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# GIS ANALYSIS OF AREA DETERMINATION METHODS IN FORESTRY

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***Abstract***

*This paper presents a GIS analysis meant to highlight problems regarding area differences in the forest sector, when different determination methods are used. The study's focus is on forest surfaces in the Bran-Moeciu area of Brasov county. These were identified on cadastral plans of forest boundaries and vectorised. These boundaries were then determined using the "Stop & Go" method with Trimble Pro XT and Trimble Pro XH GPS receivers. The analysis was centred on two issues: estimating the boundary differences between the two methods and their implication on area determinations. A simple method of determining boundary differences through their measurement in the AutoCAD software was used, of course taking into account their sign. In addition, a GIS method was developed which, with the aid of VBA code sequences, provides a rapid determination of these differences. The final conclusion was that, based on the analysed data, even if the differences are somewhat significant (sometimes over 75 metres) between the two methods, the implications on area determination is much lower (max. 2-3%), due to their somewhat uniform distribution of positive and negative values.*

***Key words***: *GIS, GPS, mountainous forests, statistical analysis.*

## INTRODUCTION

This paper's purpose is to analyse the area differences which show up when two different methods are used: the one which was exclusively used until the 1990s (based on measurements carried out on cadastral plans with forest boundaries) and the one based on topo-geodetic surveys, which appeared once property laws were put into effect. The study area is located in the Bran-Moeciu region (Figure 1), more specifically in the forest area present here.

Numerous past studies have been carried out in this area, which looked at: the influence of various factors on the precision of coordinate calculation (Teresneu et al., 2014), the precision of coordinate calculation at the canopy's edge (Teresneu and Vasilescu, 2015), the precision of coordinate calculation corroborated with parcel areas (Teresneu et al., 2011), the influence of orography on the coordinate precision (Teresneu and Vasilescu, 2019) etc. Because this study also takes into account various influences which have an effect on the coordinate precision when using GPS receivers, various studies that highlight the strong influence of stand density (Ordonez Galan et al., 2011; 2013; Weilin et al., 2000; Zhang et al., 2014), access to the number of satellites (Wang et al., 2014), the negative influence of snow cover (Janez et al., 2004), the negative impact of decidious species during their vegetation season (Dogan et al., 2014; Sawaguchi et al., 2003) were considered.

Figure 1. Study area

## MATERIALS AND METHODS

40 cadastral plans of the study area were used, which had data relating to the boundaries of forest parcels. Also, two GPS receivers were used: *Trimble Pro XT* and *Trimble Pro XH*.

Research methods that were used are: direct measurements, statistical processing and GIS methods.
With regards to the direct measurements, the two GNSS receivers previously mentioned were used to determine the coordinates of forestry parcel boundaries, by measuring the position of over 2700 points. These points were determined in valleys, slopes, forest roads and at the forest's edge. Necessary corrections were taken from the Top Geocart permanent station. Resulting data was then imported in a *.xls file (Figure 2).

| 1 | Comment | Max_PDOP | Corr_Type | Rcvr_Type | Feat_Name | GPS_Height | Vert_Prec | Horz_Prec | Std_Dev |
|---|---|---|---|---|---|---|---|---|---|
| 2 | borna 58 Mo FM | 3.7 | Postprocessed Carrier Float | ProXRT | Point_ge | 935.349 | 0.9 | **0.6** | 0.000000 |
| 3 | 2 | 11.9 | Postprocessed Code | ProXRT | Point_ge | 964.581 | 3.5 | **2.5** | 24.321031 |
| 4 | 3 | 4.3 | Postprocessed Carrier Float | ProXRT | Point_ge | 945.439 | 1.3 | **0.8** | 0.000000 |
| 5 | 4 | 12.3 | Postprocessed Code | ProXRT | Point_ge | 952.288 | 2.6 | **1.7** | 0.748816 |
| 6 | 5 | 11.6 | Postprocessed Code | ProXRT | Point_ge | 963.604 | 1.2 | **0.8** | 0.270757 |
| 7 | 6 | 3.7 | Postprocessed Carrier Float | ProXRT | Point_ge | 971.954 | 1.2 | **0.8** | 0.240139 |
| 8 | 7 | 16.3 | Postprocessed Carrier Float | ProXRT | Point_ge | 980.461 | 1.3 | **0.8** | 0.743607 |
| 9 | 8 | 7.3 | Postprocessed Carrier Float | ProXRT | Point_ge | 973.210 | 1.5 | **0.9** | 1.326025 |
| 10 | 9 | 5.0 | Postprocessed Carrier Float | ProXRT | Point_ge | 978.885 | 1.2 | **0.7** | 0.181251 |
| 11 | 10 | 3.6 | Postprocessed Code | ProXRT | Point_ge | 976.775 | 1.1 | **0.7** | 0.131620 |
| 12 | 11 | 6.0 | Postprocessed Code | ProXRT | Point_ge | 974.438 | 1.4 | **0.7** | 0.213816 |
| 13 | 12 | 13.7 | Uncorrected | ProXRT | Point_ge | 965.080 | 2.2 | **1.1** | 1.044148 |
| 14 | borna 52 Fa FM | 3.8 | Postprocessed Carrier Float | ProXRT | Point_ge | 963.363 | 1.7 | **0.7** | 0.000000 |
| 15 | 14 | 7.0 | Postprocessed Carrier Float | ProXRT | Point_ge | 966.730 | 1.9 | **0.8** | 1.016204 |
| 16 | 15 | 6.5 | Postprocessed Code | ProXRT | Point_ge | 973.871 | 1.7 | **0.8** | 1.045687 |
| 17 | 16 | 7.8 | Postprocessed Carrier Float | ProXRT | Point_ge | 978.559 | 1.9 | **0.8** | 0.157612 |
| 18 | 17 | 9.2 | Postprocessed Code | ProXRT | Point_ge | 977.109 | 3.4 | **0.9** | 0.682035 |
| 19 | 18 | 7.9 | Postprocessed Code | ProXRT | Point_ge | 983.867 | 3.0 | **0.7** | 0.273256 |
| 20 | 19 pod | 4.7 | Postprocessed Carrier Float | ProXRT | Point_ge | 998.033 | 1.8 | **0.6** | 0.000000 |
| 21 | 20 pod | 7.2 | Postprocessed Carrier Float | ProXRT | Point_ge | 998.784 | 2.5 | **1.0** | 0.000000 |
| 22 | 21 | 9.8 | Postprocessed Code | ProXRT | Point_ge | 999.790 | 2.4 | **0.8** | 0.911807 |
| 23 | 22 | 18.5 | Postprocessed Code | ProXRT | Point_ge | 1013.038 | 4.6 | **1.2** | 1.200337 |
| 24 | 23 | 9.5 | Postprocessed Carrier Float | ProXRT | Point_ge | 1037.237 | 2.2 | **0.7** | 0.729223 |
| 25 | 24 | 6.9 | Postprocessed Code | ProXRT | Point_ge | 1045.839 | 4.4 | **1.7** | 2.137337 |
| 26 | 25 | 15.1 | Postprocessed Carrier Float | ProXRT | Point_ge | 1061.498 | 2.7 | **0.8** | 0.762630 |
| 27 | 26 | 6.8 | Postprocessed Carrier Float | ProXRT | Point_ge | 1072.065 | 2.6 | **0.6** | 0.000000 |
| 28 | 27 | 15.4 | Postprocessed Carrier Float | ProXRT | Point_ge | 1088.858 | 2.8 | **0.6** | 0.499122 |
| 29 | 28 | 13.1 | Postprocessed Code | ProXRT | Point_ge | 1108.112 | 2.8 | **0.6** | 0.319059 |
| 30 | 28 | 10.0 | Uncorrected | ProXRT | Point_ge | 1127.898 | 3.7 | **0.9** | 0.746053 |
| 31 | 30 | 10.0 | Postprocessed Code | ProXRT | Point_ge | 1145.511 | 4.0 | **1.0** | 0.767480 |
| 32 | 31 | 9.6 | Postprocessed Carrier Float | ProXRT | Point_ge | 1189.852 | 3.5 | **0.8** | 1.138058 |
| 33 | 32 | 11.1 | Postprocessed Code | ProXRT | Point_ge | 1213.934 | 3.5 | **1.0** | 1.621440 |
| 34 | 33 | 9.1 | Postprocessed Code | ProXRT | Point_ge | 1229.648 | 3.3 | **0.9** | 0.874987 |

Figure 2. Initial database

Regarding GIS methods, the following steps were carried out: geo-referencing of the cadastral plans, vectorisation of forest boundaries, use of various VBA code sequences for various calculations.
Finally, statistical methods were used to determine the precision of point coordinate calculations (not detailed here), to analyse the boundary differences between the two methods and to compare the parcel areas thus obtained.

## RESULTS AND DISCUSSIONS

After geo-referencing all base plans (cadastral plans) the forestry boundaries were vectored. A hybrid AutoCAD-ArcGIS method was used (Tereşneu et al., 2016). Then the *.xls database was completed with additional data, obtained from simple calculations. A particular focus was placed on the quantification of boundary differences resulting from the application of the two methods previously discussed (Figure 3).
The forestry parcels for which boundaries were both vectored and directly measured using GPS were then identified (Figure 4).
These differences were highlighted using two methods. In the first of these, the differences were simply measured in AutoCAD (Figure 5). Measurements were done for the inflection points of the measured boundaries and their corresponding points on the vectored boundaries. In those situations where on the second boundary there were no corresponding inflection points, the differences were measured on the perpendicular line to this boundary.
These differences were then recorded in the *.xls database with a plus or minus sign, depending on their position to the left or right of the marker. The marker is the point determined using direct measurements with GPS equipment. The arithmetical sign was considered based on the technical orientation of valleys and slopes.

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| Point_ID | Dist_trapez | HP<=0,5 | HP<=1 | HP<=1,5 | HP<=2 | HP>2 | DT-HP | VP<=0,5 | VP<=1 | VP<=1,5 | VP<=2 | VP>2 | VP>3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.54 | * | 0.6 | * | * | * | 3.94 | * | 0.90 | * | * | * | * |
| 2 | 0.59 | * | * | * | * | 2.5 | -1.91 | * | * | * | * | * | 3.50 |
| 3 | 2.32 | * | 0.8 | * | * | * | 1.52 | * | * | 1.30 | * | * | * |
| 4 | 0.30 | * | * | * | 1.7 | * | -1.40 | * | * | * | * | 2.60 | * |
| 5 | 1.10 | * | 0.8 | * | * | * | 0.30 | * | * | 1.20 | * | * | * |
| 6 | 0.07 | * | 0.8 | * | * | * | -0.73 | * | * | 1.20 | * | * | * |
| 7 | 9.08 | * | 0.8 | * | * | * | 8.28 | * | * | 1.30 | * | * | * |
| 8 | 9.20 | * | 0.9 | * | * | * | 8.30 | * | * | 1.50 | * | * | * |
| 9 | 1.63 | * | 0.7 | * | * | * | 0.93 | * | * | 1.20 | * | * | * |
| 10 | 0.51 | * | 0.7 | * | * | * | -0.19 | * | * | 1.10 | * | * | * |
| 11 | 1.97 | * | 0.7 | * | * | * | 1.27 | * | * | 1.40 | * | * | * |
| 12 | 6.04 | * | * | 1.1 | * | * | 4.94 | * | * | * | * | 2.20 | * |
| 13 | 25.85 | * | 0.7 | * | * | * | 25.15 | * | * | * | 1.70 | * | * |
| 14 | 15.13 | * | 0.8 | * | * | * | 14.33 | * | * | * | 1.90 | * | * |
| 15 | 4.21 | * | 0.8 | * | * | * | 3.41 | * | * | * | 1.70 | * | * |
| 16 | 3.84 | * | 0.8 | * | * | * | 3.04 | * | * | * | 1.90 | * | * |
| 17 | 0.38 | * | 0.9 | * | * | * | -0.52 | * | * | * | * | * | 3.40 |
| 18 | 3.46 | * | 0.7 | * | * | * | 2.76 | * | * | * | * | 3.00 | * |
| 19 | 2.32 | * | 0.6 | * | * | * | 1.72 | * | * | * | 1.80 | * | * |
| 20 | 1.22 | * | 1 | * | * | * | 0.22 | * | * | * | * | 2.50 | * |
| 21 | 1.73 | * | 0.8 | * | * | * | 0.93 | * | * | * | * | 2.40 | * |
| 22 | 5.99 | * | * | 1.2 | * | * | 4.79 | * | * | * | * | * | 4.60 |
| 23 | 4.97 | * | 0.7 | * | * | * | 4.27 | * | * | * | * | 2.20 | * |
| 24 | 3.65 | * | * | * | 1.7 | * | 1.95 | * | * | * | * | * | 4.40 |
| 25 | 0.39 | * | 0.8 | * | * | * | -0.41 | * | * | * | * | 2.70 | * |
| 26 | 0.62 | * | 0.6 | * | * | * | 0.02 | * | * | * | * | 2.60 | * |
| 27 | 2.28 | * | 0.6 | * | * | * | 1.68 | * | * | * | * | 2.80 | * |
| 28 | 0.47 | * | 0.6 | * | * | * | -0.13 | * | * | * | * | 2.80 | * |
| 29 | 5.29 | * | 0.9 | * | * | * | 4.39 | * | * | * | * | * | 3.70 |
| 30 | 1.56 | * | 1 | * | * | * | 0.56 | * | * | * | * | * | 4.00 |
| 31 | 1.97 | * | 0.8 | * | * | * | 1.17 | * | * | * | * | * | 3.50 |
| 32 | 5.09 | * | 1 | * | * | * | 4.09 | * | * | * | * | * | 3.50 |
| 33 | 2.44 | * | 0.9 | * | * | * | 1.54 | * | * | * | * | * | 3.30 |
| 34 | 2.19 | * | 1 | * | * | * | 1.19 | * | * | * | * | * | 3.50 |
| 35 | 0.95 | * | 0.8 | * | * | * | 0.15 | * | * | * | * | 2.90 | * |

Figure 3. Processed database

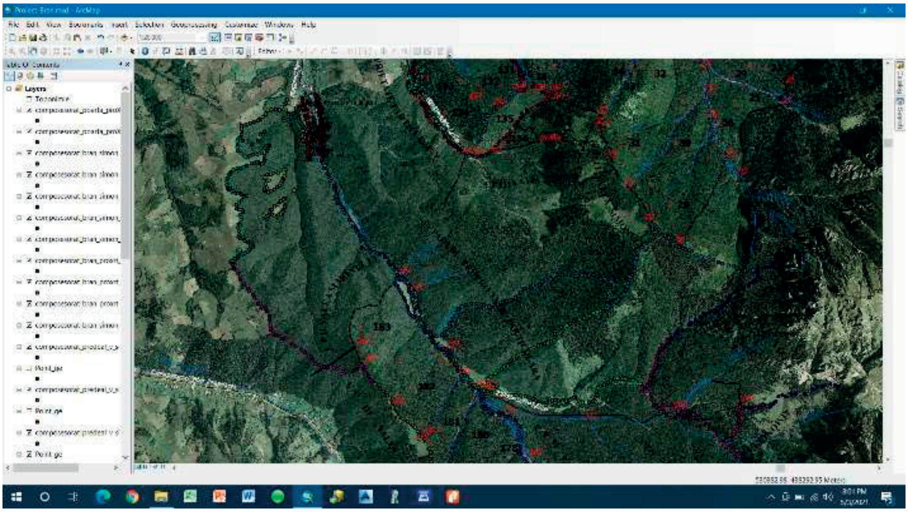

Figure 4. Identification of parcels with boundaries both measured and vectored

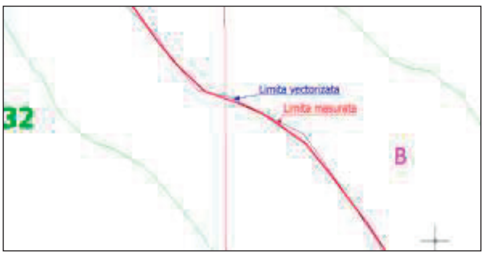


Figure 5. Determining differences in AutoCAD

The second method used involved a VBA code sequence created in ArcGIS to aid in the determination between two arcs. This script also labelled the calculated differences (Figure 6).

In addition, this method also quantifies the areas on both sides of the witness arc and also presents a final result through the summation of the two sides, with their respective signs. Several situations were summarily analyse. In each case, the problem of the deviations between vectorised and measured boundaries was analysed and also the influence these have on the calculation of the global area.

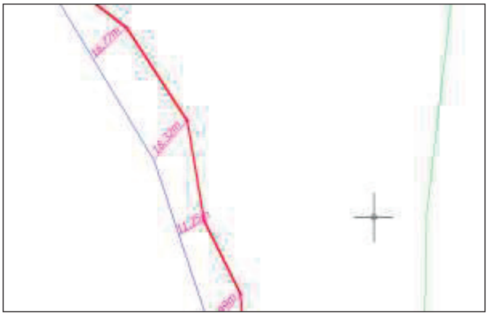

Figure 6. Automatic determination of differences in ArcGIS

In the first case, related to a forest parcel with an area of 115.98 hectares, a mean deviation of 0.98 m between the measured and vectorised boundary was recorded along with a 2.6% difference in terms of area. In the second case, related to a forest parcel with an area of 89.45 hectares, a deviation of 1.12 m between the measured and vectorised boundary was identified and an area difference of 2.8%. Finally, in the third case of a forest parcel with an area of 158.38 ha, a deviation of 0.89 m was recorded and an area difference of 2.5%.

## CONCLUSIONS

The problem of correct estimations of forest parcel areas is very important, as on it depend the calculations relating to the harvestable wood quantity (Leahu, 2001). In this paper, a comparison of forest areas as determined through vectorisation of cadastral plans with forest boundaries and through direct measurements using GPS equipment was carried out. Even if the coordinate precision of points located inside the forested areas is not very high (Teresneu et al., 2014), in the sense that millimetre or centimetre-precisions are not achievable, like in the case of the agriculture sector or in residential areas, still a pertinent comparison between the two methods was realised.

The conclusion of this study is that between the two methods there are no significantly large differences, all of them being in the 2.5-2.8% range.

Taking into account the fact that available data was collected exclusively in the mountainous area and only covered an area of a few hundred hectares, the studied problem deserved to be further analysed on larger areas. It is interesting to note that, although individual differences between vectorised and measured boundary are occasionally very large (up to 70-80 m), when their mean is calculated the obtained values are relatively small, hovering around 1 m.

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