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Soil Surface Profile Computation using Portable Profile Meter with Image Processing and Tracking Technique

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Abstract- New measurement method for soil surface profile has been described in this study. This method includes new designed soil profile meter, digital imaging equipment and image tracking & analysis software. Using such modified soil profile meter can help to observe and measure changes occur in irrigation channels, small ditches and to quantify changes at specific cross sections within soil furrows. By using image processing and tracking system we can trace marked points in fixed level of meter pins, these points have vertical displacements and vary according to existing profiles and cross-sectional shape in different locations, which give us ability to record presented form of different profiles. The modified profile meter used to measure and track changes in different profiles; two types of ditches and two types of furrow. The recorded profiles heights for different locations gave us perspicuous knowledge about the geometry of furrows and ditches shapes before and after seasonal irrigation process. The differences in measurements for same locations and sites have been noted. Designed soil profile meter successfully demonstrated changes in profiles pattern due to surface irrigation erosion in term of height variations, for shallow and wide ditches, the differences in measured heights by soil profile meter after and before the irrigation generally ranged from 0 to 11 mm, while in deep ditches, differences in heights ranged from 0 to 44 mm. With ridge profiles, soil profile meter tracked variation in measured heights from 0 to 13.88 %, also, high percentage of variation obtained by studying flat top bed furrow changes, the largest percentage was 17.1 % at beginning of the furrow line. This clarifies the ability to track and record erosion effect in different furrows and ditches by using soil profile meter as a part of used image processing and tracking system.

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I. Introduction

Improvement in furrow irrigation performance and reduction of soil erosion due to furrow irrigation erosion are very important and always connected with the way we measure furrows and ditches profiles. Different studies on furrow irrigation have been carried out to reduce water losses and erosion related to furrow irrigation, parameters such as furrow stream size, field slope, furrow length, soil type, plant coverage and soil density have been studied (Leib et al., 2005; Szögi et al., 2007; Silva, 2006; Younts et al., 2003 and Mintesinot et al., 2004).

Each type of tillage tool and ditch creating method generate a characteristic oriented roughness and profile pattern which is relatively easy to quantify using simple geometric models. Many common techniques for collecting soil surface data and the analysis of the respective dataset have been discussed. Pin meters are the devices most widely used for their simplicity. They consist in a single probe or a row of probes spaced at pre-established intervals and designed to slide up or down until the tip just touches the soil surface. Pin positions are recorded either electronically or manually (Römkens et al., 1986 and Wagner & Yiming, 1991). The chief disadvantage to this technique is its destructive impact on the soil surface while recording data in the field. Kornecki et al. (2008) designed and tested a portable meter under typical field conditions; the tool can measure depths up to 500 mm and easily be modified for usage with large ditches. The device was successfully employed after rainfall events to assess soil erosion/deposition from quarter-drains. Measuring soil profiles by Laser technology generates also had very good laboratory results, but its field use is limited because sunlight and hidden forms or shadows interfere with the readings, while high temperatures affect the performance of the sensitive measuring devices involved (Pardini, 2003; Darboux and Huang, 2003). Moreno et al. (2008) conducted study to develop a new method for measuring soil surface roughness that would be more reliable by using the principle underlying shadow analysis is the direct relationship between soil surface roughness and the shadows cast by soil structures under fixed sunlight conditions. They showed that shadow analysis yielded results significantly correlated to the pin meter findings, but with the advantage that the time invested in gathering field data was 12 to 20 times shorter. Another work has been carried out by Borselli and Torri (2010) in order to reproduce reliable rough surfaces able to maintain stable, un-erodible surfaces to avoid changes of retention volume during tests by a set of roughness indices was computed for each surface by using roughness profiles measured with a laser profile meter, and roughness is well represented by quantiles of the Abbot–Firestone curve.

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Image analysis techniques have recently been employed to measure different soil parameters e.g. two-dimensional displacement vectors in soils obtained by a block-matching algorithm (Guler et al, 1999), however, this algorithm is incapable of tracking individual particles, let alone their rotations. Several algorithms have been developed to track soil particles and measure their movements by detecting the edges of individual soil particles. Hu and Pu (2004) observed the displacement distribution in the soil near the structure using photographs and discussed the thickness of the sand–steel interface. Classical roughness parameters such as root mean square of the heights, correlation length and tortuosity are estimated on the digital elevation models (DEMs) of the database by Taconet and Ciarletti (2007) and the study showed that stereo photogrammetry provide DEMs that enable accurate studies of the geometrical properties of soils that can definitely be of use for hydraulic and erosion studies. So, using image analysis and proper tracking codes with the new manufactured soil profile meter could be effective way to calculate the final shape and geometry of soil surface profiles.

II. Material and Methods

Soil profile meter has been developed to determine specific cross sections and furrow profiles in ditches and soil, new futures were added to soil meter to overcome some existing problems related to error measurement in fields. The main concept used with soil meter is to manufacture movable, stable and precise device to measure soil profile and ditches cross-sections without deformation, designed profile meter came with attached wheels to give smooth movement on ditches sides or within soil furrows, this movement ability can be used in field during manually recording of data sets or can be replaced with modified one. For more stability and adequate measurement, it was important to provide a modified frame with tighten methods for movable parts in the soil profile meter.

Based on above mentioned points, the manufactured soil profile meter consisted of a frame holding multiple equally spaced (every 50 mm) stainless-steel pins (2000 mm long) that can be easily positioned and fully controlled by two rows of tie-bolts. Soil profile pins can move freely under gravity or be fully controlled at the time we measure sensitive profile surfaces. The pin housing consisted of two pairs of parallel aluminium bars with 950 mm length and 850 mm height, both sides are fixed together and mounted as a frame with 2 pairs of double wheel in each side (Fig. 1). The aluminium pins were located between the aluminium housing; these bars can be easily modified or replaced with another set of different diameter pins. Hydrostatic balance tool was attached to main frame to provide sufficient levelling.

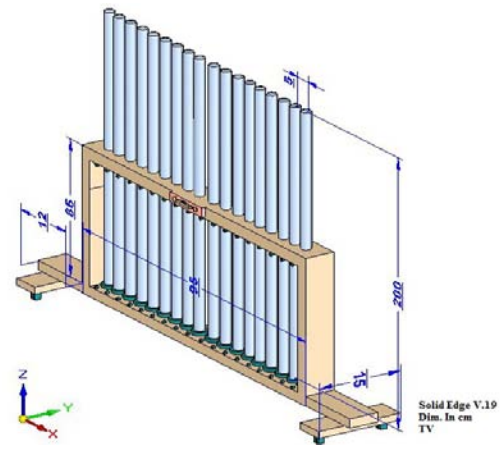

Figure 1 : Trimetric view of constructed soil profile meter

a) Image acquisition and analysis

The video and pictures for image analysis were taken by a high resolution video camera (Sony DCR-HC54E -40x optical zoom/2000x digital zoom) video camera was connected to laptop on the site of measurements as shown in Fig. 2., there is continuous video recording of soil profile meter in different locations and sets of images can be generated by using image tracking and analysis software. Practical implementation of video and image processing done by using Open CV program as a software library projected with Microsoft Visual C++ 2010 Express. Different codes used to simply access, display and trace specified marked points within images. The software classes provide C++ video recording and images capturing from video as first step for the process.

Figure 2 : Camera and sets used in experiments.

b) Tracking soil profile meter

At the time we need to record and determine profiles at fixed location, manually we can adjust pins in soil profile meter above required position without disturbing the profile form. In this case we need only to generate pictures of profile meter after and before adjusting its pins, two pictures will be generated and enough to make a comparison between them to read and analyze the vertical distance of marked points along with profile meter pins.

c) Locations, Profile measurement and differences

The designed profile meter was fabricated in January, 2012 and it used to measure different profiles before irrigation processes same year in February and again after complete irrigation season in May 2012 for fixed marked points along with the furrows and ditches. Two locations have been located in two different places, two types of ditches and two different furrows after soil preparation were noticed and marked, in each location one type of ditch and one type of furrow have been chosen. Sketching of profile geometry was done for each ditch and furrow in three different sites along with their length, these sites covered start, middle and end point of their length. Data recorded two times after and before running surface irrigation to address the change occurred in profiles and the distribution of soil erosion along subsections of ditches and furrows. Two common types of ditches were taken as ditches profile example, one type is normally made shallow and wide, and the other one made by farmers and it is deep and has no sidelong edges. Also, two type of soil furrows were profiled, ridges and flat top beds.

III. Results and Discussion

a) Images and distance differences of soil profiles

Different images generated in laboratory (Fig. 3) and field (Fig. 4) to test the concept and to adjust the image tracking and analysis software. Calibration was needed to calculate the distance constant, this constant is important to convert the distance in pictures to the actual field distances. By using Open CV program as a software library projected with Microsoft Visual C++, the marked point in each profile meter pin were clear and appeared in specific position with certain coordinates as long as the profile meter and the camera are in one fixed position Fig. 3, these coordinates can be stored to be compared directly with the new coordinates in second picture. As the soil profile meter pins moved, the distances were calculated according to the new coordinates; the distances due to marked point's movement were converted to actual field measurements to be used in drawing and to determine the soil profile geometries. Fig. 4 shows how the soil profile meter appeared in one of generated picture.

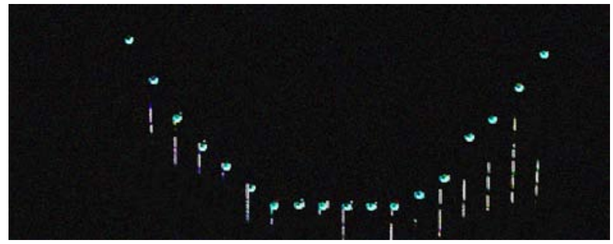

Figure 3 : Example of picture obtained during laboratory adjustment and calibration for image tracking and analysis software

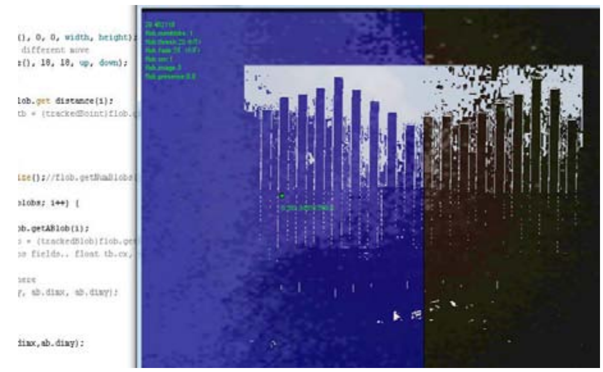

Figure 4 : Generated picture of soil profile meter with its pins in the field

b) Analysis of soil profile geometry for ditches

All measurements done by soil profile meter presented in terms of 3-D area charts. For location 1, the geometric shape of shallow and wide ditch in three different sites along with its length before and after seasonal surface irrigation presented in Fig. 5 a. at the beginning of the ditch, site 1, the maximum differences in measured height by soil profile meter concentrated in bottom of the ditch with 10, 11 and 9 mm, that's mean there is erosion occurred and affected the origin cross-section of the ditch, while in both sides of the ditch the differences in measurements after and before surface irrigation were less, 7 and 5 mm were maximum changes in readings in both sides after and before surface irrigation. In some points, there was decreasing in profile meter reading for the same point after and before irrigation, that's mean more sediment in ditch side, it was low but it was measurable, the reason may be due to accumulative of some water residue or mud in these points. At the middle of the ditch, same pattern for erosion effect but the changes occurred in soil profile meter readings were similar in bottom and sides as well. At the end of the ditch, the bottom reading by soil profile meter recorded very less change in the center of the ditch and also changes around the center, maybe due to slow water streaming at the end of the ditch made the effect of water erosion less, the changes recorded in end of the ditch generally were lower than changes notices for middle and beginning of the ditch.

For second type of ditch which was deep and has no sidelong edges in location 2, changes in side measurements for it were very less due to its special constructed shape (Fig. 5 b), but there were changes in bottom of the ditch after surface irrigation in all ditch sites, the maximum changes in reading obtained in the beginning where the differences in soil profile meter measurements were high. The values of profile meter differences reached 44, 42 and 34 mm around center point at the beginning of the ditch, while maximum difference in profile meter reading was 30 and 25 mm for center point at the middle and the end respectively.

As a comparison between erosion behaviors in above mentioned ditches, the changes occurred in the ditch in location number 1 were less and the differences in soil profile meter readings were little compared to location 2, that was because of water erosion effect was less also in location1.

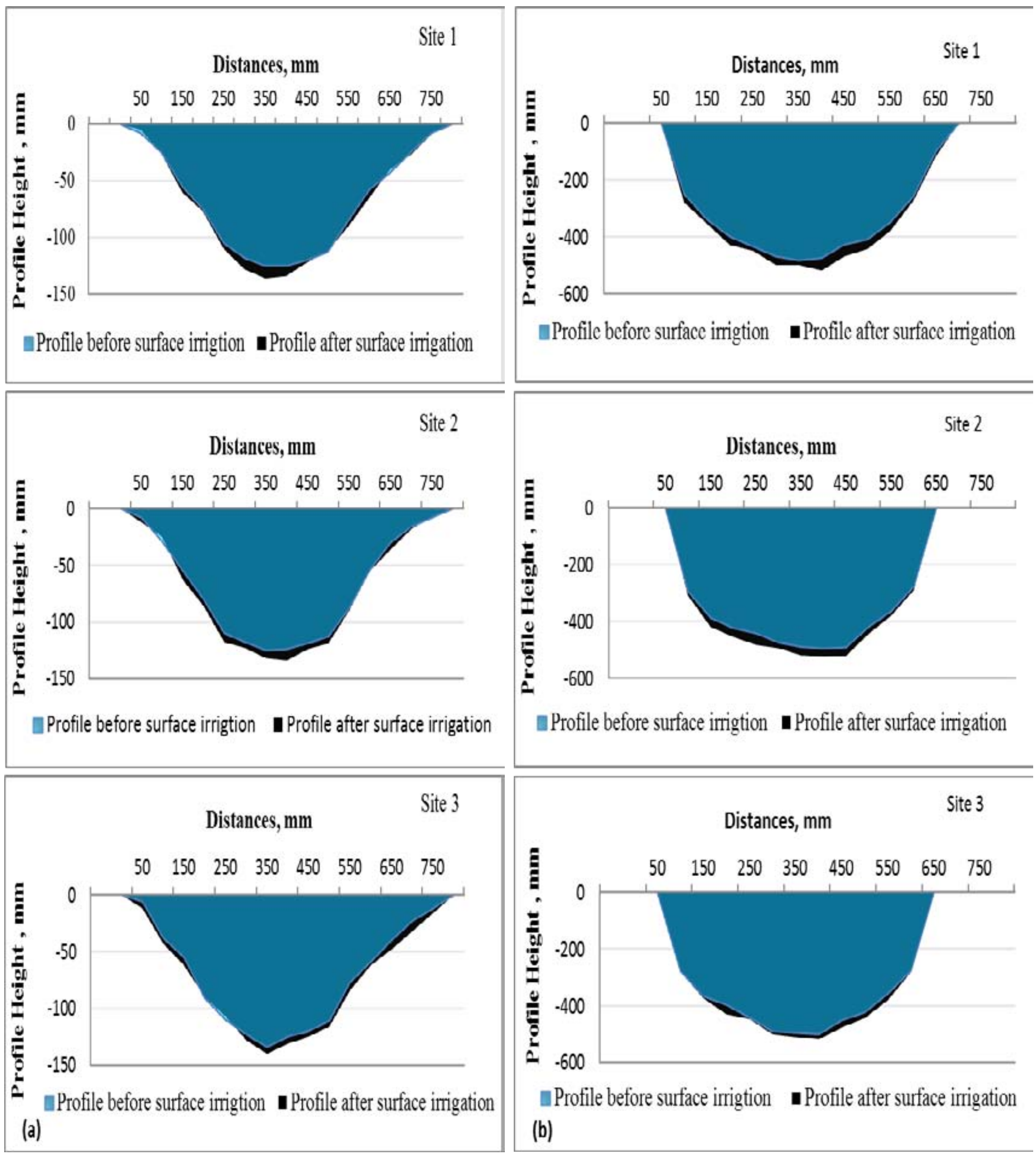

Figure 5 : Differences in Geometric shape between origin and formed ditch after surface irrigation for three different locations: (a) shallow and wide ditch in location 2 (b) deep and has no sidelong edges ditch in location 1

c) Analysis of soil profile geometry for ditches

For ridge in location 1, after using soil profile meter to measure different ridge profile points on the surface, the geometric shapes in Fig. 6 a showed that there was erosion effect along with ridge length in end, middle and beginning of the furrow. The maximum differences in measurements were about 25 mm at the beginning in the bottom followed by 22 and 15 mm for the middle and end of the furrow respectively. The differences in readings recorded by the soil profile meter for the furrow sides were very less in all furrow sites, and there were six points on ditch sides gave same profile meter reading before and after surface irrigation. For flat top bed furrow in location 2 (Fig. 6 b), same pattern was observed from data, where in the beginning of the furrow line there was maximum difference in profile meter reading followed by the middle of the furrow then the line end. Major changes done around center points in furrow bottom, but changes in both sides of the furrow were less maybe because running water in furrow remain only in bottom and don't cover all side height.

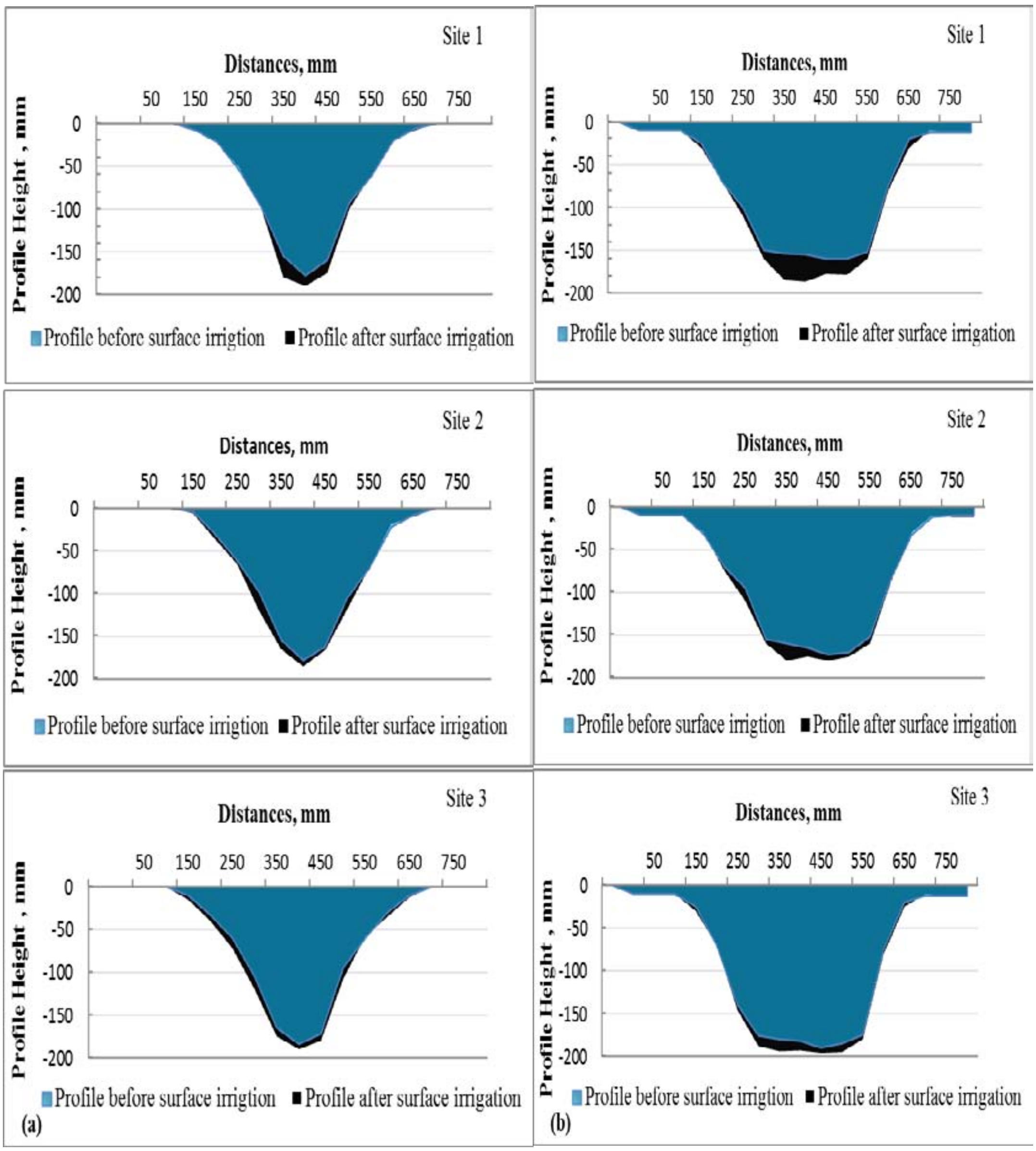

Figure 6 : Differences in Geometric shape between origin and formed furrow after surface irrigation for three different locations (a) ridge profile in location 2 (b) flat top beds in location 1

IV. Conclusion

Using soil profile meter to record different soil profiles is an effective method to which can refer to any changes could happen in soil surface. It was clear that the modified soil profile meter gave adequate results to measure different heights for different profiles, and this gave us idea about the changes happened in different locations related to seasonal surface irrigation in land. Using image tracking and analysis technique was very operative method to measure soil profiles with minimum under different conditions. In addition, designed profile meter is very flexible and can be used for a wide range to measure different type of furrows, ditches, rills and drainage canals.

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