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Yield variability related to landscape properties of a loamy soil in central Belgium

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Abstract

A field was investigated with precision farming techniques to delineate zones with different yield potential due to previous soil erosion. Winter wheat (*Triticum aestivum* L.) grain yield, straw yield, biomass and harvest index were measured with a combine harvester. Fuzzy clustering of grain and straw yield provided good delineation of zones in the field with different yield potential. Entropy and fuzziness calculations for different number of classes resulted in a division of the field into five clearly differentiated yield potential zones. Straw yield, biomass and harvest index were significantly different among zones. Grain yield was significantly different for all zones, except for two. Elevation and slope of the field were measured from a global positioning system (GPS) unit on the combine. Both were related to yield variability in the field. Average elevation, slope and soil type were calculated per cluster class. High grain yield, straw yield and biomass could be related to flat, high places in the field with little erosion. Good grain yield, low straw yield and high harvest index were found on relatively steep slopes subjected to erosion. High straw yield and low grain yield were found at low places in the field on relatively steep slopes. Lowest grain yield, straw yield and biomass were located on steepest slopes with high erosion and in depressions where accumulation of eroded soil took place and slumping and crusting of the soil were present. This information suggests that variable management on a site-specific basis would optimize yield and inputs.

Keywords: Erosion; Fuzzy clustering; Grain yield; Loess; Precision farming; Silty soils; Site-specific management; Yield losses

1. Introduction

Soil erosion by water is one of the most severe causes for soil degradation on a global scale (Oldeman et al., 1990). Erosion by water is a yearly recurring problem in Central Belgium and is much more severe than erosion by wind. De Ploey (1986) gives a critical area of 0.2 Mha where the mean loss of soil is at least

Abbreviations: DEM, digital elevation model; DGPS, differential global positioning system; FPI, fuzziness performance index; GIS, geographical information system; GPS, global positioning system; MPE, modified partition entropy; N, nitrogen; S, separate distance; USDA, United Stated Department of Agriculture

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l0 t ha^{-1} $year^{-1}$ and may be up to l00 t ha^{-1} $year^{-1}$. In the loess belt of Belgium and The Netherlands, the problems of water erosion increased steeply during the last 30 years due to large-scale farming, disappearance of retaining elements on the landscape (bushes, trees, roads, etc.), use of heavier and bigger farming implements and the use of commercial fertilizers instead of animal manure (Ruysschaert et al., 2004). A large part of the land in this region has been under intensive cultivation for several centuries and is now mainly used for production of winter wheat (*Triticwn aestivum* L), barley (*Hordeum vulgare* L.), chicory *(Cichorium intybus* L.), potato (*Solatium tuberosum* L.) and corn (*Zea mays* L.) (Deckers, 1997). The amount of soil erosion that takes place in a given storm or year is influenced by intensity of rainfall, soil type and condition, relief of the terrain, soil cover and rooting. Important relief variables associated with soil erosion are slope, grade in concavity or convexity and length of the fields (Govers and Poesen, 1988).

Variation in soil fertility and hydrologic properties across landscapes affects crop yield. Crop yield and soil erosion have been related to elevation and surface curvature (Moulin et al., 1994; Stone et al., 1985). Nolan et al. (1998) showed that simple landscape classification (upper level, shoulderslope, backslope, footslope and lower level) delimited areas with different responses to N fertilization, within a rolling field. Similarly, Khakural et al. (1998) reported that corn and soybean (*Glycine max* (L.) *Merr.*) yields were less on eroded slopes than on nearly levelled summits or at foot/toeslope positions. Corn yield was correlated with A-horizon thickness, surface pH, tillage system and growing season precipitation. Afyuni et al. (1993) found that the footslope produced the greatest corn yield and that yields decreased with progression upslope. Elevation data can be used to interpret spatial and temporal variability of grain yield by separating areas of convex curvature from areas with concave curvature (Timlin et al., 1998). Greater crop yields were obtained in footslope positions compared to backslope and sideslope positions in western Iowa (Spomer and Piest, 1982) and west central Minnesota (Khakural et al., 1996). Salviano et al. (1998) described crop yield as a function of remaining soil depth.

Our objective was to use precision farming technologies to delineate field zones into different yield potential as a function of soil and topography characteristics caused by erosion. We wanted to derive the relationship between yield potential and properties of eroded soils. Site-specific farming involves integration of geographic information systems (GIS), global positioning systems (GPS) and on-the-go data collection devices to assess variability in soil properties, yield and potential profit. This information can be used to alter management on a site-specific basis, rather than using the traditional whole-field approach (Brisco et al., 1998). With information from precision farming technologies one can attempt to identify site-specific field management that will be able to solve or reduce the problem of yield variability, taking into account environmental considerations. Building databases to quantify yield variability will improve the understanding of how various stresses affect plant growth, development or yield, and ultimately lead to optimum site-specific prescriptions (Karlen et al., 1998).

2. Materials and methods

2.1. Study area

The field (7.2 ha) was situated in Leefdaal (50°50′29″N latitude, 4°36′26″E longitude) in central Belgium on sandy-silt soils. A layer of loess from the quaternary period covered the region (Denis, 1992). Soils were formed in this yellow, unconsolidated, soft parent material that is rich in calcium carbonates (Goossens, 1984; Deckers, 1996). Soils composed of small particles would be most likely eroded (Poesen, 1993).

According to the Belgian soil classification system the following soil types were present in the field (Fig. 1):

- *Aba*: well drained silty clay loam soil with argic B-horizon;
- *AbB*: well drained silty clay loam soil with beginning B-horizon differentiation through changes in colour and structure;
- *Abp*: well drained silty clay loam soil on colluviated material.

These soil types on the field could be classified as Haplic Luvisol, Cambisol and Regosol, respectively,