CALIFORNIA

Computer Enhancement of Aerial Photographs

By Mike Porter

The application of geostatistics aids in interpolating between sampling sites, reducing the number of samples needed to provide a given level of area-specific knowledge. But, in the end, geostatistical approaches are still limited by fundamental mathematical considerations...the greater the variability of the soil, the more samples that need to be taken to achieve any given level of mapping accuracy.

Soil variability has long been known to complicate the task of efficient fertilization. Mapping soil accurately is an important aid in deciding nutrient needs, application rates and where to apply. Soil and tissue sampling helps considerably but are limited by sampling density. That is, too few samples provide too little information, but a sufficient number of samples can cut into profitability. Aerial photography can be utilized to map vineyard soils and plant nutrition quickly and easily.

Perhaps the simplest way to overcome the sampling density limitation is to have such a high information density that statistical methods are redundant. That is, instead of starting with field samples then calculating a best-estimate map, start with the map and use it to decide where to take samples. One might wonder where you get the map... the fact is you get it from the foliage. What sampling strategy could provide the density of information provided by thousands or millions of plants individually testing the soil? The trick is to extract the information quickly and easily.

This is not a new approach, of course. This is what aerial photography has been used for since Gaspard Tournachon photographed the outskirts of Paris from a balloon in 1858...rapid mapping at a high information density. As cameras, film and aircraft have improved so has the utility and cost-effectiveness of the practice. In refining the tools and techniques, a wealth of information has flowed out to people on the ground. But, as with any technology, there are still inherent limitations.

Strengths and Weaknesses

Visual interpretation of a scene is something that people are generally quite good at, whether viewing in person or looking at a photograph. Unlike the slow linear process of reading or listening to someone speak, the eyes and mind can absorb a massive amount of information at one time. In the vernacular of computers this is called parallel processing, and to date most people are still much better at this than computers.

Research into how we do this indicates that about 70 percent of the information that we glean comes from differences in contrast, that is, how light or dark one part of a scene is from those around it. This explains how we see and can inter-

ORIGINAL, true-color photo of a 40-acre wine-grape vineyard has subtle differences, difficult to discern.

COMPUTER-ENHANCED photo shows greater contrast in wine-grape foliage, indicative of differences in soil characteristics.

pret so much from black-and-white photographs, and why color-blind people (and animals) function so effectively. Only 30 percent of the information in a scene is normally obtained from differences in color, though this can be critical when dealing with foliar symptoms of nutrient problems.

The main limitation in interpreting natural-color aerial photographs for agricultural use is that most such scenes have very little contrast and only subtle color variation. Low-contrast scenes rob us of our visual strength, and modest differences in color often slip past us. What is needed then is a way to increase the contrast in a scene and/or exaggerate the colors.

Methods and Options

Increased differences in color and contrast have been achieved, typically by trying different films and filters and by various darkroom practices. One widely-used combination is "false-color" infrared film combined with a red or deep yellow filter. This changes foliage from yellow-green to red and, more importantly, increases the contrast. Having tried various films and filters, and finding them all wanting in one way or another, the next logical step was to try enhancing contrast and color in a computer.

Computer enhancement of photographs has been around for quite a few years, but for most of that time was limited to those who had access to the fastest and most powerful computers available (NASA, FBI, CIA, NSA, etc.) because the massive amount of data involved requires great speed and available memory. In recent years the capacity of desktop personal computers has risen to the level required, and sophisticated off-the-shelf software has been developed to match.

Field Use

The photos with this article show the original, true-color and an enhanced version of the same scene of a 40-acre wine-grape vineyard in Sonoma County, California. The view is obliquely across the rows so as to see the maximum amount of foliage and the minimum amount of bare soil between rows. After studying the enhanced version, one can go back to the original and find many of the subtle dif-

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maps will help define the yield limitations necessary for site-specific management. **Figure 2** compares a salinity map made using a GPS-based EM system, a soil nitrogen (N) map based on intensive soil sampling, and a yield map made from a yield monitor for an irrigated soft wheat field near Bow Island, Alberta. Note areas of high electrical conductivity (i.e. salinity) correspond to areas of high N and low wheat yields.

A fertilizer recommendation based on a composite soil sample is influenced by these saline areas with high N. This causes an under-estimation of the fertilizer requirement for most of the field while unnecessary fertilizer is applied to the saline portions of the field. Salinity is easier to identify and map than is soil N.

A detailed salinity map will permit crop selection to be used as part of precision farming. For example, when growing a saline-sensitive crop like corn or beans, saline portions of the field can be planted to a more salinity-tolerant crop like barley.

Summary

Geographic information systems (GIS) allow data from yield, salinity, topography, fertility or other maps to be combined and analyzed to generate more accurate variable rate input maps. Salinity maps are one more tool in a farmer's arsenal to better utilize and manage the information needed for precision agriculture. BC

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ferences that were there all along, but were difficult to discern at first. The enhancement process has not created any new information, merely exaggerated what was there.

The red-orange foliage in the lower portion of the scene results from soil having very high available magnesium (Mg), high cation exchange capacity (CEC) and plants with potassium (K) deficiency. This area is a former (Pleistocene) lakebed, dominated by montmorillonitic clays. The upper green portion is an alluvial fan whose watershed is largely rhyolite, giving the soil a lower CEC and a much better K/Mg ratio. The peak of the fan is at the upper left. One can see the gradation from lighter to darker green associated with decreasing rock and gravel, increasing silt content and associated variation in soil water-holding capacity. The irregular white patch in the middle-right portion results from very weak vine growth, so that we are seeing much more bare soil than in other parts of the vineyard. This section has shallow soil underlain by a calcium-cemented hardpan.

If one were not familiar with this vineyard, it could easily require many backhoe pits and samples to "investigate" the soil in enough detail to make a geostatistical map. Using the computer-enhanced photo as a guide, it would be much simpler (and less expensive) to sample in key locations, then use the photo as the map. BC

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