COMPARISON OF A MULTILATERAL-BASED ACQUISITION WITH TERRESTRIAL LASER SCANNER AND PROFILOMETER TECHNIQUE FOR SOIL ROUGHNESS MEASUREMENT

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1. INTRODUCTION

The traditional methods for measuring soil roughness have been based on the acquisition of altimetry profiles which could vary in length from a few tens of centimeters to several meters. Other approaches have been done using different techniques (photogrammetry, ultrasounds, plot scanner,...) to acquire the altimetric information from a bidimensional area [1].

Soil roughness is usually described using statistical estimators that allow assigning a numerical value to the altimetry records got from field measurements. Among the most used estimators are the standard deviation of heights (s) and the autocorrelation length (l) [2]. Both values can explain how the change of heights is in relation to a reference surface and how this variability is spread across the surroundings.

The advantages of profile-based methods are that the acquisition is fairly simple and controlled. It is usually done by measuring the heights on a vertical axis, i.e. perpendicular to the ground, which means that the estimation of statistical parameters is relatively simple with solely removing the general trend of the terrain. Furthermore, it is a very common method, so there is huge technical literature that supports the method.

Anyway, the measurements based on profiles have several drawbacks. Some authors [2] are skeptical to agree that a three-dimensional surface like the real surface of the ground, could directly be modeled from information obtained through profiles. In this sense, the consistency of s and l to define a surface is questioned regarding the minimum number of samples to acquire, the adequate length of the profiles, the right orientation, etc...

In the case of methodologies based on acquiring three-dimensional plot [1], most of the studies are limited to small areas (several square meters) and they have the handicap that extrapolation of values to a bigger area is quite limited.

The technology called laser scanner, still in a consolidation phase, allows acquisition of large volumes of information as three-dimensional point clouds [3, 4]. This technology, used in the Terrestrial Laser Scanner (TLS), allows acquiring terrestrial point clouds with a reasonable investment in equipment. For each measured point, the device records at least three values: horizontal angle, vertical angle and the distance. The current TLS options features two different approaches to calculate the distance between the device and the measured point: the technology called 'on-the-fly' is based on the elapsed time between transmission and reception of the pulse. The elapsed time, multiplied by the velocity of the light pulse gives double the distance value. The technology called 'difference of phase' gets the distance using the correlation between the emitted wave and received.

2. OBJECTIVES

The main aim of this work was to establish if there was an agreement in the soil roughness estimators when the acquisition of altimetry information is made by TLS versus the traditional profilometer technique. Both techniques are very different in acquisition, resolution and methodology of processing so a deep analysis must be considered. Measuring roughness using TLS is an innovative method because it is possible to get a three-dimensional surface of an area quite bigger than previous approaches. Anyway, such a huge area is not possible to be measured with the same conditions than profilometer does. So profilometer dataset would be considered as reference data, and TLS dataset is compared to carry out the consistency of TLS for soil roughness estimation.

3. EXPERIENCES, MATERIAL AND METHODS

Two different experiments have been done. First of them was located in the experimental fields of the Public University of Navarre (UPNA), Pamplona (Spain), on October 2008. Six different plots (20x20 m^2) were used. Each plot had a different type of roughness caused by a different type of tillage. Profilometer roughness were carried out using a Profilometer roughness measurements were carried out using a 5 m long profilometer, with a 5 mm horizontal resolution, developed at UPNA. [5] Eight roughness profiles (4- along tillage direction and 4- across) were measured in every plot. An on-the-fly based TLS was used (Trimble GS200) in the same plots. It was set for horizontal and vertical angle of 0.001 radians (20mm at 20m) and four scans were acquired for every plot according the cardinal directions (north, east, south, and west which coincide with the tillage direction).

The second experiment was located within the GRAJO experimental site [6] for July 2009 in the REMEDHUS field site. Three different bare plots (4x10 squared meters) were used: (1) a very smooth soil, (2) a soil with longitudinal furrows and (3) a soil with transversal furrows. Seven longitudinal profiles with a length of 5 m, and 7 transversal profiles with a length about 4m were measured with the UPNA profilometer. A TLS based on difference of phase (FARO Photon 120) was used for this work. The TLS's resolution was set for 0.0009 radians (9mm at 10meters) taking 6 different scans around every plot.

Several nails were used to mark the beginning and the end of each profile of the profilometer and its co-ordinates were calculated by trilateration. These positions were later used to extract the altimetry information from the point cloud acquired by the TLS and to can correlate dataset from both instruments.

Multilateral acquisition [7] is based on measuring the same area from different points of view (normally from different cardinal directions). This methodology tries to minimize the occlusions that soil produce itself when

TLS is acquiring soil roughness. This method is also proposed because it can reach a bigger area than traditional approaches avoiding the roughness disturbation working outside of the area of interest. This approach requires merging the point clouds from every isolate station, into a unique point cloud containing the records from all of the directions. To fix the fusion it is necessary to locate several points as tie target.

4. RESULTS

Traditionally *s* and *l* values derived from an altimetric profile has been a fairly trivial task, but when the process is carried out on point clouds with several millions points the challenge could be an awkward problem. On-the-fly TLS had more than one million of records for each 20x20m^2 plot, and every scan in difference of phase TLS were about 64 millions of points to process.

There is a great difference between the acquisition of the profilometer and the TLS acquisition. Profilometer uses a distance meter taking vertical measures along a horizontal profile. Its data is a vector of altimetric records with a fixed resolution at ground. Meanwhile TLS dataset is a fusion from different scans, being every scan a different resolution depending the orientation and range between TLS and area of interest. Original TLS dataset is not a regular grid but a point cloud with records from different directions and ranges. So TLS dataset has an inhomogeneous density of points across the plot and it could affect the estimations [2]. TLS information must be regularized to can get a fixed grid. An interpolation process passes from a point cloud to a fixed grid but the interpolation process acts like a smooth filter.

The fusion process is an important step. Our previous experience [7] showed that it is a good distribution to use at least four spheres located in the corners when the plot of interest is a square or a rectangle. With it, each sphere can be seen from each scanner laser station avoiding problems of visibility and averaging the global distance between TLS device and spheres. However, to use as many spheres as possible is recommended. It depends on the size of the plot and, overall, the technical characteristics of the TLS. Eight spheres for the 20x20m^2 plot and six spheres for 4x10m^2 plot were used to merge the different scans successfully.

Normally TLS data have a higher altimetric variation than profilometer. It could be because TLS dataset is coming from different stations and the fusion process adds some additional error. Moreover, an artificial bias derived from *trail error* [8] is affecting every scan with different intensity and direction.

When the comparison tries to get soil roughness estimators from profilometer and TLS, there is a high degree of dispersion between both datasets. The profilometer acquired a point exactly each 5 mm following the profile. Meanwhile TLS does it at irregular intervals within a buffer around the profile. For the same profile, the differences between *s* and *l* when they are calculated from one or another instrument are globally quite good (differences are within 5-10%) Anyway we detected several profiles where differences are bigger than expected. Gross errors are difficult to control and maybe these profiles were being affected. However, when *s* and *l* parameters are calculated using only profilometer dataset in parallel profiles, we have also detected some profiles have a different behavior than expected.

However, the analysis is open yet. A further study must be done. Data-mining analysis could be a solution to avoid gross errors and to assess a more robust solution.

5. CONCLUSIONS

The amount of information acquired by the terrestrial laser scanner becomes a *tsunami* of three-dimensional points with multiple possibilities. For soil roughness, the advantage of TLS compared to more traditional techniques is the high volume of three-dimensional information can be obtained in a relatively short time.

As disadvantages, we detects the measure is related to the perspective between TLS and terrain. This perspective is not the most appropriate (being angles of incidence very acute because TLS cannot be located with an incidence angle normal to the ground), which impairs substantially the measure because of the irregularities of the soil itself occludes the proper measure. Additionally, quantitative analysis is complex because of points with gross errors or scans with systematic errors. Both problems are difficult to detect.

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