# Spatial variability of seed depth placement of maize under no tillage in Alentejo, Portugal

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## Abstract

Among the various factors that contribute towards producing a successful maize crop, seed depth placement is a key determinant, especially in a no-tillage system. The main objective of this work was to evaluate the spatial variability of seed depth placement and crop establishment in a maize crop under no-tillage conditions, using precision farming technologies. The obtained results indicate that seed depth placement was significantly affected by soil moisture content, while a very high coefficient of variation of 39% was found for seed depth. Seeding depth had a significant impact on mean emergence time and percentage of emerged plants. Shallow average depth values and the high coefficient of variation suggest a need for improvement in controlling the seeders sowing depth.

## Keywords

maps, maize, no-tillage, seeding depth, sensing

## Introduction

Understanding crop spatial variability leads to improved crop management. Among the various factors that contribute towards producing a successful maize crop, seed depth placement is a key determinant. Although there has been much research about maize planting depth, it is important for maize farmers in Alentejo, a major region in the south of Portugal, to carry out seed depth studies, especially due to the Mediterranean conditions of soil and climate and the commonly applied practices of conservation farming systems, such as no-tillage. Alentejo, which under the Köppen-Geijer climate classification, has a *Csa* climate, is characterized by hot dry summers and cold wet winters. In this climate, the intrinsic properties of Mediterranean soils are very much influenced by their physical characteristics. Soil texture is an important property, particularly because it affects the soil moisture retention profile and extend the period with available moisture for the crop. Unfortunately, some deforestation, traditional grazing practices and conventional tillage systems, have altered the physical properties of the soil, contributing to chemical and biological changes, reducing pH and soil organic matter, and thus affecting crop yield. Conservation farming systems, especially no-tillage practices, not only reduce energy consumption, and soil erosion (Tabatabaeefar *et al*., 2008; Carvalho & Basch, 1999) but also improve crop residue retention (Govaerts *et al.,* 2009) and as a result, the total soil carbon content (*Basso et al*., 2011). Sá (2004) studying phosphorus fertilization in a no-tillage system found that after ten years of no-tillage practice there is a significant increase in soil density and soil carbon, phosphorous, organic matter and nitrogen content. According to FAO's Conservation Agriculture and AQUASTAT programs, in Portugal, in 2011,

conservation farming was carried out on 32000 ha (FAO, 2013) with maize crop being the main irrigated crop under this practice (INE, 2011). When considering the influence of seeding operation on maize crop yield, it must be noted that seed emergence uniformity has a higher correlation with vertical distribution of seeds than with their horizontal distribution (Liu *et al*., 2004).  Many studies have been conducted on seeding depth placement as described by Karayel and Ozmerzi (2008). Also, Abrecht (1989), demonstrated the effect of sowing depth and firming wheel pressure of a no-till planter on the emergence and growth of seedlings for different crops, concluding that, in maize, deep planting slowed emergence but increased seedling growth. Özmerzi *et al.* (2002) considering the effect of maize seeding depth on precision seeder uniformity, demonstrated that the least emergence time was achieved in 7.7 days with the shallowest sowing depth of 40 mm.  Tolon-Becerra *et al.* (2011) studied the effects of different tillage regimes on soil compaction and observed that maize seedling emergence was slower under conventional tillage systems, when compared with direct seeding. In the same study Özmerzi *et al.* (2002) also concluded that the maximum emergence rate was achieved when the nominal sowing depth was increased from 40 to 60 mm. Neto *et al.* (2007) evaluated maize seed depth placement in 38 farms by measuring mesocotyl length, and observed significant differences between rows in 21 areas and a 20% coefficient of variation.  It is recommended that maize seed depth placement should be based on the conditions of the seedbed. Depending on soil texture and moisture, Fancelli (2000) suggests that maize seed depth placement should be between 30 to 50 mm in clay soils and between 40 to 60 mm in sandy soils. Placements shallower than 30 mm increase the risks of drying of the seedbed, especially in sandy or loam textures, while deeper  mesocotyl elongation can be stopped by superficial soil crust. Although no-tillage seeding equipment is prepared for use on undisturbed soil, compaction may affect soil resistance to penetration. According to Garcia *et al*., (1999) there is a high correlation between soil resistance and soil moisture content. The aim of this research was to evaluate spatial variability of seed depth placement under no-tillage conditions in a non-controlled experiment at a farm in the Alentejo region, using precision farming technologies, such as GPS and aerial remote sensing. Correlation between seed depth placement and some vegetative and growth parameters of the maize crop were also evaluated.

**Materials and methods**

The 2.5 ha field surveyed is irrigated by a center pivot, and located at Lobeira farm, Montemor-O-Novo, Alentejo region (38º47'17"N 8º17'44"O, 143m), with a spring maize crop planted in May 2012. According to the FAO classification, the soil is a Cambisol, which corresponds to a homogeneous area of clay loam texture, sampled at a 0-10cm depth, from 16 georeferenced points on a 1500 $m^2$ square grid with a portable Magellan Mobile Mapper CX redeiver, with differential correction signal (DGPS), providing a position accuracy of 15 to 20 cm. Three samples were taken from each point. Average values of texture, gravimetric moisture, soil organic matter, crop residue, pH, phosphorous, potassium and bulk density data are presented in Table1. Texture was determined by Bouyoucos hidrometer method, volumetric moisture content was determined following the protocol described by Gardner (1986), organic matter by Wackley-Black protocol, pH by a potentiometric method using a 1:2.5 dilution of soil to water and phosphorous and potassium by Egner-Riehm protocol. Bulk density samples were taken with a 50mm diameter ring and determined by dividing soil dry weight at 105°C by the mass of water that would occupy the volume of the ring. Although in the

last two years maize grew in monoculture, the soil management history, since 2004, includes a traditional crop rotation of winter wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) under no-tillage conditions. Thus, maize crop residue was measured using the dried weight of 3 samples, each collected from a $1m^2$ area. Climate is Mediterranean, with an average rainfall and temperature of 6.9 mm and 22.6ºC, respectively, for the region during the period of the experiment. The maize seed used was a FAO 400 hybrid seeds for grain. The direct drill machine used was a three disk machine with a double disc furrow opener, four rows, precision vacuum, Semeato SPE06 with 75 cm row width set to 80000 seeds ha $^{-1}$ and side gauge wheels controlled for up to 50 mm planting depth. The seeder was towed by a John Deere 80 kW power tractor operated at a forward speed of 5 kmh $^{-1}$ (Fig. 1). Sowing operation was preceded by application of a glyphosate based herbicide. At the time of sowing, 7 mm of water was applied. To evaluate soil resistance to penetration, seed depth placement and plant population, samples were taken from 30 georeferenced randomized points.

Table 1. Average values of the soil characteristics in the experimental field.

| FAO soil classification | Cambisol |
|---|---|
| Texture (0 - 10 cm depth) | Clay loam |
| Sand (%) | 45 |
| Silt (%) | 18 |
| Clay (%) | 37 |
| Soil Organic Matter (%) | 2.6 |
| Crop residue (g dry matter m$^{-2}$ ) | 2340 |
| Ph | 6.1 |
| Assimilable phosphorus (mg kg$^{-1}$) | 200 |
| Gravimetric moisture content (%) | 11.2 |
| Assimilable potassium (mg kg$^{-1}$) | 198 |
| bulk density | 1.45 |



Figure 1. Double disc furrow opener vacuum seeder and tractor during the sowing operation and side gauge wheel depth control.

For each located point, data represented the average of four measurements taken to evaluate soil resistance using a Dickey John Soil Compaction Tester with a 12,7mm outside diameter tip and a 35° apex angle in a 0-50 mm depth. The same methodology was used to estimate seed depth placement by measuring mesocotyl length (Neto *et al*., 2007) of four sampled plants. Plant population was estimated by mean emergence time

and percentage of emerged seedlings using equations (1) and (2) (Bilbro & Wanjura, 1982):

$$MET = \frac{N1D1+N2D2+\cdots+NnDn}{N1+N2+\cdots+Nn} \quad (1)$$

$$PE = \left(\frac{total\ emerged\ seedling\ per\ meter}{number\ of\ seeds\ planted\ per\ meter}\right) \times 100 \quad (2)$$

where $N$ is the number of seedlings that had emerge since the previous counting and $D$ is the number of post-planting days. A week after crop emergence a selective herbicide for broadleaf weeds and grass was applied and aerial photos of the georeferenced field were taken using an RGB camera (Panasonic Lumix DC Vario, 10.1 Mpixel, CCD) assembled in an unmanned aerial vehicle flying approximately at 500 m altitude with a spatial resolution of 5 cm. On a 5 x 5m square grid, crop cover percentage was determined from the vegetative fraction using the excess green technique (Mayer *et al.,* 1999). With this technique an image of green prevalence is generated, and the vegetation fraction obtained as a ratio of the number of green pixels to the total of the pixels in the image. Parameters were described using mean, standard deviation, coefficient of variation and correlation values. To determine the influence of soil moisture and seed depth placement, collected data were subjected to analysis of variance using (IBM SPSS Statistics version 19.0,August 2010). Seed depth placement, soil moisture content and crop coverage percentage maps were created with ArcView software, version 9.0 and using inverse distance weighting interpolation method.

**Results**

Spatial variability of seed depth placement for no-till maize sowing was analyzed concerning soil resistance to penetration, soil moisture content, mean emergence time (MET) and percentage of emerged seedlings (PE). Seed depth placement, MET and PE seedlings were analyzed to determine significant differences in the variability of the parameters. Seed depth placement and soil resistance to penetration presented a negative correlation as shown in Figure 2.
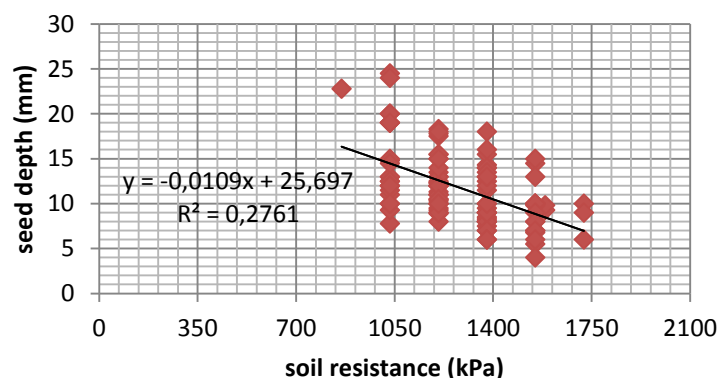


Figure 2. Relationship between seed depth (mm) and soil resistance to penetration (kPa) throughout the experimental field.

Spatial variability maps of seed depth placement and soil moisture content are represented in Figure 3. Black points represent sampling locations within the field; A and B identify the two major areas of classes of seed depth placement observed, 46%

and 50%, respectively. Influence of the average values of soil moisture content was determined for main seed depth areas A and B.
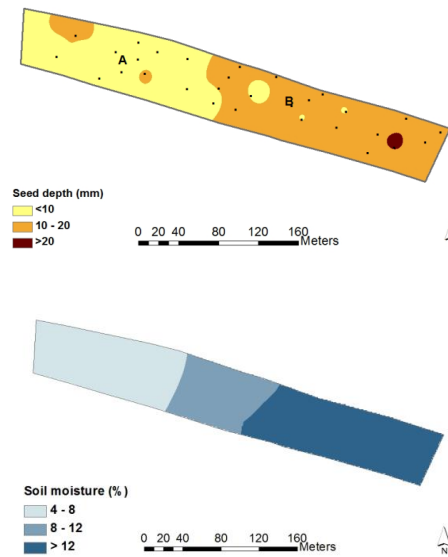


Figure 3. Spatial variability maps of seed depth placement (above) and soil moisture content (below).

Differences in seed depth placement are represented in the box-plot diagram in Figure 4.
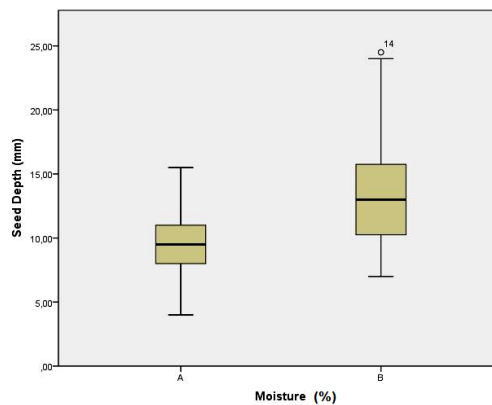


Figure 4. Average values of seed depth placement and corresponding standard deviation for soil moisture content, with average values of 7.2 % and 15.1%, respectively, in experimental field areas A and B.

Pearson's correlation values of seed depth placement with mean emergence time and percentage of emergence are given in Table 2 and Figure 5.

Table 2. Pearson's correlations for seed depth placement, mean emergence time (MET), and percentage of emergence (PE).

|  | Seed depth | MET | PE |
|---|---|---|---|
| Seed depth | 1 | 0.394 ** | 0.283 ** |
| MET |  | 1 | 0.268 ** |
| PE |  |  | 1 |

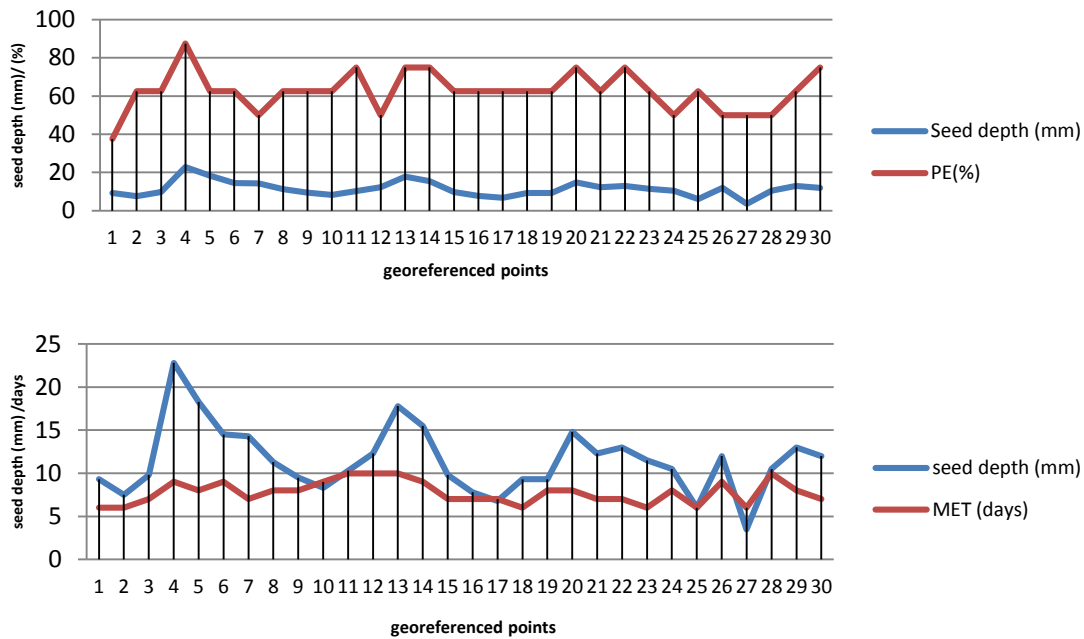correlations are presented with level of significance of ** p <0.01

Figure 5. Graphical representation of the relationship between seed depth, MET and PE.

Figure 6 shows the sub areas needed to edit the total field real image and spatial variability of crop cover, based on the different green reflectance prevalence.
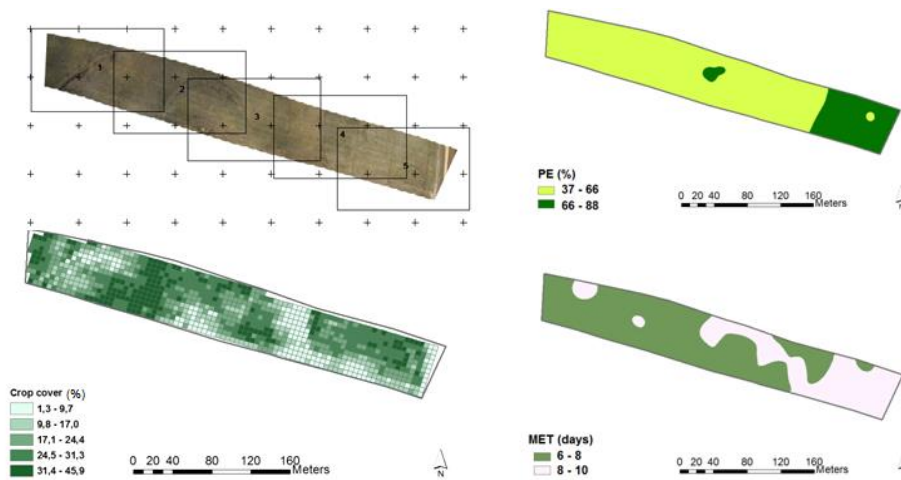


Figure 6. RGB image of the crop field after emergence (above, left) and spatial variability of crop cover (below, left) 17 days after sowing and PE (%,) (above, right) and  MET (days), (bellow, right).

## Discussion

The results of the analysis show a shallow seed depth placement distribution, with 23mm as the deepest value, and a high, 39% coefficient of variation. Seed depth placement was negatively correlated with soil resistance to penetration and was significantly influenced by soil moisture content on the sowing date. It is likely that under uniform conditions of soil moisture content and soil texture the seeder would have been able to place the seeds more regularly as the depth control was calibrated to work up to 50 mm. The absence of a dynamic control of depth can be the cause of the high coefficient of variation. Similar results were obtained by Neto et al (2007).

Nevertheless, this results agree with a preliminary trial by Conceição *et al.* (2012) who compared sowing uniformity in different tillage systems, where seed depth placement was negatively correlated with soil resistance with $R^2 = 0.59$. The observed extreme values of soil moisture content were probably due to a technical problem of the center pivot at the time of sowing. Nevertheless, the relationship between soil moisture content and soil resistance is similar to that indicated by Garcia *et al.* (1999). The spatial variability map for seed depth placement shows that seed depth usually very shallow, and two main areas can be identified and related to soil moisture content with soil moisture values of 7.2% and 15.1% in A and B, respectively. The shortest MET was found in the shallowest area with 6.2 days and the longest was in the deepest points with 9.6 days. Pearson's correlations show that seed depth was positively correlated with mean emergence time. Also Tolon-Becerra *et al.* (2011), and Ozmerzi *et al.* (2002) demonstrated that the shortest emergence time was reached in the shallowest depths, and was positively correlated with the percentage of emerged seedlings. In this experiment, the best PE result was found in the deepest zone with 87.5%. Comparing MET and PE, both parameters are significantly positively correlated. Considering that MET determines crop vegetative development, it appears that areas with higher percentage of maize crop coverage are located where, although there were a small number of plants, these were at a more advanced stage of growth, which correspond to areas with shallower depths and earlier emergencies.

## Conclusions

Among the various factors that contribute towards producing a successful maize crop, seed depth placement is a key determinant and because daily working conditions on a farm are rarely ideal in no-tillage systems, seeder equipment must respond constantly to soil physical changes. Under the experimental conditions of this study, seed depth placement was negatively correlated with soil resistance and was significantly affected by soil moisture content. Sowing depth affected positively MET and PE of plants, this probably due to more stable soil conditions at deeper depths. Shallow mean values of sowing depth and a high coefficient of variation suggest the need for improvement of depth control mechanism of seeders or a more accurate operator calibration.

## Acknowledgments

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