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Soil color sensor data collection using a GPS-enabled smartphone application

Roxanne Stiglitz [a], Elena Mikhailova [a,*], Christopher Post [a], Mark Schlautman [b], Julia Sharp [c], Roy Pargas [d], Benjamin Glover [d], Jack Mooney [d]

[a] Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634 USA
[b] Department of Environmental Engineering and Earth Sciences, Clemson University, Anderson, SC 29625 USA
[c] Department of Statistics, Colorado State University, Fort Collins, CO 80523 USA
[d] School of Computing, Clemson University, Clemson, SC 29634 USA

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ABSTRACT

Application of accurate and low-cost sensor technology to collect soil color data provides an opportunity to increase the density, quality and quantity of soil data to monitor our changing soil resources. The objective of this study was to develop a mobile application that would enable users to create their own soils database consisting of GPS location and soil color data gathered using the application and a mobile sensor. A mobile application was created utilizing the Nix™ Pro color sensor that produces multiple color results, including Munsell color notation. The application also allows users to toggle between "in-field" sampling as well as dry or moist soil samples. Users can choose to record GPS location and a photo of the soil sample to upload into an online database for storage. The application was tested for functionality in the field and for its ability to match Munsell notation values determined using a Munsell Soil Color Chart (MSCC). Field data were synchronized to a cloud database and subsequently retrieved and used to produce a Geographic Information Systems (GIS) layout showing sample point locations and soil color attributes. The Soil Scanner application allows for rapid analysis and collection of soils data that can be stored for further study and reference using various color systems and location data.

1. Introduction

Soil color is an important property used by the USDA Natural Resources Conservation Service (NRCS) to describe soils and it can be a strong indicator of other soil properties such as iron and organic matter contents (Lynn and Pearson, 2000; Sugita and Marumo, 1996). The Munsell Soil Color Chart (MSCC) notation, which commonly is used to describe soil color, often can be found in soil series descriptions and online databases provided by the NRCS to characterize and describe soil horizons (Soil Survey Staff, 2016). Studies have shown that there are discrepancies in the printing quality of MSCC color chips as well as a strong potential for fading that can make the charts unreliable (Sánchez-Marañón et al., 2005; Viscarra Rossel et al., 2006), yet the MSCC has been the standard in-field method of soil color determination for decades (Shields et al., 1965). The color charts also are more qualitative than quantitative, leading many soil scientists to turn to alternative methods of color analysis (Kirillova et al., 2015). Instruments such as spectrophotometers and colorimeters often are used in lieu of a MSCC (Thompson et al., 2013); however, these instruments can be expensive and may require an external power source which makes in-field color determination very difficult. More recently, scientists have been testing and creating new methods of color determination that are more field-friendly as well as less expensive (Levin et al., 2005).

Stiglitz et al. (2016a) tested a new and inexpensive color sensor, the Nix™ Pro, as a mobile method of soil color determination. The Nix™ Pro sensor is controlled via Bluetooth® and a mobile app through a smartphone. Multiple soil samples were analyzed for color in moist and dry soil conditions and indoor and outdoor lighting. The Nix™ Pro color values were compared to MSCC as well as a Konica Minolta CR-400 laboratory colorimeter. The results showed that the Nix™ Pro produced repeatable readings and that the color values of the Nix™ Pro and Konica Minolta CR-400 were very similar. Stiglitz et al. (2016a, 2016b) concluded that the Nix™ Pro would be a good alternative to the MSCC as an in-field soil color determination method. However, the application used to control the Nix™ Pro is not directed towards the field of soil science. Ideally, the application would allow for data storage and produce MSCC notation as well because it is the most commonly used color system.

* Corresponding author at: Department of Forestry and Environmental Conservation, Clemson University, 261 Lehotsky Hall, Clemson, SC 29634 USA.
E-mail address: eleanam@clemson.edu (E. Mikhailova).

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In a study by Gómez-Robledo et al. (2013) a cellphone application was created to determine the color of soil samples from pictures taken with the cell phone camera. Software was developed to scan the pixels in the soil sample pictures taken by the camera and convert the subsequent red, green, and blue (RGB) color values to digital red, green, and blue (XYZ) and to Munsell hue, value, and chroma (HVC). The results were promising and demonstrated that cellphone cameras and a simple color conversion application can be utilized as effective soil color sensors. Han et al. (2016) also used a smartphone camera to process color images of soil samples. After processing the RGB values obtained from the images, it was once again concluded that cellphone cameras are effective at determining soil color. Han et al. (2016) were able to accurately classify soils, however, it was noted that differences in cellphone hardware may result in a change in accuracy of results and software stability. Furthermore, environmental factors such as soil moisture and lighting conditions would still affect the study results.

Regardless of the drawbacks of cellphone cameras, these mobile devices have proven to be a useful tool in soil science and related fields. Beaudette and O'Geen (2010) developed an iPhone application to deliver on-demand access to soil survey information from any location with cellphone coverage. Migliaccio et al. (2015) proposed turf irrigation application that develops recommended irrigation schedules based on inputs of form data and real-time weather data. User input data include soil type (texture) information as well as location and rooting depth. Soil texture information is used to assign estimated field capacity. Other user inputs include information about the field area and sprinkler type (to indicate water rate). Real-time weather data, including temperature, humidity, solar radiation, and wind speed are used to estimate water loss through evapotranspiration (ET). The application was shown to reduce overall water usage when compared to time-based irrigation schedules. Bartlett et al. (2015) created a smartphone application for an irrigation scheduling tool on a cloud-based server.

Mobile technologies are advancing soil science as new applications and analysis methods are created. In addition, new technologies provide opportunities for outreach and raising awareness of many scientific issues faced today as mobile technologies are becoming more widely available and affordable (Ciampitti and McCornack, 2016). With development of new mobile devices and applications, subjects such as soil quality can be readily studied, not only by professionals but also by students in classroom settings (Karlen et al., 2003). To ensure that new applications are efficient learning tools in the classroom, Israelson (2015) proposed “the App Map” which is a basic rubric for judging the effectiveness of an application. In general, if a mobile application would function well in a classroom setting and improve knowledge of an area of science, then it would also function well in field settings.

Mobile devices offer the opportunity to quickly and easily analyze certain soil properties. However, current mobile applications commonly face limitations based on the device and environmental conditions. There should be one set device capable of running analysis on soils through an application that would allow for constantly updating soils data and storage. Finally, the application and device should be user friendly and inexpensive. As such, the objective of this study was to create an Android-based application capable of working with the Nix™ Pro color sensor that would: (i) produce cyan, magenta, yellow, and black (CMYK), XYZ, RGB, CIELab, and MSCC color values, (ii) record GPS locations, and (iii) upload collected data to a constantly updating Cloud databank.

2. Materials and methods

2.1. Developing the color application

Development of the Soil Scanner mobile application was completed using Google's integrated development environment (IDE) software, Android Studio 2.0, to compile and edit the code for the application. Java was chosen as the programming language and the Android software development kit (SDK) was used to develop the application into Android friendly software. Access to the Nix™ Pro application program interface (API) was provided by the Nix™ Pro development team allowing for smoother integration of the already-existing color sensing functions of the sensor into the Soil Scanner application. The original Nix™ Pro application is free to download and the Soil Scanner application will also be available to download upon finalization.

Upon completion, the application was able to connect to a Nix™ Pro color sensor, download a Munsell color reference table, and scan soil samples for color (Fig. 1). Resulting color systems include CMYK, CIELab, XYZ, RGB, and Munsell notations. Users have the option to choose whether the samples are analyzed in a field setting and if the soil

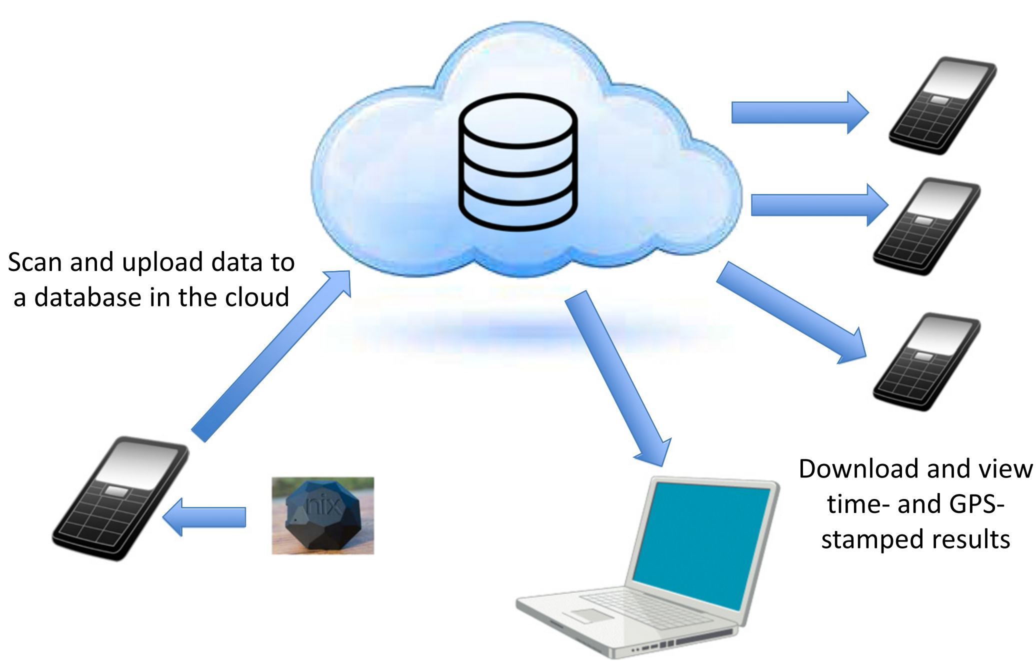

Fig. 1. Functional diagram of the Color Scanner application.