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THE APPLICABILITY OF DIFFERENT GPS - TYPES WITH THE SURVEY OF FOREST ROAD NETWORKS IN GREECE

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Abstract: *The appropriateness of different GPS (manual GPS, two receivers - a frequency, two receivers – two frequencies) in a far range of application in connection with its costs led us more concretely to the research of its reliability within the Greek forest and to the examination of its suitability for the path survey. The measurements were accomplished in different months of the year 2006 under different forest conditions. To the statistic analysis the values of the geodetic station were taken as true values. One has the horizontal coordinates of the geodetic GPS - station for the calculation of the differences, compared with which Greek coordinates system analyzes and statistically. Finally the measurements accuracy with GPS in the reference to the forest area was calculated, the suitable results were brought and the relative suggestions for its forest application in Greece (survey, area determination) indicated.*

1. Introduction

G.P.S. is considered as the most current data acquisition position system with conditions and perspectives for rapid development for the operators. Some applications of G.P.S. in forest practice are the following:

a. Geodesy
The high accuracy, which the phase measurements of carry wave offer, excellent working material for a set of geodynamic, geodetic and topographic applications.

b. Forest cadastre
With the forest cadastre work usually the kinematics and “stop and go” methodologies are applied, while one uses the static and “stop and go” methods of investigation for the triangulation work. G.P.S. forms valuable working material for the geographical information systems (GIS). On this way it is to be brought possible phenomena with the geographical area in relationship. GIS are a new technology to collecting, memories, managing and analyzing data. Many companies in Europe make – programs to GIS, in order to renew forest maps, cadastre tables and to limit the forest with the help from digital maps to, those by Internet to be taken and in the field with GPS co-operate (Doukas, 2001).

c. Construction of roads
Apart from the surveys GPS can be used also with other applications of constructions of roads, like path mappings. With the installation of developed control systems in the earth working machines the accurate position of the machine can be determined, being based upon the GPS – technology.

d. Forest management - harvest and bringing of forest products
Handy GIS – programs and suitable database is to the modern forest management at the disposal (Sprenger, 2003 a, b).
In the final years the international data acquisition position system finds a large application with the forest management, since this instrument permits the researchers to determine the productivity of the machines used with the forest work.

e. Management of a fleet of fire-fighting vehicles
The path survey of a forest area gives the possibility for informing the suitable maps, in order to repel or extinguish a fire faster.

Aim of the available work is the research of the accuracy of different GPS - types and their range of application within the Greek forest, with emphasis the examination of its suitability for forest road surveys.

2. Materials and methods

2.1. Research area

The measurements were accomplished in the year 2006 in three different areas**:**

a. In the teaching forest "Taxiarchis" with L1+L2 Topcon GPS.
In the selected area "Livadia" were surveyed pasturelands with Christmas tree plantations and forest areas by oak with G.P.S. L1+L2.

b. In the forest complex "Kromnis" in close proximity to the city "Gianitsa", district "EDESSA", with:
- L1 Etrex of GARMIN,
- L1 LEICA GPS,
- L1 THALES.

The research area is a crossing of forest roads, partly covered with beech forest and partly with grazes or shrubs (Ortho).
D01 is not forest-covered. Tractor path with width 3.0 m.
D02 beech forest with tree height 15 m and stand density index 0.8 – 1.0. Path width 3.5 m.
D03 beech forest with tree height 15 m and stand density index 0.4 – 1.0. Path width 4.5 m.
D04 shrubs with a height of 2 m and stand density index 0.4 – 1.6. Path width 4.5 m.

c. In the summit of the mountains "Kissavos", which lies opposite "Olympus", with L1 Topcon GPS.
The research area is forest grazes.

2.2. Instrument choice

The true values of the coordinates were surveyed with the geodetic station TC 805. The accuracy of the geodetic station is accordingly to the technical regulations 2-5 mm + 2 ppm, the measurement time and the distance. The technical data of the used GPS are evident in the table 1.

2.3. Work method

2.3.1. Survey process with GPS

First the receipt possibility of the signal of the inexpensive L1 GPS (Table 1) in the forest road_survey was calculated (Table 2). We can sea that, the most favourable receivers are from "Garmin" and "Leica".

Using the results of the table 2 we decided, for the improvement of the results of the "Leica" GPS to try in 5 min duration measurement and for "Garmin" GPS the measurements during August. Since the use of the LEICA in 5 minutes duration method compared with 1 min, has not improved the measurements (Tables 3, 4), and has been last by the forest road survey the time-consuming method, i.e. 1 minute method used.

Table 1: Technical data of G.P.S.

GPS type	Technical data
GARMIN e-trex Vista (Figure 5)	**Receiver:** 12 parallel channel **Antenna:** integrated **Code:** L1 **Accuracy RMS:** <15 m
LEICA GS20	**Receiver:** 12 parallel channel **Antenna:** integrated and extern **Code:** L1 **Accuracy RMS:** By simple measurement 5 m, 1m real time EGNOS or 30 cm by DGPS (L1 post processing)
Pro Mark 2	**Receiver:** 12 parallel channel, base and rover **Receipt time of the signal:** about 15 seconds **Antenna:** integrated and extern **Code:** L1 **Accuracy RMS:** By simple measurement 5 m, 1m real time EGNOS or 30 cm by DGPS (L1 post processing)
Topcon L1	**Receiver:** 40 L1 GPS (20 GPS L1+L2 during the days Cinderella), base and rover **Antenna:** integrated and extern **Code:** L1 **Accuracy RMS:** 1m real time by EGNOS or 30 cm by DGPS
Topcon L1+L2	**Receiver:** 20 GPS L1+L2 (GD), 20 GPS L1+GLONASS (GG), 20 GPS L1+L2+GLONASS (GGD), base and rover **Receipt time of the signal:** about 15 seconds/first times about 1 min **Antenna:** GPS/GLONASS, integrated UHF and extern **Code:** L1 +L2 **Accuracy RMS:** 3 cm by DGPS

Table 2: **Receipt possibility L1 GPS, by the forest road survey**

GPS type and method	Number of the points without receipt possibility	Per cent % of the total points of forest road
LEICA GS20-EGNOS (1 min), August 2006	35	55.56
LEICA GS20 (1min), August 2006	20	31,75
Pro Mark 2, August 2006	31	49,21
LEICA GS20 (1min), March 2006	2	3,17
e-trex Vista GARMIN, March 2006	2	3,17

At the same time we tried Garmin, Topcon L1 and L1+L2 with the survey of grazes. The coordinates were calculated in the variation with the max. accuracy (fixed), i.e. many "quality signals of satellite are available".

The research with forest road survey is extended with L1+L2 receiver on a mast.
While in the all GPS was applied the method "stop and go" in real time, with the GPS "promark" was used the method "Post processing".

For the calculation of differences between the horizontal coordinates of total station and G.P.S is changed in the Greek geodetic system of 1985. Then these were compared and they were analyzed statistically so that is found the means square error of coordinates and area in the different conditions survey.

2.3.2. Error theory

The measurements were accomplished in the year 2006, i.e. after the abolishment of the selective availability. To the statistic analysis the values of the geodetic station were taken as true values. For the examination of the measurement errors the following was calculated:
a. The average of the measurement avoiding from the true value with the formula of the mean arithmetic error $\mu\alpha$:

$$\mu\alpha = \pm (\upsilon)/n \qquad (1)$$

where:
(υ) = the sum of the absolute values of the actual differences (error) $\upsilon 1$, $\upsilon 2$ ...... υn,
n = the amount of the observations.
b. The mean square error of the measurements $\mu\tau$:

$$\mu\tau = \pm [(\upsilon\upsilon)/n]^{0,5} \qquad (2)$$

where:
υ = Et – EG, Et = the true values of the coordinate from the total station, EG = the coordinate determined with GPS, n = the number of measurements.
c. The mean square error during the area determination SF became from the formula calculated

$$SF = 0,7\ Sp\ Sm\ n^{0.5} \qquad (3)$$

Where:
Sp= the mean square point error, Sm= the mean side length, n= the number of measuring points.
Finally the measurements accuracy with G.P.S. was calculated, the suitable results were brought and the relative suggestions for its forestry application made.

3. Results

From the research and investigation of the data of the research areas resulting in from the geodetic station, and GPS, due to the error theory, the specifications of the tables 3, 4 and 5 were abstracted.

a. By the survey of forest roads

Table 3.:Accuracy of the GPS – types by the forest road survey

GPS TYPE	**Method**	**Time of year**	**Measurement conditions (PDOP and number of satellites)**	**Number of measure-ments**	**Mean square error of the measurements μτ in m**		
					N	**E**	**Point**
GARMIN	**Real time Stop and go**	March 2006 In Gianitsa	By all Forest roads	59	4.919	4.190	6.462
L1 THALES Pro Mark 2	**Post processing Stop and go**	August 2006 In Gianitsa	By all forest roads (PDOP<6, n>4)	32	0.373	0.348	0.510
LEICA	**5 min real time Stop and go**	August 2006 In Gianitsa	By all Forest roads (PDOP<6, n>4)	11 by the D01	1.260	0.999	1.608 (>1.216 as by the 1 min)

The research is extended.

Table 4: Accuracy of the GPS Leica GS20 by the forest road survey

GPS TYPE	Method	Year time and Area (PDOP and number of the satellites)	Per cent that Signal receipt possibility	Measurement conditions (Crown-close) (Tree height)	Number of the measurements (Km)	Mean one square error the measurements by the part μτ in m
LEICA GS20	1 min real time Stop and go	March 2006 in Gianitsa (PDOP<6 n>4)		**Forest road D 01 (Grazes)**	21 (…)	2.513
			97%	**Forest road D02 (0.8-1.0) (15 m)**	26	6.357
				Forest road D03 (0.4-1) (15 m)	10	2.258
				Forest road D04 (0.4-0.6) (2 m)	14	1.774
				Total	71	4.344
		August 2006 in Gianitsa (PDOP<6 n>4)		**Forest road D 01 (Grazes)**	17	1.216
			37%	**Forest road D02 (0.8-1.0) (15 m)**	12	(Survey is not possible)
				Forest road D03 (0.4-1) (15 m)	20	1.803
				Forest road D04 (0.8-1.0) (2 m)	12	2.378
				Total	61	-

* The research is extended

b. By the survey of forest grazes (area determination)

Table 5: Accuracy of GPS Types by the forest grazes survey

GPS TYPE	Method	Year time	Measurement conditions (PDOP and number of the satellites)	Number of measurements	Mean square error, of the measurements $\mu\tau$ in m in		Mean square error of the measurements μE in m^2 by Area determination			
					Point	Height	F He	n	Sm m	SF m^2
Garmin	**Real time Stop and go**	June 2006	Forest grazes (Kissavos)	29	3.02	2.37	1	40	10	134
								14	30	237
								8	50	298
							20	179	10	283
								60	30	491
								36	50	634
Hipper pro L1 TOPCON	**Real time Stop and go**	June 2006	Forest grazes (Kissavos)	64	0.107	0.162	1	40	10	4.7
								14	30	8.4
								8	50	10.5
							20	179	10	10
								60	30	17
								36	50	22
Hipper pro TOPCON L1+L2	**Real time Stop and go**	December 2006	Forest grazes (Taxiarchis)	7	0.066	0.055	1	40	10	2.9
								14	30	5.2
								8	50	6.5
							20	179	10	6.2
								60	30	10.7
								36	50	13.9
			Building and forest area (Taxiarchis)	4	0.215	0.063	1	40	10	9.5
								14	30	16.9
								8	50	21.3
							20	179	10	20.1
								60	30	35
								36	50	45.1

4. Conclusions-Discussion

4.1 Conclusions

- The receipt possibility of the signal in March is better, than in August, (Table 2). The use of mast improves the receipt possibility.

- With the forest routes for a crown-close 0,8 - 1 plays the foliation an important roller with the signal receipt (comparison between D01, D03, D04 and D02 in the Table 4).

- Areas under close planting cannot be surveyed (Table 4).

4.2 Accuracy

- While toward the forest roads D01, D03 in two time periods nearly the same error is calculated, but more is in August than in March, it toward D04 opposite (more in March) (Table 4). The errors (accuracy) depend more strongly on the position (PDOP) and number of received satellites (SNR), i.e. local conditions, than the time period.

- The “post office processing„ method achieved better results, as “the stop and go„ (Table 3).

- The use in the forest of the receiver with still several satellites (GALILEO), improves the signal receipt, but not the accuracy. For the improvement of the signal generally speaking Greece reference - correction stations should be used.

- When using GPS L1 + L2, during the area determination in forest grazes, is more satisfying the point measurement than L1, but in forest and built area reacts it more sensitively (accuracy mode) than the L1 – GPS (Table 5).

4.3 Suggestions

- We suggest the evaluation of the GPS on the construction of forest roads only by the generally project and mapping of a forest road in small scales (<10000).

- To the improvement of the accuracy first, Greek reference correction stations system (HEPOS) should be established and compressed thereafter.

- Where there is no point measurement possibility, the use of laser range finder from a GPS -point lying near is recommended.

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