

## TESTING OF THE GPS RECEIVER ACCURACY FROM THE POINT OF VIEW OF APPLICATION IN THE MULTI-TASK MACHINE FOR WATERCOURSES RENOVATION

### Summary

*The accuracy results for the altitude positioning of SPAN-CPT GPS receiver, as well as its main characteristics, were described in the paper. The main goal of this research was to testify if the proposed GPS steering device and system is suitable for the positioning of the machine for renovation of opened watercourses.*

## BADANIE DOKŁADNOŚCI ODBIORNIKA GPS Z PUNKTU WIDZENIA JEGO ZASTOSOWANIA W MASZYNIE WIELOZADANIOWEJ DO RENOWACJI ROWÓW MELIORACYJNYCH

### Streszczenie

*W artykule opisano testy dokładności wskazań wysokości przez odbiornik GPS SPAN-CPT i przedstawiono wybrane wyniki. Głównym celem badań było potwierdzenie, że system jest odpowiedni do pozycjonowania maszyny do renowacji otwartych cieków wodnych.*

### 1. Introduction

The research made for this article is associated with the development of the project named: "Technology and new generation multi-task machine for regenerative shaping of opened watercourses" (No. WND-POIG.01.03.01-00-165/09). The project is realized by Industrial Institute of Agricultural Engineering (Poznan, Poland) within a framework of The Program Innovative Economy 2007-2013.

The main subject of this project is to develop the principles of a new technology for shaping and renovation of opened watercourses. The second aim is to design a new machine – self-propelled, multi-task and equipped with several tools (movers, bush cutters, cutter screw, elutriator etc.), which will realize tasks within the new technology.

One of the tasks of this new machine is to achieve proper slope of the ditch bottom, which is necessary for proper water flow. The proper bottom slope for this kind of ditches is within the range of 2 – 5 ‰ [1], which means that for each kilometer of the ditch linear length, the decline should be 2 – 5 m only, therefore, for each 100 m of ditch linear length, the decline should be 0,2 – 0,5 m. This determines the minimum altitude positioning resolution of the machine on the ditch.

The current work method to achieve the proper slope of the ditch bottom is not suitable. For example actual machines aren't steered automatically by an electronic system, which controls working depth of digging tool or elutriator. In the other hand, the function of control ditch bottom decline is performed by a man with hand leveling instruments. The control can be realized after the work of the machine and the level of the ditch depth can be inaccurate.

Better solutions were implemented to steer working machines in building engineering, but these solutions become useless inside narrow ditches due the lack of

visibility as well as the non linearity of the ditches. The working machine could be often hidden inside the ditch or behind trees and bushes and the ditch may have several curves accordingly with the shape of the surroundings.

The use of the GPS technology seems to be a suitable solution for this problem, because the GPS has the following advantages: may work correctly independently of the weather conditions, the positioning signal came from satellites over the machine, so ground obstacles (plants and bushes) don't disturb the positioning during its work. In the other hand, the GPS signal doesn't have horizontal limitations and can work on all length of the renovated ditch. For example: the laser technology, used in several machines in building engineering, can work only with line of sight, over small distances, comparing with the distance of ditch renovation, which have lengths of several kilometers.

However the GPS technology may also have restrictions and disadvantages. The ordinary GPS receiver has a typical accuracy of a few meters. In order to improve this accuracy, the GPS receiver need additional reference stations, which provide additional positioning signal to correct the satellite signals. There are two kinds of correction stations: within the EGNOS (European Geostationary Navigation Overlay Service) correction stations network (stationary stations deployed all over Europe) or by using RTK (Real Time Kinematic) mobile correction stations which cooperate with the GPS receiver mounted on the machine. The mobile station can't be moved during work of the machine. Both systems have positive and negative aspects which can determine its applicability. For the application in the ditch renovation works, both systems appear to be suitable.

The EGNOS correction system, using the NAVGEO service (RTK corrections), provides positioning accuracy on the level of 0,03 m in the horizontal and 0,05 m in the vertical measurements [5]. For the ditch renovation machine, this accuracy should be about 0,05 to 0,2 m [1].

In order to testify the actual vertical accuracy, a research was performed for this article using the SPAN-CPT GPS receiver produced by Novatel Co. The tests were realized using a simple model of seeder, which is steered by GPS technology. The model of the precision seeder came from another own research of the Institute. In the model of the seeder, the SPAN-CPT GPS receiver with EGNOS correction system was used, which communicate with the correction system by GPRS (mobile phone technology) [2, 3].

Together with the EGNOS correction system, the SPAN-CPT GPS receiver has a built in gyroscope, which allows IMU (Inertial Measurement Unit) [2, 3] correction in order to steer the machine even during instantaneous lack of GPS signal from the satellites. This feature seems to be very useful from the point of view of the machine for renovation of ditches, because of the possible lack of GPS signal during work inside dense vegetations or irregular soil (ex. inside forest).

Referring to the SPAN-CPT GPS receiver manufacturer, its accuracy is greater than the machine needs, however, due the geometry of the machine as well as the relative position of the GPS receiver in the machine, further tests were considered necessary to testify it's applicability.

The GPSeeder was used in this research only as a carrier for the GPS receiver, however the results obtained can only be taken as reference for the adoption of this system in the ditch amelioration machine. Further tests must be made using the real scale machine to testify its real precision.

## 2. Characteristic of the SPAN-CPT GPS receiver and model of precision seeding

In order to steer the GPSeeder, its controller obtains the position of the GPS receiver reference point as well as many other parameters via RS232 communication port (fig. 1). Previously was assumed that the accuracy of the GPSeeder was the same as the accuracy provided by the GPS receiver itself, witch can be seen on it's windows Grafical User Interface (GUI) software (fig. 1), and in the

“sentence” continuously sent by the GPS receiver to the GPSeeder controller (via RS232). This “sentence” contains, among many other parameters of the GPS receiver (like time, working status, etc.) [2][3], information about the precision of the positioning, witch can be seen in Bold in the following example:

GPS sentence:  
 BESTGPSPOSA,COM1,0,62.5,FINESTEERING,1036,  
 484878.000,00000028,63e2,0;SOL\_COMPUTED,  
 SINGLE,51.11629893124,-114.03820302746,1052.3434,-  
 6.271287293,61, **0.06934, 0.05115,0.08561**,  
 "",0,0,60.000,10,10,0,0,0,0, 0\*1051ada9

In this sentence, the different parameters are separated by commas, therefore, referring to the documentation provided by the manufacturer of the receiver, the error associated with the latitude, longitude and altitude measurements (in this example they are:  $\pm 0,06934$  m,  $\pm 0,05115$  m and  $\pm 0,08561$  m respectively) is easily recognizable.

Besides the connection to the computer and the controller of the seeder, the GPS receiver is also connected to the GSM modem via RS232, witch allows the EGNOS correction system to work (fig. 1). The cost of operation of the receiver depends on the tariffs of the chosen mobile phone operator.

The system is powered by a 12V automotive battery and placed on the GPSeeder. The fig. 2 shows the approximate location of the GPS receiver center in the seeder, used as reference for the measurements.

It's easily understood that if any of the machine wheels is at a different altitude of the other two, the measurement of the position will be affected by the angle of rotation of the seeder. The location of the receiver reference in the geometrical center of the figure created by the center of the wheels will minimize this effect.

The IMU (Inertial Measurement Unit) included in the receiver allows the correction of the measurements. In this tests however, this unit was not initialized in order to test the accuracy of the EGNOS corrections alone.

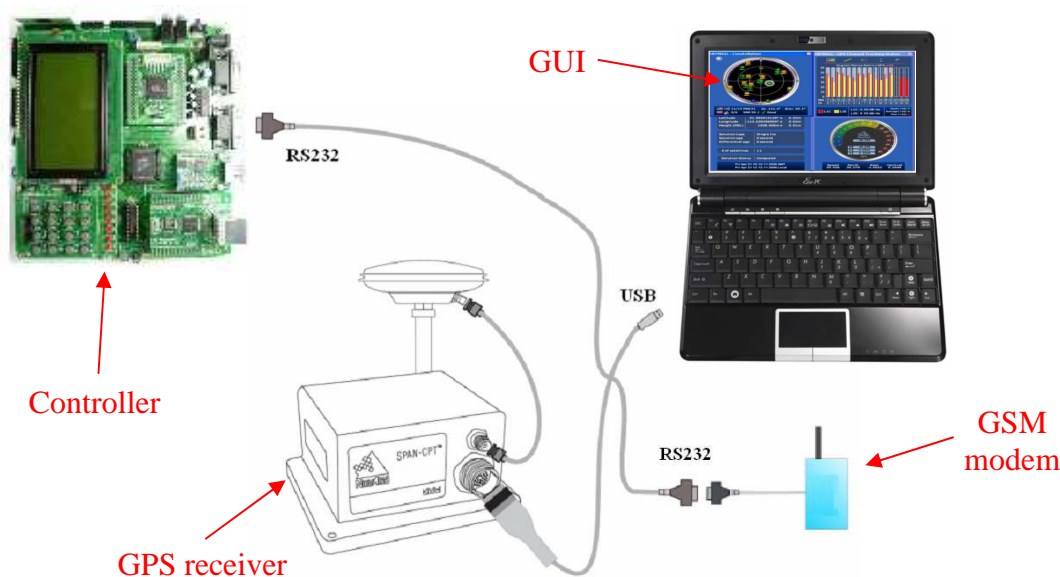


Figure 1. Connections of the GPS receiver

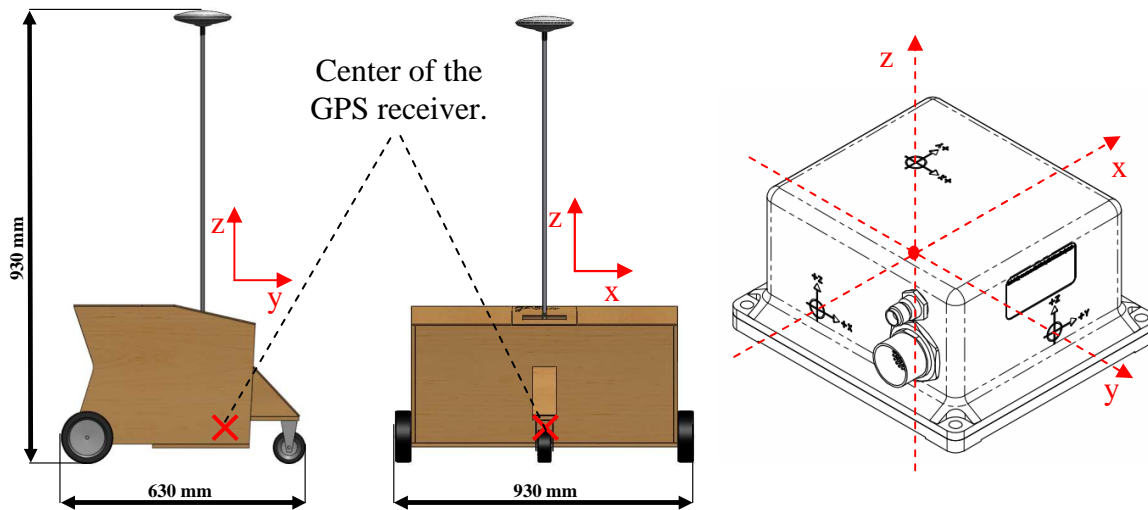


Figure 2. GPSeeder and the location of the receiver

### 3. Measuring procedure

In order to testify the accuracy of the system receiver-machine, a series of tests were performed in the Institute, in order to compare its altitude measurements with the measurements made using a laser distance meter (Leica DISTRO™ A8), according to the schematic shown in fig. 3.

The following procedure was used:

1. Place the laser distance meter in the terrain so that the laser beam (horizontally aligned) indicates the path of the seeder.

2. Draw several points on the floor over the path of the GPSeeder.
3. Place the ruler over each point vertically and measure the altitude using the projected point of the laser beam in the ruler.
4. Measure the distance of the ruler using the laser distance meter.
5. Repeat the steps 3 and 4 for all points.
6. Place the center of the GPS receiver vertically over each line and read the altitude and the error shown in the seeder LCD.

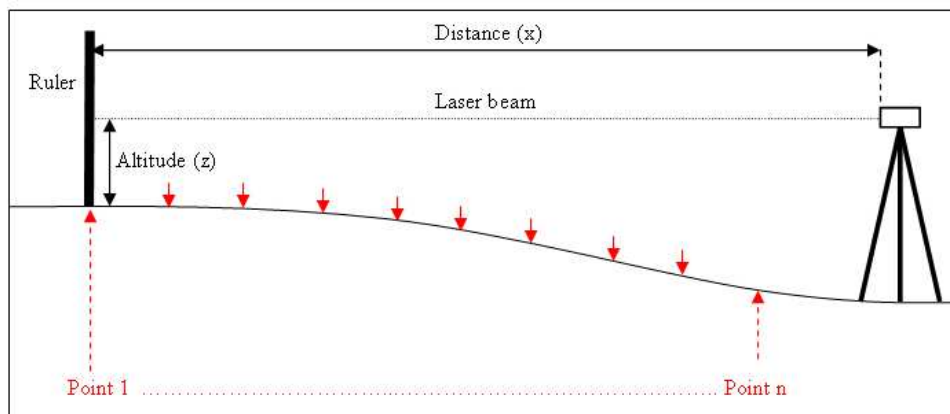


Figure 3. Laser altitude measurement schematic

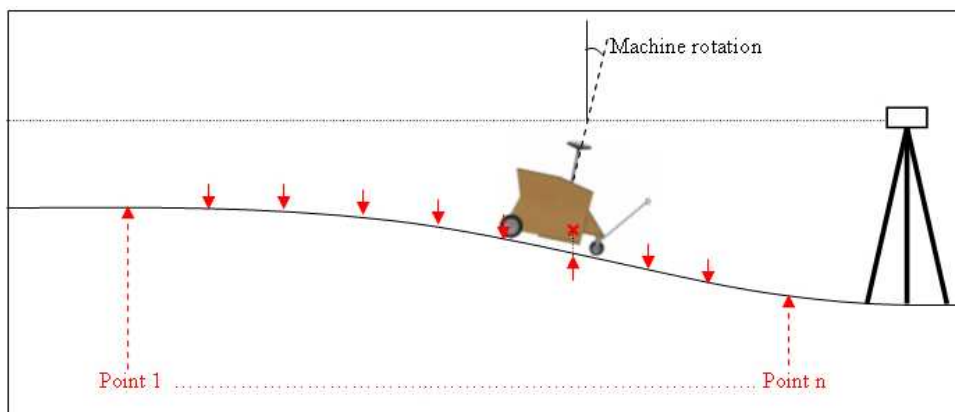


Figure 4. GPS altitude measurement schematic

Perform this measurements in one irregular terrain intends to simulate the real operation of the machine, where small differences in the level of the wheels (few centimeters) cause a small rotation on the GPS receiver. However, the irregularity of the soil where the tests were performed was small comparing with the real operation of the ditch amelioration machine.

#### 4. Instruments

- The ruler is graduated in millimeters and was leveled by a 2D bubble leveler (fig. 5).



Figure 5. 2D bubble leveler

- The laser distance meter has a maximum error of  $\pm 1.5\text{mm}$  for distance measurements below 30 m and the leveler of the laser beam has a maximum error of  $\pm 0,15^\circ$ [4]. Therefore the error of the altitude measurement caused by the level error of the beam is its vertical deviation in the ruler. At 30m distance, the error is given by the eq. 1:

$$\Delta z = x \times \text{tg}(\Delta\theta) \quad \Rightarrow \quad \Delta z_{\text{max}} = 30 \times \text{tg}(0,15^\circ) = \pm 0,0785\text{m} \quad (1)$$

The error caused by the level of the laser beam is relatively high, so in order to minimize it, the altitude

measurements were performed done at a short distance (lower than 15 m).

#### 5. Results

There were performed 4 tests in 3 different land profiles: one irregular ascendant terrain profile (profile 1), one irregular descendant terrain profile (profile 2) and in one quasi regular artificial profile (profile 3). To test the repeatability of the results, in the first profile, the same measurements were made moving the seeder in both directions (uphill and downhill). In order to compare the measurements, one was taken as reference.

The graph 1 and the table 1 show the results obtained for the first two tests corresponding to the first profile.

In all tests, the GPS and laser altitude measurements were referred to the first measurement according with the formula:

$$Z'_n = Z_n - Z_0$$

Where  $Z_n$  is the measured altitude,  $Z_0$  is the altitude of the reference point and  $Z'_n$ , the calculated altitude.

The errors shown in the table are the ones indicated by the GPS receiver, and  $Z_{\text{laser}} - Z_{\text{GPS}}$  is the difference of the altitude measured by the laser and by the GPS.

In the second test, the measurements were made in another small hill, and the results can be seen in the graph 2 and the table 2.

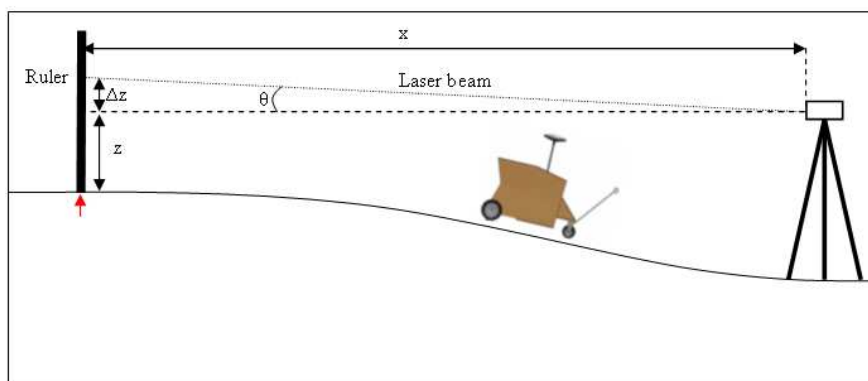
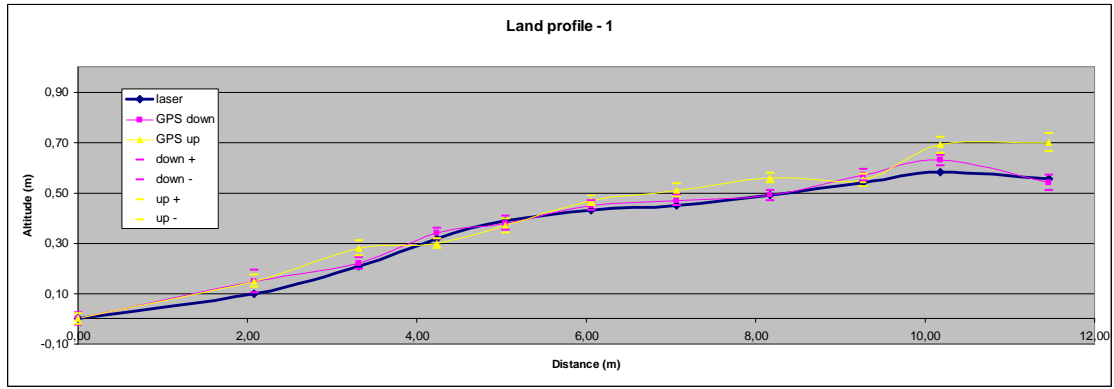


Figure 6. Altitude measurement error

Table 1. Profile 1, measured by laser and GPS in meters [m]

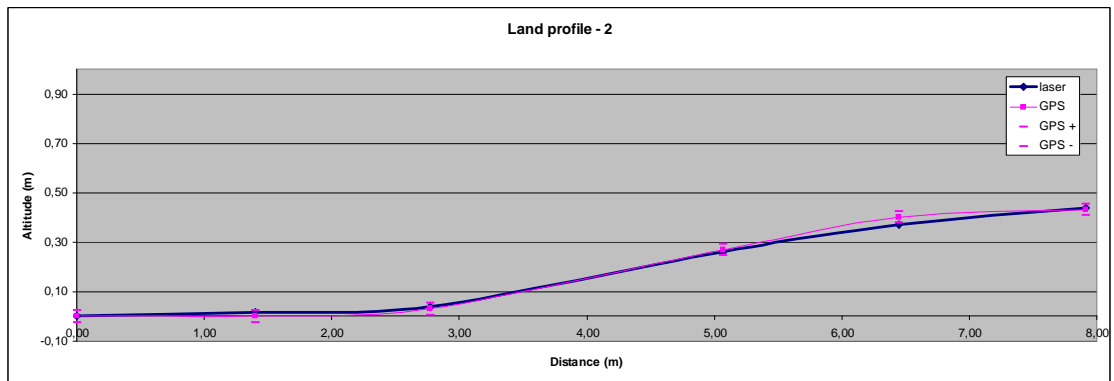
| X     | Z <sub>Laser</sub> | Z GPS <sub>down</sub> | Z GPS <sub>up</sub> | Error GPS <sub>down</sub> | Error GPS <sub>up</sub> | Z <sub>laser</sub> -Z <sub>GPS</sub> down | Z <sub>laser</sub> -Z <sub>GPS</sub> up |
|-------|--------------------|-----------------------|---------------------|---------------------------|-------------------------|---|---|
| 11,46 | 0,56               | 0,54                  | 0,70                | 0,03                      | 0,04                    | 0,01                                      | -0,15                                   |
| 10,18 | 0,58               | 0,63                  | 0,69                | 0,02                      | 0,03                    | -0,05                                     | -0,11                                   |
| 9,27  | 0,54               | 0,57                  | 0,55                | 0,02                      | 0,02                    | -0,03                                     | -0,01                                   |
| 8,17  | 0,49               | 0,49                  | 0,56                | 0,02                      | 0,02                    | 0,00                                      | -0,07                                   |
| 7,07  | 0,45               | 0,47                  | 0,51                | 0,02                      | 0,03                    | -0,02                                     | -0,06                                   |
| 6,06  | 0,43               | 0,45                  | 0,47                | 0,02                      | 0,02                    | -0,02                                     | -0,04                                   |
| 5,05  | 0,39               | 0,38                  | 0,37                | 0,03                      | 0,03                    | 0,01                                      | 0,02                                    |
| 4,24  | 0,32               | 0,34                  | 0,30                | 0,02                      | 0,02                    | -0,02                                     | 0,02                                    |
| 3,31  | 0,21               | 0,22                  | 0,28                | 0,02                      | 0,03                    | -0,01                                     | -0,07                                   |
| 2,08  | 0,10               | 0,15                  | 0,15                | 0,05                      | 0,02                    | -0,05                                     | -0,05                                   |
| 0,00  | 0,00               | 0,00                  | 0,00                | 0,03                      | 0,02                    | 0,00                                      | 0,00                                    |



Graph 1. Profile 1 – Visualization of the measurements

Table 2. Profile 2, measured by laser and GPS in meters [m]

| X    | Z <sub>Laser</sub> | Z GPS | GPS Error | Z <sub>laser</sub> -Z <sub>GPS</sub> |
|------|--------------------|-------|-----------|--------------------------------------|
| 0,00 | 0,00               | 0,00  | 0,020     | 0,00                                 |
| 1,40 | 0,01               | 0,00  | 0,023     | 0,01                                 |
| 2,77 | 0,04               | 0,03  | 0,023     | 0,01                                 |
| 5,07 | 0,26               | 0,27  | 0,023     | -0,01                                |
| 6,45 | 0,37               | 0,40  | 0,023     | -0,03                                |
| 7,91 | 0,44               | 0,43  | 0,023     | 0,01                                 |



Graph 2. Profile 2 – Visualization of the measurements

In the last test, the measurements were made over an almost flat slab of concrete. In this situation, the altitude was almost constant, as shown in the graph 3 and the table 3.

## 6. Conclusions

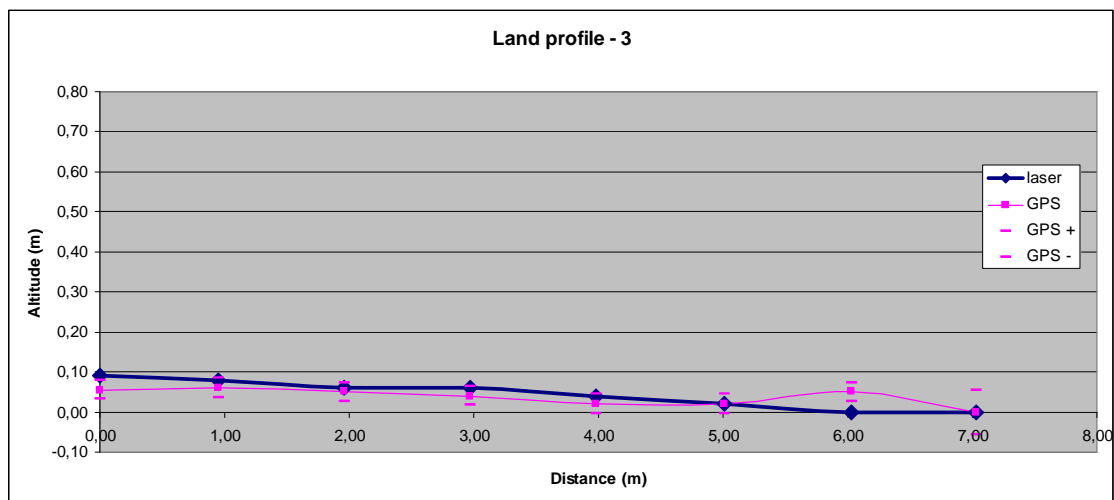
In all tests, the error shown by the GPS receiver was similar with the difference from the measurements made by the GPS and by the laser ( $Z_{laser}-Z_{GPS}$ ).

Aware of the factors that may affect the altitude measurements made by the GPS receiver, this results are considered satisfactory for the proposed application.

As an example, in the third test, the GPS system was able to map the soil profile almost as precisely as the laser system. This exceeds the needs of the ditch amelioration machine. Even in the worst situation, where the difference between the laser and the GPS measurements was 15 cm, the result is satisfactory for the proposed application.

Table 3. Profile 3, measured by laser and GPS in meters [m]

| X    | Z <sub>Laser</sub> | Z GPS | Error GPS | Z <sub>laser</sub> -Z <sub>GPS</sub> |
|------|--------------------|-------|-----------|--------------------------------------|
| 0,00 | 0,09               | 0,05  | 0,020     | 0,04                                 |
| 0,95 | 0,08               | 0,06  | 0,024     | 0,02                                 |
| 1,96 | 0,06               | 0,05  | 0,024     | 0,01                                 |
| 2,97 | 0,06               | 0,04  | 0,024     | 0,02                                 |
| 3,98 | 0,04               | 0,02  | 0,024     | 0,02                                 |
| 5,01 | 0,02               | 0,02  | 0,024     | 0,00                                 |
| 6,03 | 0,00               | 0,05  | 0,024     | -0,05                                |
| 7,03 | 0,00               | 0,00  | 0,055     | 0,00                                 |



Graph 3. Profile 3 – Visualization of the measurements

In the real operation of the ditch amelioration machine, which moves slowly on the ditch, the expected randomness of the error, will prevent high irregularities in the ditch slope. Even in the presence of small punctual irregularities (1-20 cm) in the ditch, the flowing water and the soil deposition will easily eliminate them, flattening its slope and allowing the smooth water flow.

Besides that, the dimensions of the machine and the correct placement of the receiver in the machine may have impact in the final accuracy of the system, so further tests must be performed in the real size model to confirm these results.

## 7. Bibliography

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