receivers, A3 antenna, with a single L1 frequency. The dwell time at each point was 15-30 minutes, with recording epochs of 15 seconds, using Trimble Digital Fieldbook software.

The field data were recorded in RINEX files and processed in a similar way to the data processing shown for geodetic point repositioning. The spatial coordinates, in the national reference system, are shown in Table 4.

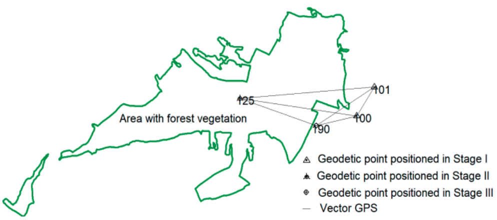


Figure 10. Stage III of the creation of the net of control points, from the case study location (Crainic, 2011)

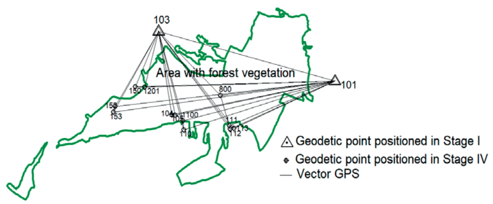


Figure 11. Phase III of the creation of the net of control points, from the case study location (Crainic, 2011)

Table 4. Inventory of coordinates of topographic detail points in the 1970 STEREOGRAPHIC System and the 1975 Black Sea Elevation System

Point	X (m)	Y (m)	Z (m)
134	644,584.550	278,203.908	181.286
234	644,939.695	278,112.170	171.015
334	645,023.830	278,368.765	157.488
434	644,674.220	278,464.376	188.085
135	644,945.487	278,111.532	171.006
235	645,372.203	277,995.343	150.68
335	645,461.943	278,218.134	150.633
435	645,031.728	278,366.624	158.325
137	645,033.838	278,372.179	159.337
237	645,463.709	278,223.065	150.465
337	645,563.133	278,513.615	156.778
437	645,130.634	278,657.004	183.237
141	645,132.388	278,663.880	183.938
241	645,565.867	278,519.434	156.734
341	645,659.912	278,921.284	164.783
441	645,263.970	279,063.858	185.715
542	645,695.198	278,886.566	161.832
145	644,693.770	279,261.232	183.484
245	644,865.868	279,205.283	175.01
345	645,010.838	279,629.022	179.204
445	644,678.617	279,735.686	180.764
146	644,871.401	279,203.777	175.771
246	645,261.477	279,072.244	185.082
346	645,395.497	279,492.996	181.909
4460	645,017.111	279,627.817	178.463
147	645,265.558	279,070.387	185.429
247	645,654.991	278,926.764	165.169
347	645,580.324	279,428.708	185.993
447	645,402.790	279,490.095	182.45
547	645,590.356	279,102.534	176.347

Exploitation of digital cartographic material related to the case study location.

For the exploitation of the raster cartographic material, obtained by converting the landscape map from analogue to digital format, the MapSys 10.0 software was used, going through the following steps which are summarised in Figure 3 (Tămâioagă G. & Tămâioagă D., 2007; Crainic et al., 2022; Matei et al., 2022).

In the first variant for georeferencing, four common feature points were used, which have spatial coordinates referenced in a local reference system (Cioflan (Irimie) et al., 2023).

These points are the corners of a planning map sheet at a scale of 1:20000, on which the 21 plots studied are represented - Figure 1, in A3 format, i.e. a rectangle with length L = 42.0 cm and width l = 29.7 cm. (Crainic et al., 2022; Sabău & Crainic, 2006 b).

In this case, the width of the sheet is parallel to the direction of geographic North, and the width is oriented East. Therefore, based on the A3 size, ΔX = 29,7 cm, and ΔY = 42,0 cm. If the scale of the map is taken as 1:20000, then the relative coordinates of the format shown are ΔX = 5940 m and ΔY = 8400 cm.

Finally, the feature point in the S-V corner of the format will be given the number 1, and assigned arbitrary coordinates, in the case of this study, X1 = 10000 m, and Y1 = 10000 m. Next, the other minutiae, have the following characteristics:
- point 2 in the N-W corner, X2 = X1 + ΔX = 10000 m + 5940 m = 15940 m, and Y1 = 10000 m;
- point 3 in the N-E corner, X3 = 15940 m, and Y3 = Y1 + ΔY = 10000 + 8400 m = 18400 m;
-point 4 in the S-E corner, X4 = X1 10000 m, and Y4 = Y3 = 18400 m.

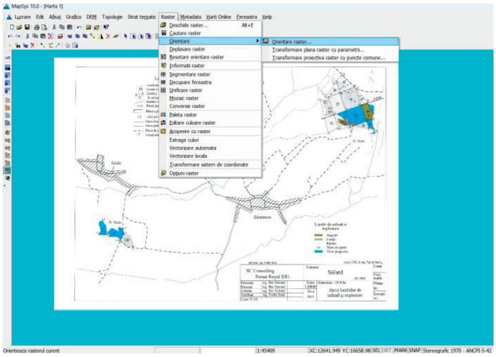


Figure 12. Starting the raster orientation and georeferencing process on four points in the local projection system with MapSys 10.0 software

Consequently, the coordinates of these four points will be used for georeferencing the raster of the forest management map used by transforming to common points.
After georeferencing the raster, it was vectorized, thus obtaining the polygons corresponding to the plots and implicitly to the studied and analysed stands.

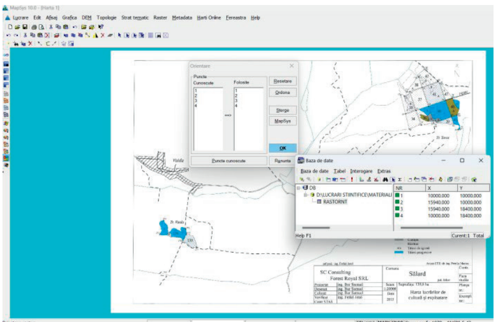


Figure 13. Implementation of common points and raster georeferencing in the local projection system with MapSys 10.0 software

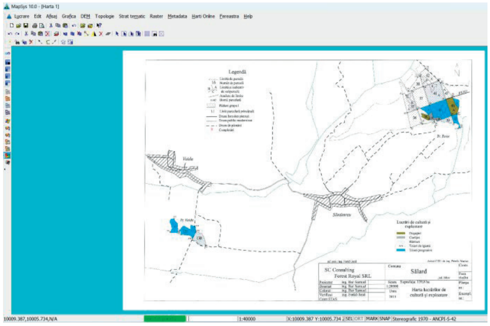


Figure 14. Geo-referenced raster in local projection system with MapSys 10.0 software

Figure 15. Vector of the georeferenced raster in the local projection system

As a result, the areas of the stands were determined and compared with their values presented in the forestry plan in force.
In the second version of the study, the raster will be georeferenced according to the coordinates of the characteristic points that have been determined by satellite positioning, with the GPS system (using the fast static method), which are shown in Table 5. These feature points were located near the (forest) boundary markers that delimit the adjacent plots.
The steps of the raster georeferencing process, in the variant using coordinates in the national reference system, are like those followed in variant I of the study.

Table 5. Inventory of coordinates of topographic points, which were used for raster georeferencing

Nr. point	X (m)	Y (m)	Z (m)
1/134	644,584.550	278,203.908	181.286
2/235	645,372.203	277,995.343	150.68
3/247	645,654.991	278,926.764	165.169
4/146	644,871.401	279,203.777	175.771

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The georeferenced raster is shown superimposed on the orthophoto map of the study area in Figure 16.

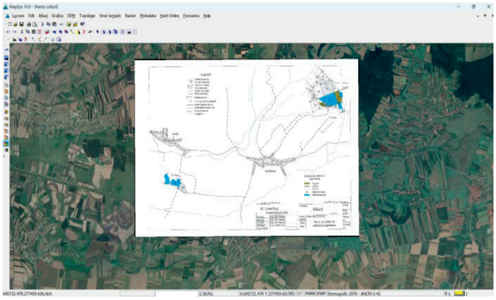

Figure 16. Screenshot of a geo-referenced raster in the national reference system with MapSys 10.0 software

Following the raster vectorisation process, the vector obtained is presented relative to the orthophoto plan.

On the vectors obtained in the two study variants, quantitative assessments were carried out on the stand area of the plots surveyed and analysed. As a result, the values obtained from the two calculation methods were compared to each other and to the area in forest management, using formulas 1 and 2 for the analysis.

$$\Delta S_I = S_{mp} - S_I; \quad (1)$$

$$\Delta S_{II} = S_{mp} - S_{II}; \quad (2)$$

where: ΔS_I - area difference for calculation variant I, ΔS_{II} - area difference for calculation variant II, S_{mp} - the surface from the management plan, S_I - area determined on the raster vector oriented in calculation variant I, S_{II} - area determined on the raster vector oriented in calculation variant II (Figure 17).

Figure 17. Vector obtained in the second study variant

Table 6. Evidence of assessed areas and differences reported to the forest management area in the two study variants

Plot nr.	S_{mp} (ha)	S_I (ha)	S_{II} (ha)	ΔS_I (ha)	ΔS_{II} (ha)
34	10.7	8.81	9.67	1.89	1.03
35A	5.7	5.08	5.56	0.62	0.14
35B	3.7	3.96	4.35	-0.26	-0.65
36A	3.2	2.54	2.89	0.66	0.31
36B	1.4	1.37	1.51	0.03	-0.11
36C	6.2	4.49	5.00	1.71	1.20
36D	1.7	1.89	2.06	-0.19	-0.36
37	14.4	12.14	13.54	2.26	0.86
38A	5.9	4.98	5.48	0.92	0.42
39	4.2	2.98	3.40	1.22	0.80
40A	16.6	14.12	15.42	2.48	1.18
40B	1.2	1.00	1.12	0.20	0.08
41A	17.6	15.12	16.73	2.48	0.87
41B	2.6	1.76	1.95	0.84	0.65
42A	6.4	6.04	6.62	0.36	-0.22
42C	1.3	1.18	1.28	0.12	0.02
42D	2.3	1.99	2.18	0.31	0.12
45	2.2	2.33	2.63	-0.13	-0.43
46A	7.4	6.64	7.34	0.76	0.06
46B	1.8	1.63	1.74	0.17	0.06
47A	4.2	3.40	3.71	0.80	0.49
Total	**120.7**	**103.45**	**114.17**	**17.25**	**6.53**

Figure 18 shows the correlation between the differences ΔS_I and the areas in the forest management, corresponding to the plots evaluated in variant I of the study.

The analysis of the elements in Figure 18 shows that there is a strong linear correlation between the ΔS_I area differences and the forest management areas.

The coefficient of determination $R^2 = 0.8065$ and the correlation coefficient $R = 0.898$. As a result, the regression line has a positive slope.

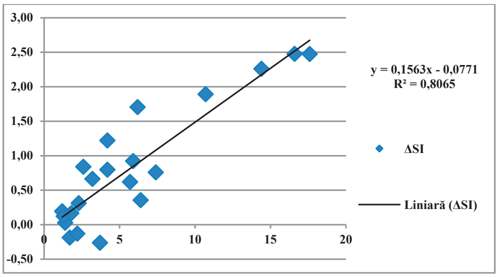

Figure 18. Correlation between ΔSI differences and forest management areas, stands studied

For the ΔS_{II} area differences, no significant correlation was found between these and the areas in the forest management for the 21 stands studied in Figure 19.

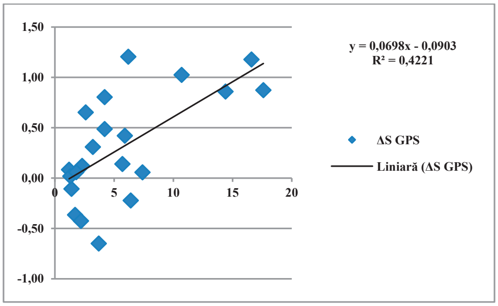

Figure 19. Correlation between ΔSII differences and forest management areas, stands studied

From the comparison and analysis of the total areas evaluated by the two variants of research, the total value of the area differences in the two variants is as follows: $\Sigma\Delta SI = 17.25$ ha, $\Sigma\Delta SII = 6.53$ ha. The surface difference for the first study option represents 14.3% of the surface in the management plan. For the second variant of the study, the surface difference represents 5.4% of the surface in the management plan. As a result, it is found that the II working variant provides superior precision for the quantitative exploitation of analogue forest maps, converted into a raster format.

CONCLUSIONS

The use of G.N.S.S. technology and the G.P.S. system for the positioning of detailed topographic points in the forest fund, by static method, ensures superior accuracy in determining their coordinates.

The use of the regional datum for processing satellite records for positioning by static methods, ensures the optimization of the calculation steps, and the achievement of a superior precision and accuracy.

The coordinates of the geodetic points, which were recalculated using the regional datum, have a high precision and accuracy.

The georeferencing of the raster for the forest management map of the case study area, through the two variants, offers the possibility of differentiated exploitation of the forest map material.

The differences in area ΔS_I and ΔS_{II} respectively highlight the particularities of the georeferencing and vectorization process of the raster used.

The use of topographical points positioned with the GPS system, with high precision, for the georeferencing of the rasters, ensures a relatively high precision in the process of their quantitative exploitation.

Also, the readability and accuracy of the analogue forest management map influence the georeferencing accuracy and thus the quantitative exploitation process of the obtained raster and vector data.

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REFERENCES

Bodog, M.F., & Crainic, G.C. (2016). Some Specific Characteristics of the Geomatic Applications in the Agro-Forestry Sector. *Annals of the University of Oradea, Environmental Protection Fascicle*, University of Oradea Publishing House, Vol. XXVII, 2016, ISSN - 1224-6255, 337-346.

Boş, N. (2011). Geomatics and the realization of the cartographic base of the forest fund in Romania. *Forest Magazine, No. 6*, 126, 27-36.

Cioflan (Irimie), F., Crainic, G C., Iovan, C., Irimie, F. & Covaci, F. (2023). Aspects relating to quantitative and qualitative assessments of topographic details, on map material, in analog and digital format. *Annals of the University of Oradea, Fascicle: Environmental Protection*, 85 - 94.

Crainic, G.C., Covaci, F., Sabău, N.C., Sicoe, S.I., Irimie (Cioflan), F., Bodog, M.F. & Iovan, C.I. (2023). Works specific to the introduction of silvopastoral systems in the forest fund. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. XII*, 74-85, Print ISSN 2285-6064.

Crainic, G.C., Bodog, M., Iovan, C., Cioflan (Irimie), & Flavius, I. (2022). Differentiated use of cartographic material in the forestry sector, in the plain area. *Annals of the University of Oradea, Fascicle: Environmental Protection, Vol. XXXIX,* 79 - 86. doi.org/10.5281/zenodo.4362307, ISSN 2065-3484.

Crainic, G.C., Irimie, F., & Irimie, F.M. (2021). Realization of a geographical informatic system for inaccessible forest fund. *Annals of the University of Oradea, Fascicle: Environmental Protection, Vol. XXXVII*, 185 - 196. doi.org/10.5281/zenodo.4362307,

Crainic, G.C., Bodog, M., Sicoe, S., Bungău, D., Druţă, N., Ardelean, R. & Bar, I. (2018). Aspects relating to technology topographic details G.N.S.S. positioning system G.P.S. in the forestry massive. *Annals of the University of Oradea, Fascicle: Environmental Protection, Vol. XXXI,* 121-132, ISSN 1224-6255.

Crainic, G.C., Damian, V.L. & Spilca, M. (2011). Posibilities of realisation of the minor control network with gnss tehnology in the occupyed areas with forest vegetation in mountain areas. *Research Journal of Agricultural Science, University of Agricultural Science and Veterinar Medicine of the Banat Timişoara, 43*(3). ISSN - 2066-1843, 283-291.

Crainic, G.C. (2011). *Research on the modernization of topographical works in the forestry sector*. Ministry of Education, Research, Youth and Sports, Transilvania University of Brasov, Faculty of Forestry and Forestry, Department of Forestry, Forest Management, Land Surveys, Brasov, PhD Thesis.

Damian, V.L. & Crainic, G.C. (2016). Possible use of geomatics for the analysis of spatial distribution of chestnut *(Castanea sativa* Mill*)* populations in Romania. *Annals of the University of Oradea, Fascicle: Environmental Protection*, *Vol. XXVI,* 185-194, ISSN 1224-6255.

Giurescu, C.C. (2004). *The history of the Romanian forest from the earliest times to today*. Third edition, revised and added. Bucharest, RO: Orion Publishing House.

Marton, G., Albotă, M., Filotti, D., Molea, O., Şalariu, I. (1976). *Polyglot dictionary of geodesy, photogrammetry and cartography*. Bucharest RO: Tehnical Publishing House.

Marton, H. (2007). *MapSys, TopoSys - User manual*. Odorheiu Secuiesc, Romania.

Matei, L., Crainic, G.C., Curilă, S. & Curilă, S. (2022). *Designing and creating a related database current activities in the forestry sector*, Analele Universităţii din Oradea, Fascicula: Protecţia Mediului, Vol. XXXIX, 113 – 120, ISSN 2065-3484. doi.org/10.5281/zenodo.4362307.

Olariu, B., Vîrghileanu, M, Mihai, B.A., Săvulescu, I., Toma, L. & Săvulescu, M.G. (2022). Forest Habitat Fragmentation in Mountain Protected Areas Using Historical Corona KH-9 and Sentinel-2 Satellite Imagery. *Remote Sens., 14*(11), 2593. https://doi.org/10.3390/rs14112593.

Petrila, M., Apostol, B., Gancz, V., Loreţ, A. (2010). *Applications of geomatic technologies in forestry.* Silvic Publishing House.

Pica, A., Boja, F., For a, C., Moatar ,M., & Boja, N. (2022). Advantages of using gnss technology and QGIS software in inventory stands exploiters. *Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. XI*, 434 -443, Print ISSN 2285-6064.

Sabău, N.C. (2010). *Terrestrial measurements*. Oradea University Publishing House.

Sabău, N.C., Crainic, Gh.C. (2006 a). *Remote sensing and forest cadastre*. Publishing House of the University of Oradea, 318 pages, ISBN (10) - 973 - 759 - 203 - 4, ISBN (13) - 978 - 759 - 203 - 3. Recognized by CNCSIS, code. 149.

Sabău, N.C., Crainic, Gh.C. (2006 b). *Applications of remote sensing in forest cadastre*. Publishing House of the University of Oradea, 156 pages, ISBN (10) - 973 - 759 - 203 - 4, ISBN (13) - 978 - 759 - 203 - 3. Recognized by CNCSIS, cod. 149.

Tămâioagă, G. & Tămâioagă, D. (2007). *Automation of cadastre works*. Bucharest RO: Matrix Rom Publishing House.

Tereşneu, C.C. & Tereşneu, C.S. (2023). GIS facilities for the automation of cadastral documentations. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. XII*, 371-376, Print ISSN 2285-6064.

****Forest management of Production Unit I Sălard, Bihor County*. (2018).

****Forestry map of Production Unit I Sălard*, Bihor County. (2018).