GIS-Based Site-Specific Management of Cocoa

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Two goals of site-specific management are to describe the spatial variability of nutrients at the field-scale and design management practices most suited to that landscape. The characteristics of established cocoa plantations often make this a challenging task.

Mapping nutrient variability requires intensive soil sampling across fields. Soil testing has not been properly calibrated for many tropical crops and soils. Remote sensing imagery is also costly and access has been limited in tropical areas. A different approach, at least initially, may be needed to design appropriate nutrient recommendations. Interpretation of nutrient removal data could be an effective alternative until soil test calibrations are developed from data generated locally. Meanwhile, soil testing can still be employed as a monitor of other important physical and chemical characteristics.

Cocoa is a widespread plantation crop, but several historical factors have contributed to poor development. Depressed international markets have traditionally characterized the crop as a low user of technology and inputs. Higher quality cocoa varieties having the distinctive cocoa flavor and aroma used in fine chocolates suffer from high susceptibility to disease. Yields are low...only about 900 kg dry beans/ha...even under optimal conditions. A newer clonal variety (CCN51) developed in Ecuador has high yield potential and resistance to common fungal diseases, making it an acceptable alternative to produce cocoa for bulk use in most cocoa products and chocolate formulas. The clone can also compete in higher quality markets with careful post harvest care and fermentation. Under full solar exposure and high plant density, CCN51 can reach yields over 4,000 kg of dry beans/ha. That productivity level has sparked interest in rejuvenating established cocoa plantations.

The Cañas Cocoa Enterprise initiated activities with CCN51 in 1991 at Naranjal, Guayas Province, Ecuador. The prospect of high yields provoked a fast and disorganized development wherein only approximate field sizes and shapes were known and no accurate record of field area existed. Four different planting densities were laid out from 1991 to 1993 to identify the yield potential of the site. New fields were also planted during 2000 to 2003. Establishment of a geographic information system (GIS) would be the only way to accurately determine size and distribution of fields...a crucial first step.

CCN51 cocoa clonal material has high-yield potential under complete solar exposure and high planting density.

At Cañas, yields were relatively

Figure 1. Relative size and shape of fields at Canas, obtained with the help of aerial photograph (layer below) and GPS measurements.

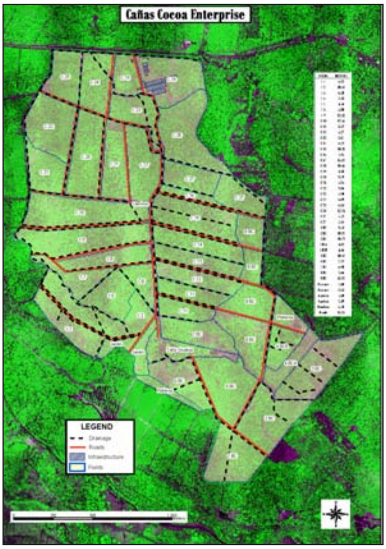
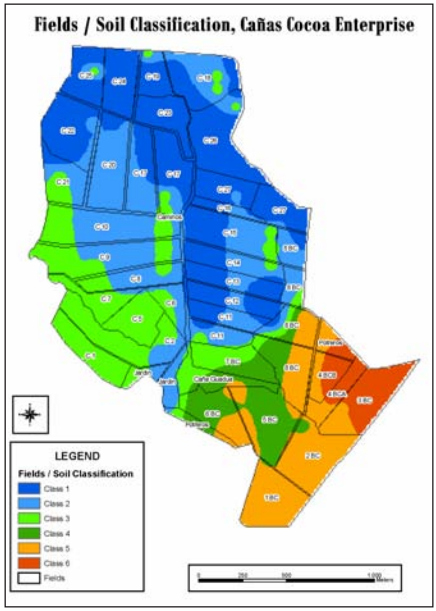


Figure 2. Layer of actual field size over a layer of soil classes.



high during the early 1990s, but were short-lived under conditions of full sun exposure, high plant densities, and poor plant nutrition. Management evolved to include a generalized soil testing program in 1999 which improved yields. Sustained improvement in international markets from 2003 onwards created the resources needed to establish a regularly maintained agronomic database capable of providing real unit area yields built on exact field measurements. Geo-referenced and ortho-rectified aerial photographs had recently become readily available. Global positioning system (GPS) field measurements defined actual field sizes along with the existing drainage pattern, thus comprising the basic platform to integrate any further accumulated data (**Figure 1**).

When the map layer of actual field boundaries was superimposed over the soil class map layer, it became obvious that little regard had been given to potential productivity of the site (**Figure 2**). Soil suitability classes were initially determined by soil texture of the first 90 cm and depth of the water table. Unfortunately, an excellent opportunity had been missed to properly organize the plantation's fields. The map layer representing depth of the water table alone (**Figure 3**) was now most useful at this stage of the plantation's development since it is possible to modify drainage patterns to eliminate this limiting factor from affected fields.

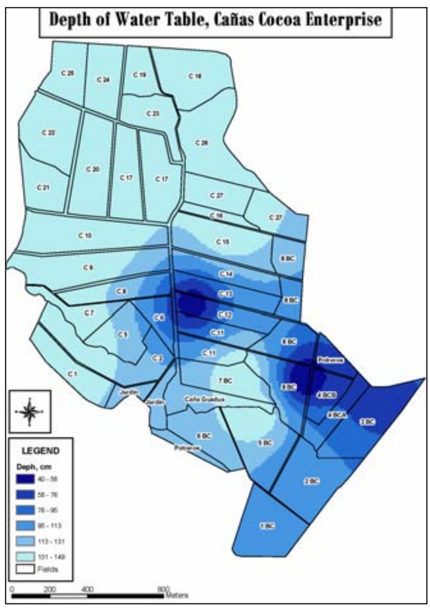


Figure 3. Layer of actual field size over a layer of soil drainage.

Figure 4. Normalized yield history of cocoa field by plant density.

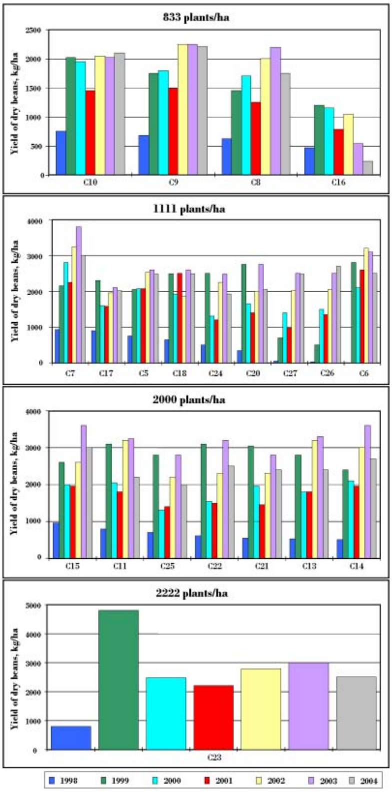
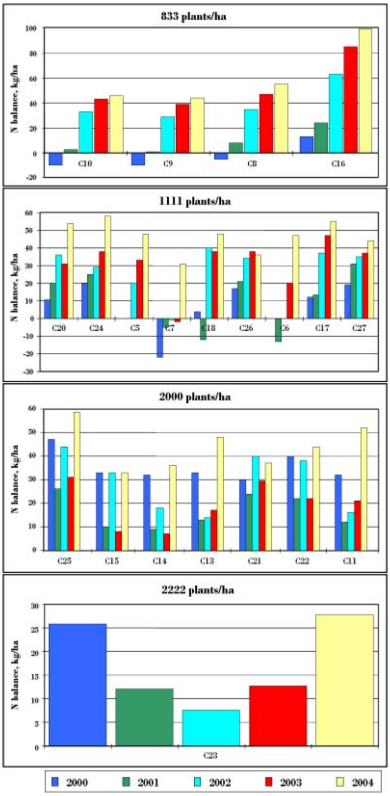


Figure 5. Nitrogen balance history of cocoa field by plant density.



Once the correct field measurements were determined, all accumulated yield data were normalized to reflect this fact. A history (1998 to 2004) of field-specific cocoa yields, arranged by planting density, is presented in **Figure 4**. Yield was positively correlated with high plant densities under full sun. The first attempt at soil testing and controlled fertilizer applications is evident as all fields produced excellent responses to applied nutrients in 1999. However, yield declines were evident for several fields in the following 2 years. This yield reduction indicates that the soil testing system was failing to provide an accurate indication of crop nutrient requirement. Managers were relying on established critical levels since no calibration data for P and K response existed. Nutrient applications were increased every year to cope with yield losses caused by apparent lack of adequate nutrition.

In 2005, after the completion of a nutrient uptake study for CCN51, managers initiated a different approach to designing fertilizer recommendations based on total crop nutrient uptake (**Table 1**) and removal. The data allowed managers to estimate nutrient balances for each field based on fruit pod harvests (**Figures 5 and 6**). The balances considered leaf litter and pruned branch recycling within each field. Empty pods are also returned to the field. Nutrient balances also assumed 50% use efficiency for N and 70% use efficiency for K.

Table 1. Total nutrient uptake of CCN51 clonal material, Cañas Cocoa Enterprise Naranjal, Guayas, Ecuador (2005).

N	P_2O_5	K_2O	MgO	S
---- kg/t of dry cocoa beans ----				
28.5	13.2	57.7	12.0	3.4

Figure 6. Potassium balance history of cocoa field by plant density.

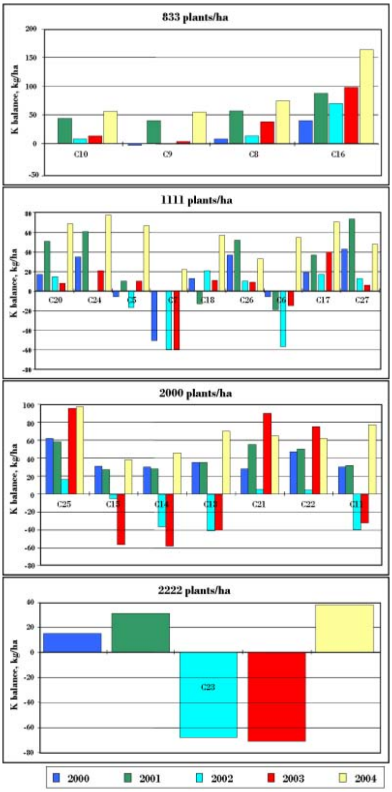
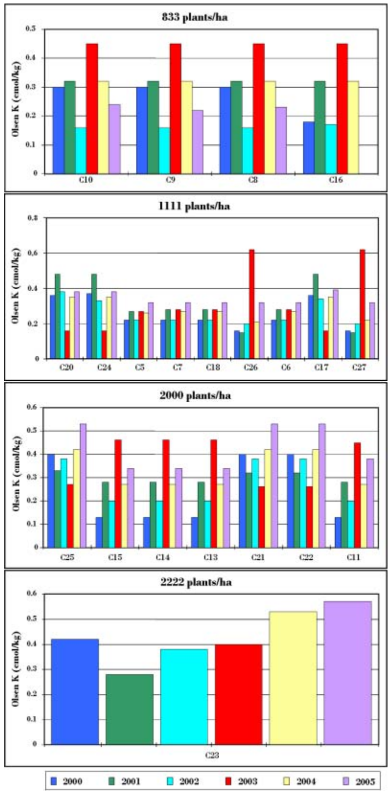


Figure 7. Soil K history of cocoa fields by plant density.



Nitrogen balances suggest that excessive amounts of N were used over the years, particularly in 2004. Potassium data indicate negative balances at higher plant densities, although amounts used in 2004 appeared to be in excess. Lack of balance between N and K could help explain yield reductions observed after the first yield response to fertilizer in 1999. This is also evident from accumulated soil K data (**Figure 7**).

Management of information using GIS-based site-specific management has allowed the Cañas Cocoa Enterprise to compile exact field measurements in relation to yield, soil testing, nutrient removal, and any other production factor deemed worthwhile monitoring. One especially useful example allowed managers to track the severity and dynamics of the fungal disease *Monilla* sp. The enterprise can now manage variability within fields, and if desired, even reorganize its fields to minimize impact on production. Eventually, yield and nutrient removal information can be correlated to obtain soil critical levels for all nutrients except N. In this way, soil testing can be a reliable diagnostic tool. BC

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