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Reliability Check of Positioning Accuracy Under The Canopy of Broadleaf Deciduous Forest (Broadleaf Oak-Quercus Conferta)Using Network-Based Rtk Techniques

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ABSTRACT

The creation of Permanent Reference Stations and the implementation of network positioning techniques can significantly improve the accuracy in positioning in forest and forest area.The HEPOS System (HEllenicPOsitioning System)is the first Network of Permanent GPS Reference Stations that developed in Greece. The system provides high accuracy satellite-based positioning services. The aim of the paper is to investigate the positioning accuracyunder the canopy of broadleaf deciduous forest(Quercusconferta)in accordance with different growth seasons(with and without leaves).So two measurement testing courses were established: during the summerwhen the tress had leaves and during the springwhen the trees had no leaves.TheGPS receiver Leica GS09 GNSS and the Total Station LEICA TRC 407 (for true values) are used.Real Time Kinematic positioning (RTK)are applied by using theHEPOS. Four RTK GPS techniques: the VRS, the MAC, the Single-Base and the Network-based DGPS technique were implemented.

KEYWORDS : Permanent reference GPS station networks, VRS, MAC, Singe Base, DGPS

INTRODUCTION

Demands for higher accuracy in positioning are increased year by year.In order to cope with this requirements, a lot of countries have been installed and operate networks of permanent reference stations. Also techniques of exploitation of GNSS satellite data, with the primary purpose of improving the positioning accuracy of these systems in real-time applications andto minimize the effects of the errors of GNSS systems,were developed and applied. These techniquesare known as RTK networking techniques andhelps significantly to increase the accuracy in positioning mainly in real time. Such techniques are: the Virtual Reference Stations-VRS, the Area correction parameters-FKP (FlachenKorrektur Parameter) and the technical Master-Auxiliary Concept (MAC)-Main and auxiliary stations.

The high accuracy positioning in forest environments is an extremely difficult case.Many factors can cause errors in position calculation in the forest. Such factors are: the ionosphere and the troposphere delays, the multipath propagation of GPS signals (Hofmann – Wellenhof et al, 2008, Scott D. Danskin et al, 2006, Burlet, 2001), the tree canopies that block satellite signals (Zheng et all, 2005,), the canopy type, the presence of the foliage. The lower PDOP value (Stjernberg, 1997, Sigrist et al, 1999, Karsky et al., 2000, Mancebo and Chamberlain 2001, P. Holden et al, 2001, Piedallu and Gégout, 2005, Ch. Argiropoulouand Doucas, 2015a, Ch. Argiropoulouand Doucas, 2015b, Deckert and Bolstad, 1996), the topography (Liu and Brantigan 1996, Burlet, 2001, Ch. Argiropoulouand Doucas, 2015b,) and the GPS receiver type and quality (Darche, 1998, Wing et all, 2005) are also some of the main factors that influence the accuracy of GPS positions.

The creation of Permanent Reference Stations and the implementation of network positioning techniques can also significantly improve the accuracy in positioning in difficult environments as are the forestal ones.

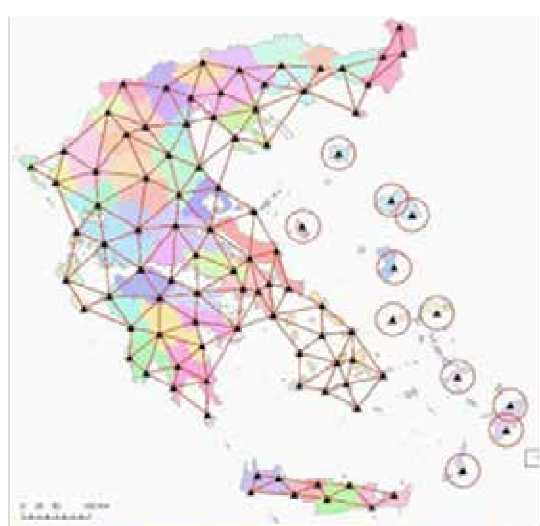
Following the example of this development, the HEPOS (HEllenicPOsitioning System) system was created in Greece by Ktimatologio SA, a state-owned private sector company that is in charge of establishing the Hellenic cadastre. HEPOS is a system that provides high-accuracy satellite-based real-time positioning services using the Global Positioning System (GPS) and constitutes the first Greek Network of Permanent GPS Reference Stations.

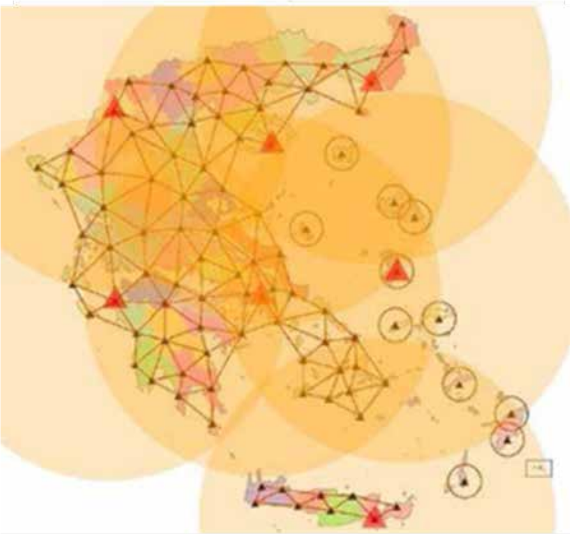
HEPOS consists of 98 permanent reference stations (RS) distributed all over Greece. The reference stations transmit their measurements to a control center, which is situated at the headquarters of Ktimatologio SA in Athens. The user connects to the control center to get the required data in real time via GPRS or GSMmodemfor real-rime (RT) either via the web server or post-processing applications (Gianniou and Mastoris, 2006, Gianniou, 2008).

The 87 of 98 reference stations are networked stations, located in the mainland and used for network solution (VRS, FKP & MAC techniques) and the 11 are single reference stations, sited on the islands of Eastern Aegean Sea and used only for single base solution. There are also 7 reference stations used for Single-Base DGPS solution (Figure 1).

HEPOS supports all real-time GPS techniques as well as all standard data formats. Depending on accuracy requirements, the user can select DGPS or RTK, achieving sub-metre or centimetre-level accuracy respectively. Furthermore, depending on the capabilities of the equipment, the user can choose between network-solution or conventional single-base GPS-surveying.

Fig. 1, The 98 permanent reference stations of HEPOS and the 7 permanent reference stations for Single-Base DGPS solution





Sources: www.hepos.gr

When the network techniques are used the HEPOS system provides usually higher accuracy. Using the real-time services of HEPOS and the RTK techniques a user can achieve cm-level accuracy by measuring at an unknown point for a few seconds only. On the other hand using the DGPS technique the accuracy in positioning is better than meter (sub-meter accuracy), while when using the HEPOS system can reach up to 0.20 meter depending on the user equipment (www.hepos.gr, accessed May 27, 2015).

The aim of the paper is to investigate the positioning accuracy under the canopy of broadleaf deciduous forest (Quercusconferta) in accordance with different growth seasons (with and without leaves) and also to evaluate the reliability of the HEPOS system.

STUDY METHODS

Material and Methods

To achieve the above described aim two measurement testing courses were established in the study area: first during the summer when the trees had leaves and second during the spring when the trees had no leaves.HEPOS system was used and an implementation of four Real Time (RTK) GPS techniques took place: the Network-based technique with Virtual Reference Stations (VRS), the Network-based technique Master-Auxiliary Concept (MAC), the Single-Base RTK technique and the Network DGPS technique.

The surveying instruments that used for the study were: a) the Total Station LEICA TRC 407 whose measurements are taken as "true values", b) the GPS receiver Leica GS09_GNSS which functions impeccably with the network of permanent Reference stations of HEPOS and c) the reflector 360°(Figure 2).

The results were obtained by comparing the measurements of points as recorded by the GPS receiver Leica GS09 GNSS with the measurements of points as recorded by the total station Leica TCR 407.

The measurements took place at the end of August with beginnings of September 2012 (trees with leaves) and at the end of March with beginnings of April 2014 (trees without leaves).The data logged in real-time. The measurement GPS time at each point was 2 minutes and were made every 1 second. The cut-off angle of the satellite signals was 15 degrees and the height of the antenna pole was 2.00 m.The measurement units were meters.

At the summer the coordinates of a hundred points were determined. 500 observations were capture using the Total Station and the GPS receiver with the implementation of the four Real Time (RTK) GPS techniques.

Work were carried out with the following sequence: the points was determinate simultaneously with total station and GPS by using the technique of DGPS. This was possible due to the use of a special reflector 360° (Figure 2). The reflector brought two receptions: under of its main body for the adaptation of the antenna pole and above of its main body for the adjusting the antenna of GPS. Then followed the determination of the coordinates of the same points with the other three techniques that mentioned above.

At the spring, the points that were determined was fewer. That was because at the area were carried out forest road passing place works and tree cutting works. So in that second visit to the area were identified forty seven of the hundred points and finally the coordinates of these points were determined. 235 observations were capture. Therefore the final number of points that included at the research and involved in errors calculation they were forty seven and no hundred.

It must be noted that the GPS antenna pole always placed near to the trunk of the trees and not at the edge of the trees canopy. The aim was to increase the degree surveying difficulty.

Fig. 2, Reflector 360° on GPS receiver

Much attention was given a) to the values of the Position Dilution of Precision (PDOP) b) to the number of satellites obtained during the positioning and used to calculate the position of each one point and c) to the determination of ambiguity. These data were recorded during the execution of the field measurements and studied thoroughly during the treatment.

A good estimator of the impact of forest canopy on GPS positional fixes is the root mean-square-error (RMSE) because it depicts the deviation from the truth and not from the mean as is the case with the standard deviation (Sigrist et al, 1999). The (root) mean-square-error of measurements is a common measure of accuracy (Mikhail & Gracie, 1981). So to draw conclusions about the accuracy obtained with HEPOS system and to compute the deviation from the true value, the root mean-square-error (RMSE) and the positional accuracy error ($RMSE_{EN}$) are calculated. RMSE were therefore computed for all fixes.

The root mean square error (RMSE) measuring the distance between the GPS coordinates and total station coordinates. The root mean-square-error (RMSE) of the E (East) component is given by the expression (1):

$$RMSE_E = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(E_i - e_i)^2} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_E)^2} \quad (1)$$

where Ei are the total station coordinates, ei are the GPS coordinates and n are the total number of measurements.

The root mean-square-error (RMSE) of the N (North) component is given by the following expression (2):

$$RMSE_N = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(N_i - n_i)^2} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_N)^2} \quad (2)$$

The root mean-square-error (RMSE) of the H (Height) is given by the expression (3):

$$RMSE_H = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(H_i - h_i)^2} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_H)^2} \quad (3)$$

where Ei, Ni and Hi are the total station coordinates, ei, ni and hi are the GPS coordinates and n are the total number of measurements.

The positional accuracy error defined by the mean square error ($RMSE_{EN}$) of the coordinates (e, n) measured by GPS and controlled by the total station measurements (Ktimatologio SA, 2007). It is given by the expression (4):

$$RMSE_{EN} = \sqrt{\frac{(U_E^2 + U_N^2)}{n}} \quad (4)$$

where U_E is equal with (Ei- ei), U_N equal with (Ni-ni) and n are the total number of measurements.

Description of Study Area

The measurements were carried out in the National forest of Vertiskos Mountain, Macedonia, Northern Greece,manages from the Forest Service of NigritaSerres,(Figure 3).

The wider research area from a phytosociological point of view, according to the classification of forest vegetation of Greece by S. Dafis (1973), is part of the Submediterranean vegetation zone (Quercetaliapubescentis-Hilly, semi-mountainous and mountainous area with an altitude of 300-1000m). The zone is divided ecologically and floristically into two divisions: the subzone of the Hophornbeam and Hornbeam (Ostryo-Carpinion) and the subzone of the broadleaved Oaks (Quercionconfertae).The measurements were carried out in the subzone of the broadleaved Oaks (Quercionconfertae) at an altitude of about 900m.This type of vegetation covers one third of all Greek forests.

Fig. 3, Study Area

Vegetation Sampling Design

To assess the effects of vegetation and more specifically the effects of the foliage and the canopy of broadleaf deciduous forest (Quercusconferta) on GPS position accuracy, sampling was conducted to include measurements at the summer when the tress had leaves and also at the spring when the trees had no leaves. The forest consists of 34 stands and at the test the western boundary of the standsthat numbered as 26and 27 was determinate. It is a wooded area with main forest species of broad-leaved oak (Quercusconferta). The height of the trees was about 10-12 meters and the age of trees was 20-30 age years. The canopy density was about 70% -90% (Figure 4). A digital camera was used to record the canopy of each point. So, for each point two photos was taken. One when the trees had leaves (at the summer-figure 5) and one when the tress had no leaves (at the spring -figure6). A general view of the area is given in Figure 7.

Fig. 4, Overall view of the canopy density on the test course

Fig. 5, trees with leaves

Fig. 6, trees without leaves

Fig. 7, general view of the area

In a region that is diametrically opposite (part with light blue color on the figure 7) was impossible to use the internet. So there was no way to transfer data from HEPOS system. That's because probably the area was not covered by GPRS network. Another characteristic of that area is that a stream cross this. In that case the positioning became by the method of absolute positioning. So the permanent reference stations of HEPOS system was not used. The receiver was also operated as a single passive receiver. In that region five points were determined.

Owing to these points two tables with positioning errors were created: one in which in the errors calculation the five points included (47 points) and one in which they were not involved (42 points).

RESULTS

During the surveying the following results were observed per measurement testing course:

Measurements during the summer when the trees had leaves:

The number of observed GPS satellites throughout the duration of the study ranged from four to eight. Theavailable GPS satelliteswas nine.

The number of points in which the determination of ambiguity took place for the Single Base technique was 7, for the VRS technique was 4, and finally for the MAC technique was 6.

The PDOP indicator received:

Values<4 for the 53% of points at the implementation of the Single-Base technique, for the 68% of points at the implementation of the VRS technique, for the 87% of points at the implementation of the Network-based DGPS technique and for the 62% of points at the implementation of the MAC technique.

Values 4-6 for the 41% of points at the implementation of the Single-Base technique, for the 28% of points at the implementation of the VRS technique, for the 13% of points at the implementation of the Network-based DGPS technique and for the 38% of points at the implementation of the MAC technique.

Values 7-8 for the 4% of points at the implementation of the Single-Base technique, for the 2% of points at the implementation of the VRS technique, and for the 27% of points at the implementation of the MAC technique.

Values 9-11 for the 2% of points at the implementation of the Single-Base techniqueand at the implementation of the VRS technique.

Measurements during the spring when the trees had no leaves.

The number of observed GPS satellites throughout the duration of the study ranged from four to nine. The available GPS satellites was ten.

The number of points in which the determination of ambiguity took place for the Single Base technique was 13, for the VRS technique was 14, and finally for the MAC technique was 18.

The PDOP indicator received:

Values <4 for the 94% of points at the implementation of the Single-Base technique, for the 83% of points at the implementation of the VRS technique, for the 45% of points at the implementation of the Network-based DGPS technique and for the 85% of points at the implementation of the MAC technique.

Values 4-6 for the 6% of points at the implementation of the Single-Base technique, for the 15% of points at the implementation of the VRS technique, for 49% of points at the implementation of the Network-based DGPS technique and for the 11%of points at the implementation of the MAC technique.

Values 7-8 for the 4% of points at the implementation of the Network-based DGPS technique and for the 2%at the implementation of the MAC technique.

Values 9-11 for the 2% of points at the implementation of the Network-based DGPS technique and for the2%at the implementation MAC technique.

The station that provided the corrections at the application of Single Base technique was the 070A which is located at MitrousiSerres and in distance roughly 24.00 Km. That base (baseline) is considered small to moderate and does not affect dramatically in the reduction of accuracy.

As we mentioned in the previous paragraph (Vegetation Sampling Design) two tables were created: one which included the five points in the errors calculation and one without such participation. Below is presented the tables of results from each case of study and for all measurements that were performed.

TABLE – 1
ERRORS PER GPS RTK-TECHNIQUE AND VEGETATION-TYPE(WHEN QUERCUS CONFERTA -BROADLEAF OAK-HAD AND HAD NOT LEAVES) FOR THE TOTAL OF THE POINTS

RTK technique	Errors (meters)	Environment of measurement (Vegetation type)	
		Quercusconferta with leaves	Quercusconferta without leaves
SINGLE BASE	$RMSE_E$	0.725	0.686
	$RMSE_N$	1.166	0.609
	$RMSE_H$	5.766	5.169
	$RMSE_{EN}$	1.373	0.918
VRS	$RMSE_E$	1.030	0.686
	$RMSE_N$	1.189	0.547
	$RMSE_H$	4.819	4.812
	$RMSE_{EN}$	1.573	0.877
DGPS	$RMSE_E$	0.789	0.940
	$RMSE_N$	0.993	1.088
	$RMSE_H$	4.859	5.568
	$RMSE_{EN}$	1.269	1.438
MAC	$RMSE_E$	1.084	0.671
	$RMSE_N$	1.238	0.592
	$RMSE_H$	4.870	5.004
	$RMSE_{EN}$	1.645	0.895

TABLE – 2
ERRORS PER GPS RTK-TECHNIQUE AND VEGETATION TYPE(WHEN QUERCUS CONFERTA -BROADLEAF OAK-HAD AND HAD NOT LEAVES) WITHOUT THE INVOLVEMENT OF FIVE POINTS

RTK technique	Errors (meters)	Environment of measurement (Vegetation type)	
		Quercusconferta with leaves	Quercusconferta without leaves
SINGLE BASE	$RMSE_E$	0.724	0.584
	$RMSE_N$	1.145	0.615
	$RMSE_H$	5.945	5.315
	$RMSE_{EN}$	1.354	0.848
VRS	$RMSE_E$	1.027	0.621
	$RMSE_N$	1.038	0.552
	$RMSE_H$	4.889	4.945
	$RMSE_{EN}$	1.460	0.831
DGPS	$RMSE_E$	0.658	0.915
	$RMSE_N$	0.751	1.105
	$RMSE_H$	4.990	5.525
	$RMSE_{EN}$	0.999	1.434
MAC	$RMSE_E$	1.083	0.666
	$RMSE_N$	1.099	0.609
	$RMSE_H$	4.944	5.172
	$RMSE_{EN}$	1.543	0.902

CONCLUSIONS

The conclusions arising from the processing and the comparison of the results are:

The number of the observed GPS satellites, despite the difficult environment,such as forestallare, where the receivers are unable to obtain data from all satellites due to the canopy, was,equally to the two different growth seasons,very satisfying.

The ambiguities were difficult to determinate. We believe that this has happened because of the effect of multipath error and the reflected of signals on the surface of the trees.A prerequisite to the determination of ambiguity is the open sky and no impediment to the reception. When these prerequisites are satisfying, the determination of ambiguity is possible to materialize even with a marginal number of satellites.As we can conclude the canopy and more specifically the leaves reflects to the determination of the ambiguitiesremarkably. The number of points in which the determination of ambiguity take place, almost doubled up to tripled when the trees had no leaves.

Although, in the forest the minimum requirements for the geometry of the satellites are not satisfied, the values of the PDOP indicator was very satisfactory.

As becomes evident, from the data of the Tables, the positionalaccuracy error-$RMSE_{EN}$ almost doubled when the trees had leaves. This treaty applies to all techniques except the Network DGPS technique where the error is almost the same. So we can say that the canopy and the leaves effects dramatically in positioning accuracy.

The best results when the trees had leaves, consideration the positional accuracy, were presented, in order of priority, a) in the Network DGPStechnique, b) in the Single Base technique, c) in the VRS technique and finally in the MAC technique.

The best results when the trees had no leaves, consideration the positional accuracy, were presented, in order of priority, a) in the VRS technique, b) in the MAC technique, c) in the Single Base technique and finally in the Network DGPS technique.

The implementation of the Network DGPS technique of HEPOS system is easier than the implementation of the VRS, Single Base and MAC techniques (in difficult environments as are the forestal ones) because the measurements based on code and the determination of ambiguity it is not necessary. That makes the Network DGPS technique easier and more productive.

From the data of the tables it also became apparent that the participation or not of the five points in the calculation of errors is not differentiates dramatically the final result. In fact the differences identified in the 2nd and 3rd decimal place with very little difference between them. This of course is due and to the fact that the number of points relative to the total of these is small. It is characteristic, that in the case of positioning during the period in which the trees had leaves, the smallest difference is located with the Single Base technique and the greater with the DGPS technique. Correspondingly in season without leaves the two technical reverses their positions about differences.

Because the connection to the control center of HEPOS, for receive data in real time, becomes via GSM and GPRS, should essentially a study area to be covered by GPRS network. After that is recommended, before the beginning of work in forest environments, to be investigated, through the mobile operator, if the study area is covered by GPRS network. In the event negative report is not possible the reception of data and therefore the use of HEPOS system.

The HEPOS system can cope perfectly even in difficult surveying conditions and difficult surveying environments such as the forestall ones.

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REFERENCES

[1] ArgiropoulouChrysanthi, K-A Doucas (2015a), "The effect of the canopy of Scots pines (P. sylvestris) in positioning accuracy utilizing the Network of Permanent GPS reference stations of the HEllenicPOsitioning System (HEPOS)." International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-4, Issue-9, pp 1-8 | [2] ArgiropoulouChrysanthi, K-A Doucas (2015b), "Evaluation of reliability of HEllenicPOsitioning System (HEPOS) in forest and forest lands (area)." International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-4, Issue-12, pp 63-68 | [3] Burlet, E. (2001), "Global Positioning System." Grundlagen und AnwendungsmöglichkeitenimForstwesen. Lecture Notes, ETH Zürich. pp 6, 8, 9/39. | [4] Dafis, S. (1973), "Classification of forest vegetation of Greece. Ass. Tutor at the School of Agronomy-Forestry of Auth, vol. 15/2, pp. 75-91. | [5] Danskin S.D. and Pete Bettinger, Thomas R. Jordan (2006), "Assessing gps accuracy, waas, and a choke ring antenna solution in a southern hardwood forest". Proceedings of the 5th Southern Forestry and Natural Resources GIS Conference, Asheville, North Carolina, June 12-14, 2006. | [6] Darche, M.H., (1998),"A Comparison of Four New GPS Systems under Forestry Conditions." Forest Engineering Institute of Canada Special Report 128, Pointe Claire, Quebec, Canada. 16 p. | [7] Deckert C., Bolstad P.V. (1996), "Forest canopy, terrain, and distance effects on global positioning system point accuracy." Photogrammetric Enginnering& Remote sensing, Vol. 62, pp. 317-321. | [8] Gianniou M. (2008), "HEPOS and modern network GPS techniques", GIS GPS 2008: A supplement to Civil Engineering Surveyor, The Journal of the Civil Engineering Surveyors UK , 2008, p.p 4-7 | [9] Gianniou M. and D. Mastoris (2006), "Development of the Greek positioning system HEPOS", Fourth panhellenic conferenceHellasGIS, Athens, Greece. | [10] Hofmann – Wellenhof. B. &Lichtenegger, H. &Wasle, E. (2008), "GNSS: Global Navigation Satellite Systems – GPS, GLONASS, Galileo, and More." Springer, 516 p. | [11] Holden, N.M. & Martin, A.A. &Owende P.M.O. & Ward, S.M. (2001), "A Method For Relating GPS Performance To Forest Canopy." International Journal Of Forest Engineering, Vol. 12, no. 2: 7-12 pp. | [12] Karsky, D., Chamberlain, K., Mancebo, S., Patterson, D. and Jasumback, T. (2000), "Comparison of GPS Receivers under a Forest Canopy with Selective Availability Off." USDA Forest Service Project Report 7100. 21 p. | [13] Ktimatologio SA (2007). "Technical training requirements of forest maps", Athens, Greece. | [14] Liu, C.J., and Brantigan, R. (1996), "Using differential GPS for forest traverse surveys." Canadian Journal of Forestry Research 25, 1795-1805. | [15] Mancebo, S., and K. Chamberlain (2001), "Performance Testing of the Trimble Pathfinder Pro XR Global Positioning System Receiver." USDA Forest Service Technical Note. l0p. | [16] Mikhail, E. M. and Gracie, G. (1981), "Analysis and Adjustment of Survey Measurements". Van Nostrand Reinhold Company, New York: 340 pp. | [17] Piedallu, C. and Gégout, J.-C. (2005), "Effects of Forest Environment and Survey Protocol on GPS Accuracy." Photogrammetric Engineering & Remote Sensing Vol. 71, No. 9, September 2005, pp. 1071–1078. | [18] Sigrist, P. & Coppin, P. &Hermy. M. (1999), "Impact of forest canopy on quality and accuracy of GPS measurements." International Journal of Remote Sensing, vol. 20, issue (18), pp: 3595–3610. | [19] Stjernberg, E. (1997), "A Test of GPS Receivers in Old-growth Forest Stands on the Queen Charlotte Islands." Forest Engineering Institute of Canada Special Report 125, Vancouver, BC, Canada. 26 p. | [20] Wing, Michael G., Eklund, Aaron, Kellogg, Loren D., (2005),"Consumer-Grade Global Positioning System (GPS) Accuracy and Reliability". Journal of Forestry, Volume 103, Number 4, June 2005, pp. 169-173(5), Publisher: Society of American Foresters. | [21] www.hepos.gr, accessed May 27, (2015). | [22] Zheng J., Wang Y., Nihan N. (2005), "Quantitative Evaluation of GPS Performance under Forest Canopies." Proceedings of the 2005 IEEE International Conference on Networking, Sensing and Control, Tucson, pp. 777-782, IEEE. | | | |