Precision Agriculture, 2, 7–23, 2000

Mapping Grain Sorghum Yield Variability Using Airborne Digital Videography

CHENGHAI YANG cyang@weslaco.ars.usda.gov

USDA-ARS Kika de la Garza Subtropical Agricultural Research Center, 2413 East Highway 83, Weslaco, Texas 78596

GERALD L. ANDERSON

USDA-ARS Northern Plains Agricultural Research Laboratory, Sidney, Montana

Abstract. Mapping crop yield variability is one important aspect of precision agriculture. Combine-mounted yield monitors are becoming widely available for measuring and mapping yields for different crops. This study was designed to assess airborne digital videography as a tool for mapping grain sorghum yields for precision farming. Color-infrared (CIR) imagery was acquired with a three-camera digital video imaging system from two grain sorghum fields in south Texas over the 1995 and 1996 growing seasons. The multispectral video data obtained during the bloom to soft dough stages of plant development were related to hand-harvested grain yields at sampling sites determined from unsupervised image classification maps of the two fields. Significant correlations were found between grain yields and the red band, the green band, and the normalized difference vegetation index (NDVI). Regression equations were developed to describe the relations between grain yields and each of the three significant spectral variables using an exponential model and two segmented models. Multiple linear regression equations were also determined to relate grain yields to the three bands and NDVI. These equations were then used to estimate grain yields at each video image pixel within each field and to generate grain yield maps. Comparisons of the estimated average yields from the regression equations with the actual yields indicated that yield estimation errors from the equations ranged from 0.0 to 10.0% in 1995 and from 0.2 to 7.3% in 1996 for field 1, and from 4.0 to 11.2% in 1995 and 6.3 to 12.5% in 1996 for field 2. Although the equations developed for one field in a given year may not apply to the same field in any other year, the practical value of these relationships is for mapping within-field grain yield variations. The results from this study showed that airborne digital videography, combined with ground sampling, regression analysis, and image processing, could be a useful approach for mapping spatial crop yield variability within fields.

Keywords: digital videography, grain sorghum, image processing, yield variability, yield mapping

Introduction

Crop yields integrate the accumulated effects of many spatially-variable factors such as soil properties, fertilization, topography, and infestations of weeds, insects, and diseases; therefore, a yield map is one of the most important pieces of information for precision farming. It not only helps identify within-field spatial variability for variable rate applications, but also enables a farmer to evaluate the economic returns of different farming management strategies (Birrell *et al*., 1995; Yang *et al*., 1998). In recent years, considerable effort has been focused on the development and use of mechanical yield monitors for mapping crop yields. Yield monitors have been developed by several manufacturers, and are beginning to have broader acceptance by producers (Searcy, 1995).

Remote sensing has been used to monitor crop growing conditions and to estimate crop yields for many years. Morain and Williams (1975) estimated wheat production over a 10-county area using Landsat multispectral scanner (MSS) imagery and a yield model. Colwell *et al.* (1977) evaluated the use of Landsat MSS data for directly predicting grain yield for winter wheat. Significant correlations were found between transformations of Landsat MSS data and individual field yields as estimated using traditional sampling techniques. They also concluded that Landsat MSS data could be effectively used to estimate leaf area index (LAI), which is a good indicator of potential yield. Wiegand *et al.* (1979) related LAI measurements of winter wheat to three vegetation indices derived from Landsat MSS data and discussed the implications of LAI estimates for evapotranspiration and crop yield modeling. Tucker *et al.* (1980) found significant linear relationships between various combinations of the red and near-infrared (NIR) radiance data and grain yields within a winter wheat field. Wiegand and Richardson (1984) related grain sorghum yields to nine spectral measures (five vegetation indices and four individual bands) derived from Landsat MSS data and found that all the five vegetation indices and three of the four bands were significantly related to grain yields. They have also provided the rationale and equations for relating spectral observations to crop growth and economic yields (Wiegand and Richardson, 1984, 1990).

More recently, video imaging technology has emerged as a remote sensing tool for natural resource assessment (Everitt, 1988; Everitt *et al.*, 1991, 1995; Mausel *et al.*, 1992). This technique has great potential for precision farming because of its high spatial resolution and its real-time monitoring capability for both visual interpretation and digital processing. Digital counts and vegetation indices derived from the video imagery data have been used to estimate plant height, leaf area index, biomass and crop yield (Richardson *et al.*, 1990; Wiegand *et al.*, 1988, 1992, 1994; Yang and Anderson, 1996, 1997, 1999). In most of these studies, grain yields have been simply correlated with digital data from individual bands and vegetation indices. Moran *et al.* (1997) reviewed the remote sensing approaches for estimating crop yields and suggested that multispectral images obtained late in the crop growing season could be used to map crop yields with approaches as simple as regression. They also suggested that remote sensing information could be combined with crop growth or agrometeorological models to predict final yield.

A precision farming research project was initiated with the USDA-ARS Kika de la Garza Subtropical Agricultural Research Center at Weslaco, Texas in 1995. This project was designed to evaluate remote sensing, especially aerial digital videography, as a tool for determining within-field plant growth variability and mapping grain yields for precision farming. Yang and Anderson (1999) reported on the use of airborne videography to identify spatial plant growth variability for grain sorghum. Results showed that digital video imagery could effectively identify within-field plant growth variability and that unsupervised classification maps from the imagery could differentiate grain production level and growth conditions. This paper reports on the use of aerial digital videography for mapping grain sorghum