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THE INFLUENCE OF OROGRAPHIC AND TREE STAND FACTORS ON THE PRECISION OF PLANIMETRIC COORDINATES DETERMINED USING GPS EQUIPMENT IN A FOREST ENVIRONMENT

Cornel C. TEREŞNEU[1] **Maria M. VASILESCU**[1]

Abstract: *This paper reports the findings of a study concerning the statistical analysis of the precision for planimetric coordinates determined using a GPS equipment in a forest environment. A forest area of over 9500 ha was surveyed, located in the area of the Barsa River, close to the Zărnești town. More than 14000 point coordinates were determined. The measurements were carried out with two GPS receivers: Trimble Pro XH and Pro XT, using the Stop&Gomethod with post-processing. Data regarding the field collected coordinates were grouped according to: composition, age and consistency of tree stands, terrain shape, and aspect. This stratified data was processed using the Statistica software. Coordinate precision was analysed by taking into consideration each criteria individually, as well as in combinations of 2 factors (which resulted in 25 combinations), 3 factors (145 combinations), 4 factors (142 combinations) and 5 factors (103 combinations). Looking at the arithmetic means, the best situation is for spruce stand with an age of 101-120 years and the worst situation is for the spruce stands located on northern slopes. Regarding orography, the fact that the lowest precision is found in valleys was highlighted. Stand age also has a significant influence in the analysis of the precision factor, with the young and dense tree stands having the lowest precision. Regarding aspect, research shows that the most favourable situation is for the NE-SV aspect, while the least favourable is for the NS aspect.*

Key words: *forest, GIS, GPS, statistical indice.*

1. Introduction

Forest surveying has always been difficult. Even if the precision required in these situations is not as high as in the case of built-up areas, solutions for accurate measurements are still sought. Difficulties arise especially in the case of retrocession of forest parcels, as their boundaries often do not align with natural

[1] Faculty of Silviculture and forest engineering, *Transilvania* University of Brasov, Șirul Beethoven no. 1, Brasov 500123, Romania;
Correspondence: Maria M. Vasilescu; email: vasilescumm@unitbv.ro.

boundaries [9]. Therefore, in these cases a number of factor have a negative influence upon the accuracy of coordinate calculations. Some examples of such influences are: the time difference between the satellite and the receiver clock [5], landform [8-9], the shape and consistency of tree stands [4, 14-15]. This last effect is much more pronounced if measurement is made during winter, if the canopy is covered with a thick layer of snow [3]. However, it has to be mentioned that significant progress has been made to diminish the effect of canopy and that, because of the evolution of GPS receivers, measurement of acceptable precision have been made even with Garmin-type receivers [7]. Another difficulty for Global Navigation Satellite System (GNSS) measurements in forests is the number of visible satellites [13], which in most cases does not satisfy the required accuracies. Another influence which has to be considered is that of the vegetative season during which the survey is carried out [2, 6]. It is well known that in deciduous stands the most favorable time for surveying is in leaf-off conditions.

Research was carried out in the upper Bârsa River area, close to the town of Zărneşti (Figure 1). Approximate coordinates of the research site are 45^{0}34’ şi 25^{0}16’. More than 9500 ha of forest area were surveying, with over 14,000 point coordinates determined. For this paper the precision for the spruce stands is analyzed.

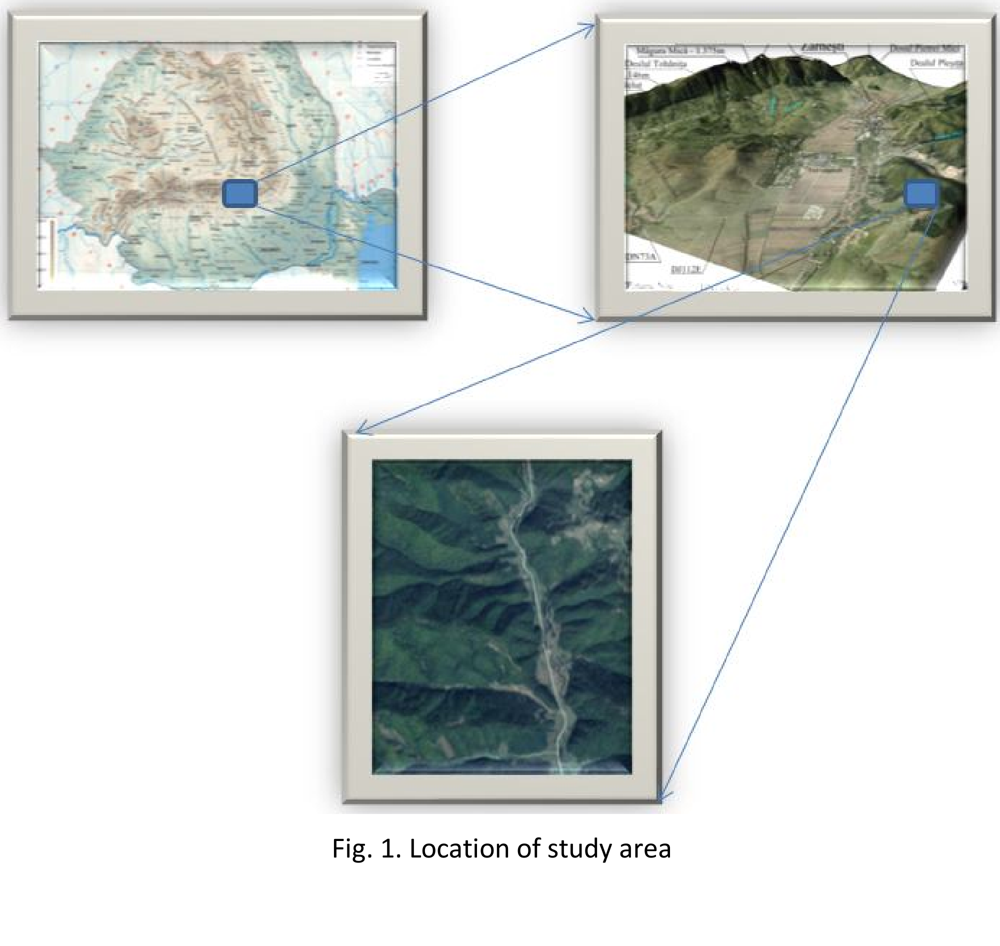

Fig. 1. Location of study area

2. Material and Methods

To carry out measurement in spruce stands in the studied area, photogrammetric methods could potentially be used [11-12], but for now these are cost-prohibitive [1]. Therefore, the only viable alternative is that of using GNSS equipment. Two double-frequency *Trimble ProXT*and *Trimble ProXH*GPS receivers were used to determine point coordinates. In addition, base cadastral plans of the area (1:5000 scale, with silvic boundaries), orto-rectified images obtained from flights carried out in 2012 and all data regarding orographic and tree stand conditions were used.

Regarding the research methods, mainly the direct measurement with the semi-kinematic "*Stop&Go*" method was used. Data from GPS receivers was downloaded and processed using the *Trimble GPS Pathfinder Office* software. Post-processing of this data involved corrections received from the permanent stations of Top GEOCART Brasov. Even if the distance between this permanent station and the research site was adequate, to ensure a high precision a number of points located near the surveyed forest were surveyed using the static method with base receivers. Rovers received signals not only from the aforementioned base station, but also from the points determined earlier. Later, data was imported in the Geographical Information System (GIS) project of the area [10]. To analyze field data in accordance with orographic and tree stand conditions, correlation between these data sources had to be obtained. To this end, the polygons relating to silvic parcels and subparcels were exploded into lines that were homogenous regarding the studied characteristic. The following characteristic were considered: landform, aspect, tree stand composition, tree stand consistency, tree stand age. Point precision was determined by analyzing combinations of:

- Two criteria (composition-landform, composition-consistency, composition-age, composition-aspect): 25 combinations;
- Three criteria (composition-landform-consistency, composition-landform-age, composition-landform-aspect, composition-consistency-age, composition-consistency-aspect, composition-age-aspect): 145 combinations;
- Four criteria (composition-landform-consistency-age, composition-landform-consistency-aspect, composition-landform-age-aspect): 142 combinations;
- Five criteria (composition-landform-consistency-age-aspect): 102 combinations.

3. Results

For an objective analysis, experimental data was graphically represented by the distribution of cumulated relative frequencies (%) by categories (Figure 2). Al distributions are exponential, with obvious differences between the analyzed combinations. The following statistical indices were used: minimum, maximum, mean, mode, standard error, frequency, standard deviation, coefficient of variation.

Figure 2 shows that the best precision is obtained for point located on, while the weakest precision if for points in valleys.

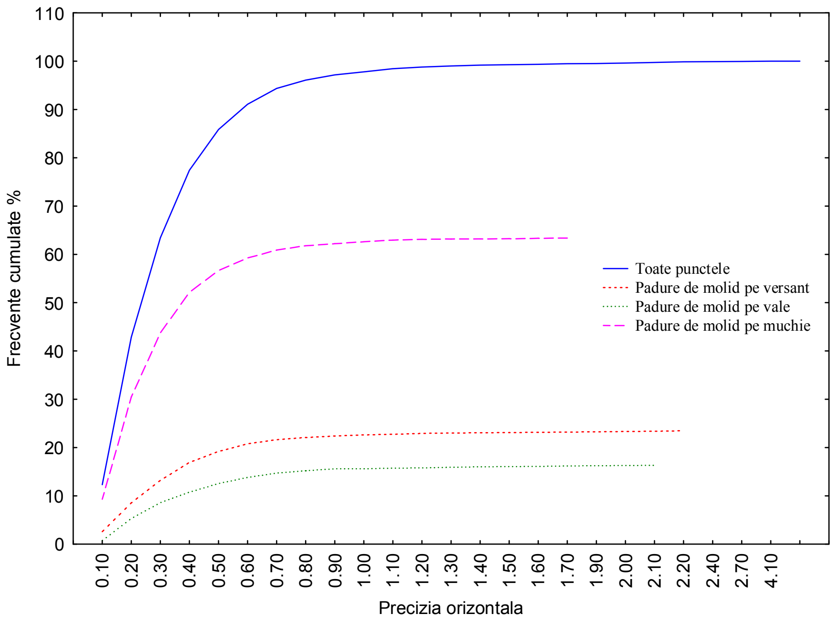

Fig. 2. Cumulative relative frequencies distribution

Analysis of the frequency for various horizontal precisions leads to the following statements:

- For two-factor analysis: the highest frequency is for points having a horizontal precision of 0,316m (16%), while the lowest frequency is for points with a horizontal precision of 0,402 (0,5%);
- For three-factor analysis: the highest frequency is for points with an average horizontal precision of 0,315m (5%), while the lowest frequency is for points with a horizontal precision of 0,367m (a single point);
- For four-factor analysis: the highest frequency is for point with a horizontal precision of 0,3m (56%), while the lowest frequency is for points with a coordinate precision of 0,8m (two points);
- For five-factor analysis: the highest frequency is for points with a horizontal precision of 0,3m (45%), while the lowest frequency is for points with a horizontal precision of 0,7m (4 points).

Further analysis of the variation of horizontal precision as highlighted by the arithmetic mean shows the following:

- For two-factor analysis: the best arithmetic mean is recorded in the case of spruce stand with an age of 101-120 years (0,25m), and the worst situation is for spruce stand on northern slopes;
- For three-factor analysis: the most favorable conditions are for spruce stands with an age of 61-80 years and a western aspect, the mean having a value of 0,117m. The weakest precision is associated with spruce stands with an age of 21-40 years and eastern aspect, it having a value of 0,70m;
- For four-factor analysis: the best precision has a value of 0,10m and is recorded in multiple situations: spruce stands located on ridges, with a

consistency up to 0.6 and a NV-SE aspect; spruce stands located on ridges, with a consistency up to 0.6 and an age of 101-120 years; spruce stands located on ridges, an age of 1-20 years and NE-SV aspect; spruce stands located on ridges, with an age of 101-120 years and an E-V aspect; spruce stands located on ridges with an age of 101-120 years and an N-S aspect, spruce stands located on slopes with an age of 61-80 years and an V aspect; the worst value for the arithmetic mean is recorded for spruce stands located in valleys, with an age of 41-60 years and a N-S aspect;

- For five-factor analysis: the best value for the arithmetic mean is also 0,10m and is also recorded in multiple situations: spruce stands located on ridges, with a consistency up to 0.6, an age of 101-120 years and a NE-SV aspect; spruce stands located on ridges, with a consistency of 0.7-0.8, an age of 1-20 years and a NE-SV aspect; spruce stands located on ridges, with a consistency of 0.7-0.8, an age of 101-120 years and a N-S aspect; spruce stands located on ridges, with a consistency of 0.9-1.0, an age of 1-20 years and a NE-SV aspect; spruce stands located on ridges, with a consistency of 0.9-1.0, an age of 101-120 years and an E-V aspect; spruce stands located on slopes, with a consistency of 0.9-1.0, an age of 81-100 years and a V aspect; the worst value for arithmetic mean in this case is for spruce stands located in valleys, with a consistency of 0.7-0.8, an age of 81-100 years and a NE-SV aspect.

There are cases where the standard deviation has a higher value than the arithmetic mean. This situation leads to cases where the coefficient of variation is above 100%. Such cases are recorded for: spruce stands with a consistency up to 0.6 on northern slopes; spruce stands with a consistency of 0.7-0.8 and a S aspect; spruce stands with a consistency of 0.9-1.0 and a S-V aspect, spruce stands with a consistency up to 0.6 and an age of 121-140; spruce stands with a consistency of 0.7-0.8 and an age of 41-60 years and a NE-SV aspect; spruce stand located on valleys with a N-S aspect; spruce stands on S-V slopes; spruce stands on valleys with an age of 41-60 years; spruce stands on slopes, with an age of 21-40 years; spruce stands on slopes, with an age of 121-140 years; spruce stands with an age of 61-80 years and an E aspect; spruce stands with an age of 121-140 years and a N aspect;

4. Discussion

Global analysis of experimental data for spruce stands leads to a number of conclusions:

- Orography has a strong influence of the horizontal precision for point coordinates, with the most favorable condition associated mainly with high landforms, and the lowest precisions recorded in the case of valleys;
- Aspect has a significant influence on the studied indicator. Although numerous variants for aspect have been taken into consideration (12, specifically), a grouping of these into two main categories was observed: one favorable for satellite motion and one disfavorable for it. In the first category point coordinates precision is always higher compared to points in the second category;
- Stand age does not seem to have a strong influence on horizontal precision for point coordinates, as one might tend to believe. A very good precision is

noticed for young stand, which do influence satellite signals with their height or do not produce the multipath effect, after which precision drops pretty sharply for stands with an age of 21-40 years. Then a certain consistency of precision is noted, up to the age of 80 years. After this, precision again begins to increase. The fact that differences between precision are relatively low is mentioned (the difference between the maximum and minimum value is 34%);

- Consistency has a certain influence on horizontal precision of point precision only when trees are sufficiently sparse (consistency index of less than 0.6). When this index has values above 0.7, precisions are relative close (for both the precision class of 0.7-0.8 or 0.9-1.0);
- Analysis of two factors at once for spruce stands lead to the following: the most favorable situation is for stand with an age of 61-80 years that are located on western aspects, while the least favorable situation is for spruce stands with an age of 21-40 years and a northern aspect; the favorable situation is explained by the fact that thinning operations have begun and satellite signal is therefore less affected by tree stand density, while the expositions is favorable to the satellite motion tracks; the unfavorable situation is somewhat expected due to the fact that the stand is very dense and furthermore, is located on an exposition unfavorable to satellite motion;
- Analysis of three factors at once for spruce stands shows that the best horizontal precision for point coordinates is recorded for: spruce stands located on ridges, with a consistency of up to 0.6 and an E-V aspect; spruce stands located on ridges, with a consistency of up to 0.6 and an age of 101-120 years; spruce stands located on ridges, with an age of 1-20 years and an E-V aspect; spruce stands located on ridges, with an age of 101-120 years and an E-V aspect; spruce stands located on ridges, with an age of 101-120 years and a N-S aspect; spruce stands located on slopes, with an age of 61-80 years and a V aspect. The worst precision is for spruce stands located on valleys, with an age of 41-60 years and a N-S aspect; the explanation for the most favorable conditions is in fact a combination of the favorable individual factors explained above – where tree stands are young or sufficiently mature (and the satellite signal is less affected), or the presence of high landforms and expositions that correlate with the satellite motion tracks; regarding the opposite situations, of tree stands with low precisions – this is mainly due to the unfavorable landforms, with tree stands age and exposition perpendicular to the satellite motion tracks further adding to the effect;
- Finally, analysis of 4 factors that have a simultaneous effect on the horizontal precision of point coordinates in spruce stands shows that the most favorable situations are: spruce stands located on ridges, with a consistency of up to 0.6, an age of 101-120 years and an E-V aspect; spruce stands located on ridges, with a consistency of 0.7-0.8, an age of 1-20 years and an E-V aspect; spruce stands located on ridges, with a consistency of 0.7-0.8, an age of 101-120 years and a N-S aspect; spruce stands located on ridges, with a consistency of 0.9-1.0, an age of 101-120 years and an E-V aspect; spruce stands located on slopes, with a consistency of 0.9-1.0, an

age of 81-100 years and a V aspect. In this case, the worst precision is recorded for spruce stands located on valleys, with a consistency of 0.7-0.8, an age of 41-60 years and a N-S aspect; In this case also, it is noticed that the best results are influenced by a high landform (edge), low consistency, old or very young age that does not block satellite signals and an exposition favorable to satellite motion tracks; to the opposite side are tree stands located in valleys, where the satellite signal is very weak (or even missing), with average ages and consistency and an exposition perpendicular to the satellite motion tracks.

5. Conclusions

Regarding the global precision for the points surveyed during this research, it is noticed that it is a good or even very good one. If data is grouped into precision classes of 25 cm, it is noticed that the highest weight is for points whose precision has a center-class value of 0,175m (62%).

By analyzing the factors that influence the horizontal precision of point coordinates in forests it can be said that each of these factors has a certain influence. If we were to establish a hierarchy of these factors by influence, it would be this: landforms (with the best results on high landforms and the worst results on valleys), aspects (with the best results for aspects favorable to satellite motion and the worst results on aspects perpendicular to the previous ones), tree stand consistency (with very good precisions for consistencies up 0.6 and a certain sameness for the other two studied categories), tree stand age (with the best results for young stands where tree height does not influence satellite signals and in mature stands where regenerative cuts were applied, and the worst results in tree stands with an age class of 2-4 and very high densities).

Regarding the combined influence of these factors, it is shown that the least favorable situation is recorded for tree stands located on valleys, with a N-S aspect, a consistency of 0.9-1.0 and an age of 21-40 years, while the best precision is recorded for spruce stands located on ridges, with an E-V aspect, a consistency lower than 0.8 and an age either above 100 years or below 20 years.

References

1. Boș, N., 2011. Geomatica și realizarea bazei cartografice a fondului forestier din România. In: Revista Pădurilor, vol. 6, pp. 27-36.
2. Dogan, U., Uludag, M., Demir, D.O., 2014. Investigation of GPS positioning accuracy during the seasonal variation. In: Measurement, vol. 53, pp. 91-100.
3. Janez, G., Adrados, C., Joachim, J. et al., 2004. Performance of differential GPS collars in temperate mountain forest. In: Comptes Rendus Biologies, vol. 327(12), pp. 1143-1149.
4. Ordonez Galan, C., Rodriguez Perez, J.R., Garcia Cortez, S. et al., 2013. Analysis of the influence of forestry environments on the accuracy of GPS measurements by means of recurrent neural networks. In: Mathematical and Computer Modelling, vol. 57(7-8), pp. 2016-2023.
5. Păunescu, C., Dimitriu, S.G., Mocan, V., 2012. Sistemul de determinare a poziţiei utilizând sateliţi (GNSS).

Bucharest University Publishing House, Bucharest, Romania.
6. Sawaguchi, I., Nishida, K., Shishiuchi, M. et al., 2003. Positioning precision and sampling number of DGPS under forest canopies. In: Journal of Forest Research, vol. 8, pp. 133-137.
7. Taczanowska, K., Gonzales, L.M., Garcia-Masso, X. et al., 2014. Evaluating the structure and use of hiking trails in recreational areas using a mixed GPS tracking and graph theory approach. In: Applied Geography, vol. 55, pp. 184-192.
8. Tereşneu, C.C., 2011. Some aspects of accuracy of determining the coordinates points in forestry. In: Studia Universitatis “Vasile Goldiş” Arad, Engineering and Agro-Tourism Series, vol. 6(2), pp. 7-10.
9. Tereşneu, C.C., Vasilescu, M.M., Hanganu, H. et al., 2011. Analiză GIS privind implicaţiile redeterminării poziţiei bornelor silvice. In: Geodezie – present şi viitor, vol. 1, pp. 355-364.
10. Tereşneu, C.C., Vorovencii, If., Vasilescu, M.M., 2014. Statistical study on the accuracy of determining points coordinates in mountain forests from Bran-Brasov, Romania. In: Proceeding of the 14th SGEM Geoconference on Informatics, Geoinformatics and Remote Sensing, vol. 3, pp. 893-900.
11. Vorovencii, If., 2014a. A change vector analysis technique for monitoring land cover changes in Copsa Mica, Romania, in the period 1985-2011. In: Environmental Monitoring and Assessment, vol. 186(9), pp. 5951-5968.
12. Vorovencii, If., 2014b. Detection on environmental changes due to windhrows using Landsat 7 ETM+ satellite images. In: Environmental Engineering and Management Journal, vol. 13(3), pp. 565-576.
13. Wang, H., Zhan, X., Zhang, Y., 2008. Geometric dilution of precision for GPS single-point positioning based on four satellites. In: Journal of Systems Engineering and Electronics, vol. 19(5), pp. 1058-1063.
14. Weilin, L., Buo, X., Yu, L., 2000. Applications of RS, GPS and GIS to Forest Management in China. In: Journal of Forestry Research, vol. 11, pp. 69-71.
15. Zhang, H., Zheng, J., Dorr, G. et al., 2014. Testing of GPS Accuracy for Precision Forestry Applications. In: Arabian Journal for Science and Engineering, vol. 39(1), pp. 237-245.