GPS METHODS IN SUPPORT OF GIS TECHNOLOGIES FOR MANAGEMENT OF FOREST TERRITORIES

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Abstract

Forests are one of the most important elements of the Earth's biosphere. They cover more than 30 % of the surface and serve as habitats for organisms, water cycle modulators, soil conservers and many more. Their proper management and preservation is of paramount importance, with endeavors in this direction made since 12th century A.D. Nowadays government agencies and scientific organizations, engaged in the field of forest management, rely strongly on advanced GIS technologies. These structures are responsible for investigation, evaluation and monitoring of forest ecosystems and biodiversity, preservation through different laws and regulations, artificial planting of new forests. Such activities require extensive field work, including feature data collection and update, accurate real time or post processed positioning, reliable navigation and orientation in difficult terrain. Modern GPS methods have proved as the most appropriate for such jobs, providing good precision and high productivity in real time on the field. Depending on the accuracy needed, there are various types of GPS methods. As these are satellite based technologies, they all need good sky visibility and signal strength, which is sometimes very difficult under forest canopy and deep canyons.
In this article are presented modern GPS methods used in the GIS industry. In addition, a comparison and feasibility analysis of real feature data, collected through different GPS methods in the forests of Vitosha Mountain also takes place.

Keywords – GPS, GIS, Trimble, Geoinformation

INTRODUCTION

In the last decades forests in Bulgaria are suffering more and more sensibly from various natural disasters – fires, wind throws, deceases and insects. The reason for this is poor forest management, as well as increased intensity of extreme climate events, like hurricanes, temperature variances, flood rains, which cause stress in the forest ecosystems. By statement of the State Forestry Agency (STA) of Bulgaria the forest territories, destroyed in the recent years account for over 60 000 da. Illegal cutting also causes significant problems onto the forest ecosystems, huge part of which are inside the "Natura 2000" protected areas.
The lack of sufficient budget funding is the reason why most of the forests destroyed cannot be recovered in time, which causes degradation and alteration of the natural habitat for the species, lowering the biodiversity and eco-functions of these territories. Bad forestry practices like planting easily vulnerable monocultures in such areas are adding to the problem.
To help the situation, in November 2009 was created the Vitosha Initiative Group, which in collaboration with STA and Gorichka Initiative gave a start to the project "Recovery of priority forest habitats in Natura 2000 areas", financed by the European funds. Within the project so far was created a database of the destroyed forest territories in Bulgaria, with its goal to provide actual information for their status and involve more attention and funding from the public and private sectors of the economy. Also, an advanced methodology for forestation was developed, with its pilot implementation in the destroyed forest area "Ofeliite" in the Vitosha Mountain on 1 May 2010, where and when 500 spruce trees were planted. A total of 45 000 trees in 180 da of destroyed territories in Vitosha and the Rhodopi mountains are expected to be forested this year [1].
Activities like these require proper mapping and database management, largely available through modern GIS technologies. Such activities rely on accurate geometric and attribute data for the destroyed areas and for every new planted tree even. The mapping of area and point positions requires huge surveying work, where GPS methods have proved for years as the most effective tool. Depending on the accuracy needed and the environment in which they are used, there are different GPS methods.
This paper provides field analysis of four modern GPS methods, tested individually and together for mapping part of the forestation in Ofeliite area on 1 May 2010. Described are practical problems, comparative accuracy results are given, as well as suggestions for implementation in future forestation processes in Bulgaria.

BRIEF DESCRIPTIOIN OF GPS TECHNOLOGY

GPS segments

The Global Positioning System (GPS) provides determination of positions of observing sites on land or at sea, in the air and in space by means of artificial satellites. The system is developed and managed by the US military and consists of space, control and user segments. The space segment provides 24-hour worldwide coverage by the means of at least 24 satellites in 6 orbital planes. Several active spare satellites for replenishment are usually operational. With the full constellation, the space segment provides global coverage with four to eight simultaneously observable satellites above 15° elevation at any time of the day. The operational control segment consists of master control station, monitor stations and ground antennas. The monitor stations are equipped with a precise atomic time standard and receivers which continuously measure ranges (a.k.a. pseudoranges) to all satellites in view. The master station collects the tracking data from the monitor stations and calculates the satellite orbit and clock parameters. The results are then passed to one of the ground antennas for eventual upload to the satellites. The user segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. Receivers vary greatly in size and complexity, though the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply. The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver display device and, if the receiver provides data capture capabilities, stored by the receiver-logging unit.

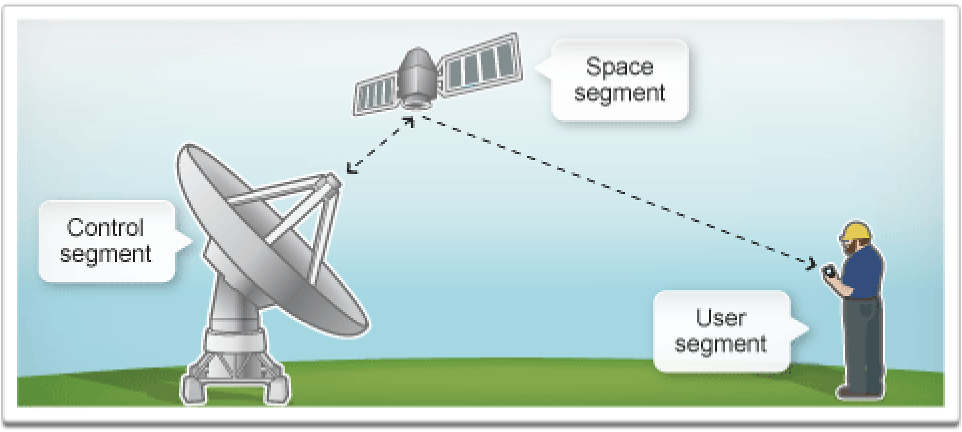


Figure 1. Scheme of GPS segments

Signal structure

GPS positioning is performed by simultaneous measurements of the signal from at least four GPS satellites. The satellite signal consists of carrier frequency, ranging code and navigation message. Each satellite from the GPS constellation emits two carrier frequencies: L1 – 1.57542 GHz and L2 – 1.22760 GHz (a third carrier L5 – 1.17645 GHz is provided through the new generation of satellites). The carriers are modulated by ranging codes and navigation messages, for the purpose of time measurements and information download. Basically, there are several coarse (C/A) and precise (P) ranging codes, the former with known open structure, the latter encrypted for military uses only. The navigation message essentially contains information about the satellite orbit, the satellite health status, various correction data, status messages and other data.

Observables and error sources

In concept, the satellite navigation observables are ranges which are deduced from measured time or phase differences based on a comparison between received signal and receiver-generated replica signals. Unlike the terrestrial electronic distance measurements, satellite navigation uses the “one-way concept” where two clocks are involved, namely one in the satellite and the other in the receiver. The ranges are biased by satellite and receiver clock errors, so they are denoted as pseudoranges. Depending on the observables used, there are code pseudoranges and phase pseudoranges. The precision of a pseudorange derived from code measurements is roughly 3 m with C/A code and 0.3 m with P code. Phase pseudoranges are much more accurate, because the phase of an electromagnetic wave (what the GPS signal in fact is) can be measured to better than 5 mm.
The code and phase pseudoranges are affected by systematic errors or biases and random noise as well. The error sources can be classified into three groups, namely satellite-based errors, propagation-medium-related errors, and

receiver-related errors [2]. Some of the systematic errors can be modeled; others can be eliminated (or at least strongly reduced) by appropriate combinations of the observables.

Positioning methods

GPS measurements can be classified as static and kinematic, the latter used for positioning of moving objects. Furthermore, they can be grouped as absolute and relative positioning methods. Unlike the absolute positioning (also known as uncorrected), the object of a relative measurement is to determine the coordinates of an unknown point with respect to a known point which, for most applications, is stationary. Relative positioning in real time is known as differential positioning, where the accuracy of the measurement is artificially augmented by applying differential corrections onto the raw GPS observations. Finally, depending on the user needs GPS positioning is available either in real time or through subsequent postprocessing. In the next chapter are described some contemporary GPS methods, used for collection and management of GIS data for forestation of “Ofeliite” area in the Vitosha mountain.

DESCRIPTION OF THE GPS METHODS USED FOR MAPPING FORESTED AREAS IN VITOSHA MOUNTAIN

On 1 May 2010 over 100 volunteers were involved in planting 500 spruce trees in „Ofeliite” destroyed area in Vitosha Mountain. The project was appropriate field for tests of surveying and mapping such areas by GPS methods. For that purpose four types of GPS positioning methods were selected, namely uncorrected (absolute), relative postprocessed, code differential (MSK), and phase differential (VRS). The field survey group consisted of four surveyors, each one responsible for different type of positioning method. The equipment and field software used is produced from the industry-leader in GPS receiver manufacturing Trimble Navigation Ltd. The features, selected for data collection (positioning) were 19 newly planted trees, as well as the area comprising them. The goal is to determine the most appropriate GPS method for data collection in such environments and for such purposes.

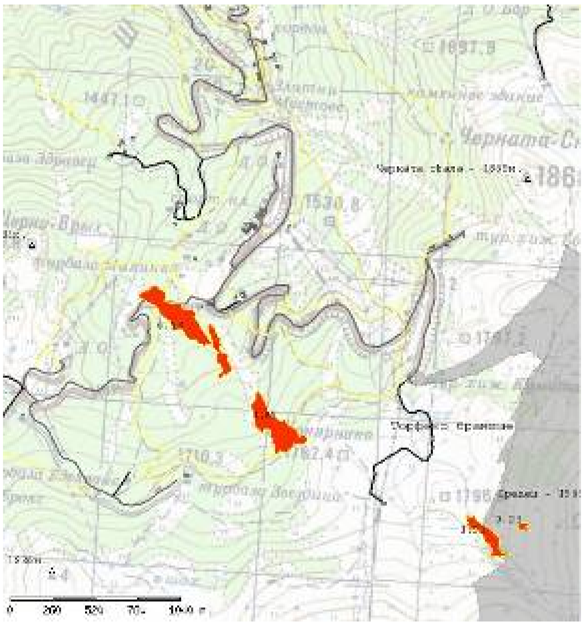


Figure 2. Map of the forested area

Uncorrected positioning

This mode of positioning relies upon a single receiver station. It is also referred to as 'stand-alone' GPS, because, unlike differential positioning, ranging is carried out strictly between the satellite and the receiver station, not on a ground-based reference station that assists with the computation of error corrections. As a result, the positions derived in absolute mode are subject to the unmitigated errors inherent in satellite positioning. Overall accuracy of uncorrected positioning is considered to be in the meter range.
In the current field test such positioning was performed with Trimble® Juno™ SC – light, compact field computer with GPS, yielding accuracy of 2-5 m. It is equipped with the Trimble TerraSync™ Professional field software.

Figure 3. Measurement of spot for tree planting with Juno SC

Data collection with Juno SC is quite easy, since the device is very light and easy to use – the responsible field surveyor learned how to use it on the site. Its GPS sensor is very sensitive - even under dense forest canopy it was acquiring GPS position faster than the other GPS units. Its drawback is the relatively low accuracy.

Postprocessed differential positioning

Post-processing is a method used to obtain precise positions of unknown points by relating them to known points such as established control points (reference stations).
The GPS measurements are usually stored in computer memory in the GPS receivers, and are subsequently transferred to a computer running the GPS post-processing software. The software computes baselines using simultaneous measurement data from two or more GPS receivers.
The baselines represent a three-dimensional line drawn between the two points occupied by each pair of GPS antennas. The post-processed measurements allow more precise positioning, because most GPS errors affect each receiver nearly equally, and therefore can be cancelled out in the calculations.
For this test the uncorrected data, collected with the Juno SC receiver, were postprocessed by using the precise ephemerides from the permanent station SOFI – part of the European Permanent Network, a science-driven network of continuously operating GPS reference stations with precisely known coordinates. According to the technical specifications, the postprocessed accuracy which can be achieved with the data from Juno SC should be in the 1-3 m interval. Postprocessing took place on 8 May 2010 by Trimble Pathfinder Office software.

Code real-time differential positioning

As was stated above, differential-mode positioning (DGPS) relies upon an established control point. The reference station is placed on the control point. This allows for a correction factor to be calculated and applied to other roving GPS units used in the same area and in the same time series. This correction factor is broadcasted to the field users in the form of differential corrections over radio frequency channels by the so called MSK (Multi-shift keying) reference stations in the KHz band.

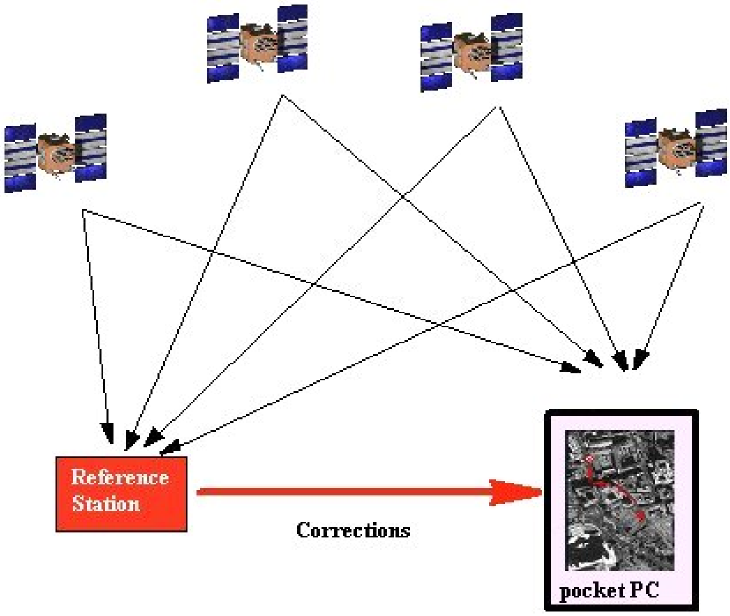


Figure 4. Principle of differential positioning

Inaccuracies in the control point's coordinate are directly additive to errors inherent in the satellite positioning process. Error corrections derived by the reference station vary rapidly, as the factors propagating position errors are not static over time. This error correction allows for a considerable amount of error to be negated, potentially as much as 90 percent.

For utilizing the MSK differential corrections, a Trimble Pathfinder ProXT GPS receiver was used. Since it doesn't have an integrated controller device, as such a Trimble Nomad field computer with TerraSync was used. Radio-broadcasted differential corrections were being received from the Sofia MSK station (288.5 KHz), located between the villages of Gorni and Dolni Bogrov, by a Trimble GeoBeacon radio modem device and transferred to the ProXT GPS receiver through wireless Bluetooth link.

Figure 5. Surveyor, using Trimble Nomad field computer (below in his left hand) and Pro XT GPS receiver (above in his left hand), together with GeoBeacon radio modem (in the right hand)

Code differential positioning with MSK station corrections is significantly more precise method than the uncorrected positioning, with accuracies reaching the submeter level. The GPS receiver Trimble Pathfinder ProXT is supposed to be mounted on a special pole or a backpack, and the GeoBeacon - on a belt around the waist, which accessories were unfortunately not available and everything had to be carried by hands. It caused some problems in negotiating the steep terrain and the timber left from the cutting activities in the area. Another drawback was the occasional losing of signal lock to the MSK station correction stream, especially in the lower parts of the terrain. By specifications MSK signal should be received at distances of up to 200 km, with the Sofia station located at 14 km. Nevertheless, the data were collected properly and wirelessly transferred in the Trimble Nomad field device, with only a few points stored as uncorrected positions.

Phase real-time differential positioning

Phase differential positioning relies on transmitting the phase measurement of the GPS signal in real time from the reference station to the rover. This method is also known as RTK (Real Time Kinematic), and is the most productive and precise in that the greatest number of points can be determined in the least time with the highest accuracy. There are several ways to transmit RTK correction to the users. A VRS system is one option for providing real-time differential correction to the GPS receiver. It is the most commonly used technology behind most network correction services worldwide. Corrections are necessary to eliminate errors and improve the accuracy of GPS positions in collected data. VRS corrections are available from a variety of public and commercial services. VRS networks and subscription services provide dual-frequency (L1/L2) real-time differential GPS (DGPS) corrections to improve accuracy as data is collected. A VRS service uses data from several (permanent) reference stations to compute corrections that are generally more accurate than corrections from a single reference station. It calculates the most suitable corrections according to the exact user position, the latter transferred to the service center by NMEA protocol over GSM/GPRS. These corrections are then broadcast back to the user over the Internet.

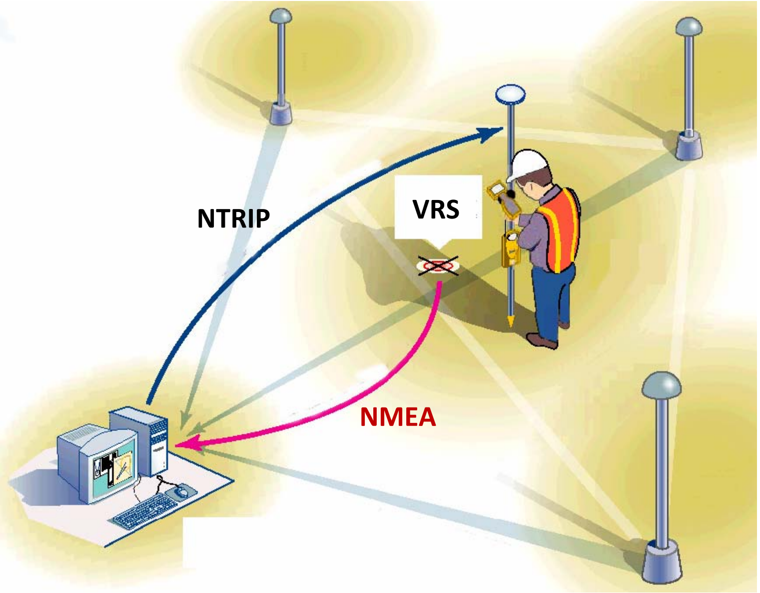


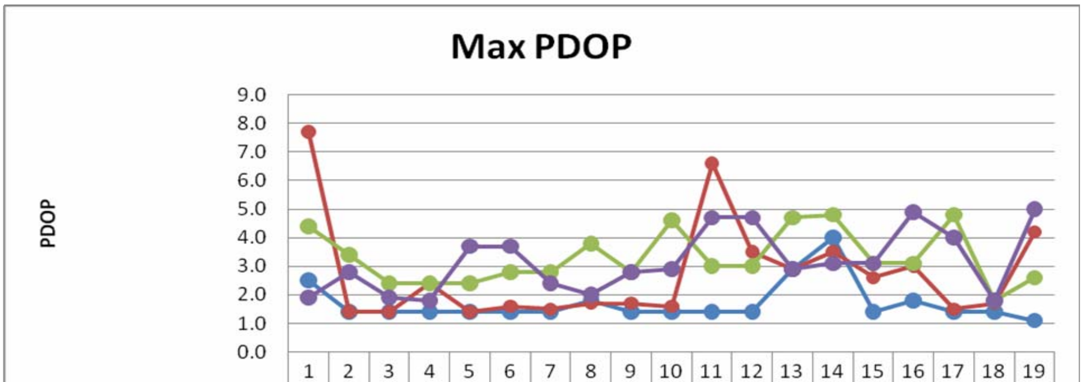
Figure 6. VRS technology

For the current field test a Trimble GeoXH receiver was used, equipped with TerraSync field software. This receiver utilizes the new Trimble H-Star^{TM} technology, which provides 30 cm accuracy in real time by using VRS differential corrections. The last were provided by Geonet – a Bulgarian company, specialized in accurate GPS positioning services. Its corrections were being received through Nokia GSM mobile phone, which were connected by Bluetooth with the GeoXH field computer. The network has 90 % coverage of Bulgaria, which leads to fast and accurate positioning wherever there is GSM signal. On Vitosha Mountain there was no problem collecting data by this method, with stable correction stream at almost every position. It should be mentioned, that while the other methods described needed some technical time to converge to the desired accuracy, the VRS method provides the 30 cm accuracy almost instantly.

Figure 7. Mapping a planted tree by VRS (on the left), Uncorrected (in the middle) and MSK positioning methods

ANALYSIS OF THE RESULTS

The results from the field test are presented in the following tables. Table 1 presents a comparison of the PDOP criteria of the GPS measurements – criteria of the good geometry of the satellites used. In the ideal case this criteria should be 1.00. It can be noticed, that the data for the 19 point features (trees), collected with the Juno SC has better PDOP that the other methods. This is owed to the GPS sensor in this receiver – it is designed for stable positioning in hard conditions (but with less accuracy). By theory, anything under PDOP of 6.00 is regarded as good measurement, so in this case almost all data is reliable.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Juno Uncorrected	2.5	1.4	1.4	1.4	1.4	1.4	1.4	1.8	1.4	1.4	1.4	1.4	2.9	4.0	1.4	1.8	1.4	1.4	1.1
Juno Postprocessed	7.7	1.4	1.4	2.4	1.4	1.6	1.5	1.7	1.7	1.6	6.6	3.5	2.9	3.5	2.6	3.0	1.5	1.7	4.2
ProXT MSK	4.4	3.4	2.4	2.4	2.4	2.8	2.8	3.8	2.8	4.6	3.0	3.0	4.7	4.8	3.1	3.1	4.8	1.8	2.6
GeoXH VRS	1.9	2.8	1.9	1.8	3.7	3.7	2.4	2.0	2.8	2.9	4.7	4.7	2.9	3.1	3.1	4.9	4.0	1.8	5.0

Table 1. Satellite geometry chart (PDOP)

Table 2 presents the horizontal accuracy of the positioning methods used in the field test. It can be easily noticed that the VRS and the MSK methods give by far better accuracy than the data, collected with the Juno SC. The differential methods' data is well in the submeter level, with the data collected by the VRS method reaching decimeter precisions. The precision jumps in the green line (the MSK method) represent the loss of signal lock to the MSK station, providing the code differential corrections. More stable is the VRS correction stream, without any loss of signal lock between the correction provider and the GeoXH unit. The worst results with VRS corrections are at points 13, 14 and 15, where the accuracy reaches 0.9 m. Still, this is far better than the rest of the methods. The blue and the red lines represent data, both collected by Juno SC field computer – the former uncorrected, the latter corrected with precise ephemerides from SOFI station with 1 week delay.

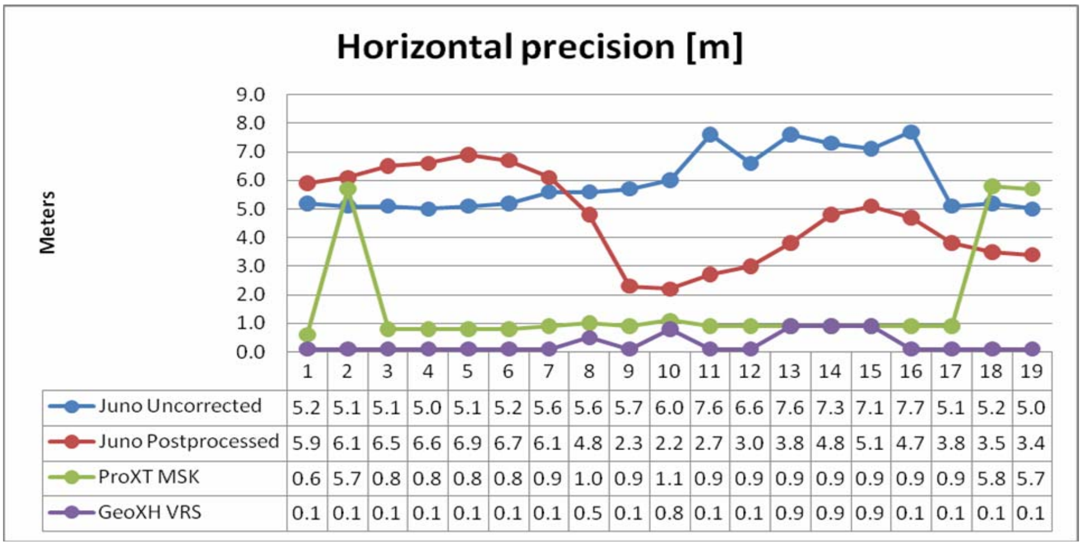


Table 2. Horizontal precision chart

Table 3 presents the vertical accuracies, achieved with the four positioning methods. The results are almost the same as these of the horizontal accuracies, the only difference being the better values of the vertical precision, achieved by postprocessing the Juno SC data.

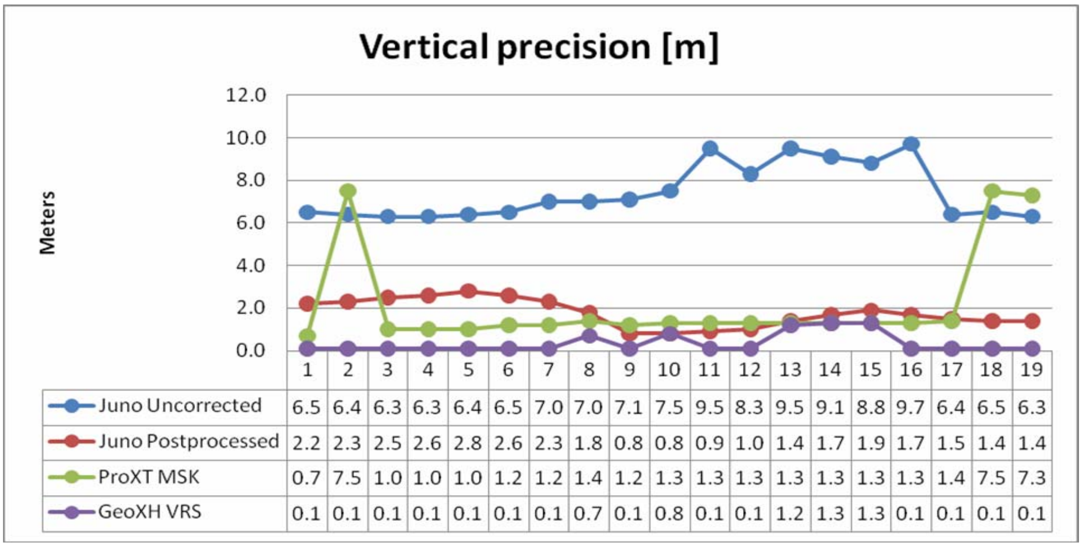


Table 3. Vertical precision chart

Table 4 presents the results of the area measurement. All GPS receivers were set to collect data at an interval of 1 second. The surveyors walked around the area, comprising the 19 planted trees in the exactly same route, one after the other. Here, the worst and average results for the horizontal and vertical accuracy again are better with the VRS method.

Method	Positions	Time interval	Max PDOP	GPS Area [m]	Avg Vert Prec [m]	Avg Horz Prec [m]	Worst Vert Prec	Worst Horz Prec
Uncorrected	524	1 s	1.8	0.572	6.3	5.0	6.3	5.0
Postprocessed	524	1 s	2.2	0.564	2.0	3.8	3.0	5.7

ProXT MSK	496	1 s	7.9	0.572	3.1	2.3	7.8	6.0
GeoXH VRS	506	1 s	5.4	0.583	0.4	0.3	2.0	0.9

Table 4. Area feature results

On the figure below is displayed the map, produced by the GPS test session. The Coordinate system used is UTM 34 N, the datum is WGS 84.

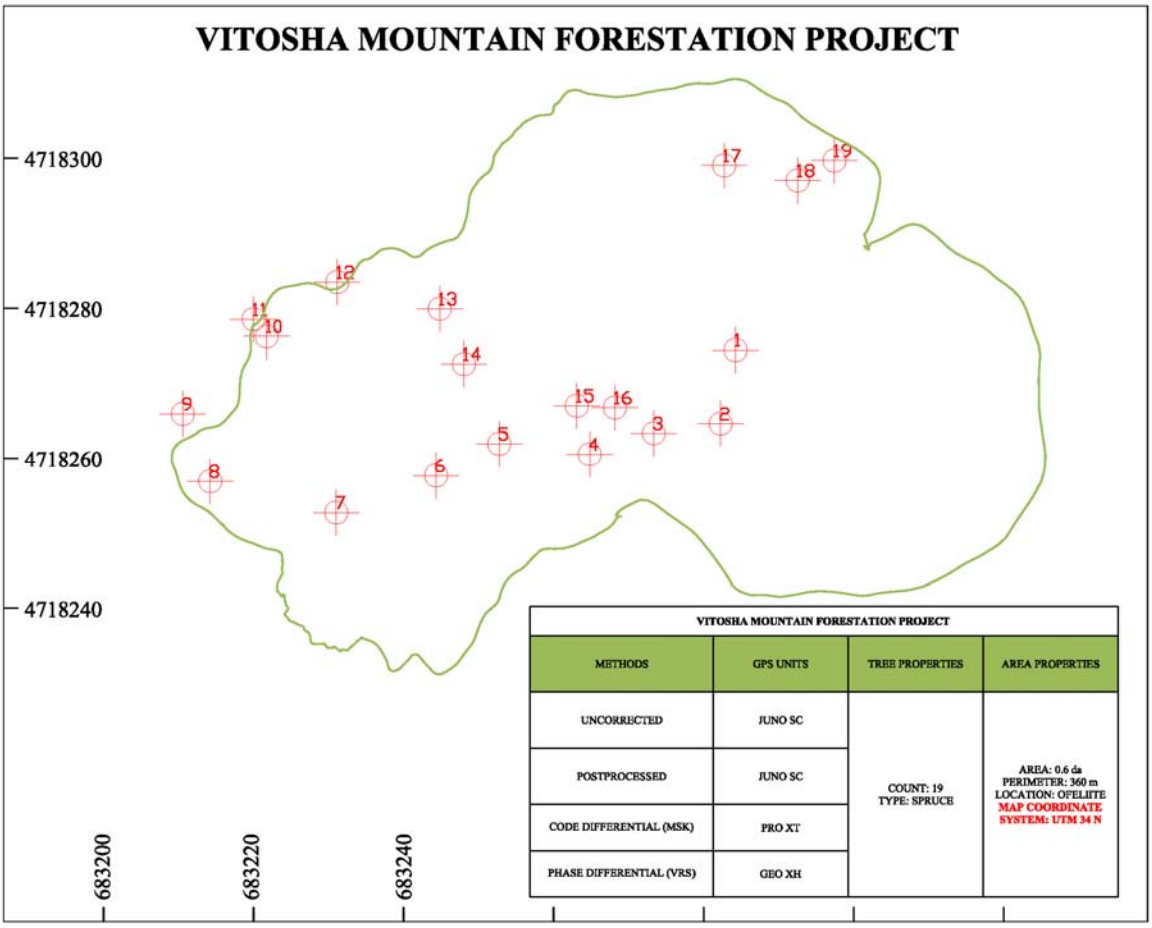


Figure 8. Mapping properties

CONCLUSIONS

Modern GIS technologies rely strongly on GPS methods for data collection and management. Various industries utilize the benefits of the fast, effective, productive and accurate positioning methods that GPS provides. One of them is the forest management – a complex area that requires sophisticated database management. In this paper was presented a test experiment of how GPS methods may be applied in a forestation process of an area, destroyed by illegal cutting and insects. Four different methods were described and utilized in the test, and the results presented graphically. The most accurate of them – the VRS method, achieved accuracy in the decimeter level, even in a relatively harsh terrain. It is up to the GIS specialists to review the results and analyze which method best fits their needs. As a final remark it should be mentioned, that these GPS methods can be applied successfully in any other field where GIS technology is involved.

REFERENCES

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BIOGRAPHY

Dipl. Eng. Asparuh Kamburov is a PhD student at the University of Mining and Geology – Bulgaria. His interests are in the field of precise GNSS positioning, with a dissertation work in the Wide Area Real Time Kinematic method application for the geodesy in the seismic industry. Ne has been working in the seismic industry for four years, performing survey projects for oil and gas exploration in Bulgaria, Libya, Tunisia, Morocco and Cambodia. Currently he is working at the Bulgarian Geoinformation Company, which is dedicated in GPS and know-how support for the Mapping and GIS industries in Bulgaria. This is his fifth publication in the area of GPS technology.