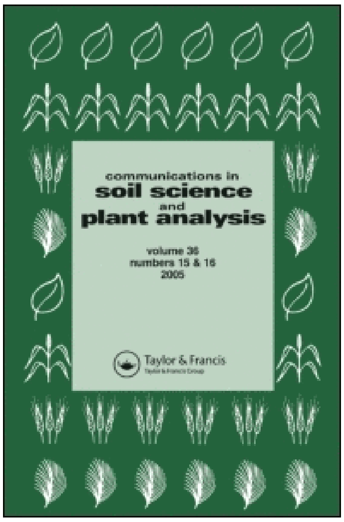

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Stretching Soil Sampling to Watershed: Evaluation of Soil-Test Parameters in a Semi-arid Tropical Watershed

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Abstract: Soil sampling is an integral component of fertility evaluation and nutrient recommendation for efficient use of nutrients in crop production. Little attention has been devoted to evaluating methodology for sampling watersheds under dryland agriculture. A stratified random sampling methodology for sampling the Appayapally watershed in Mahabubnagar district of Andhra Pradesh state in the semi-arid tropical region of India was adopted and evaluated. The watershed has an area of about 500 ha, with gentle sloping lands ($<1\%$ slope), and 217 farmers own land in the watershed. The soils are Alfisols. A total of 114 soil samples were collected from the top 15-cm layer to represent the entire watershed. Each sample was a composite of 7–8 cores, randomly collected from the area represented by a crop and group of farmers. The soil samples were air dried, ground, and analyzed for pH, electrical conductivity (EC), organic carbon (C), total nitrogen (N), and extractable phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), and boron (B). Statistical analysis of the results on soil fertility parameters showed that the mean- or median-based results of soil tests performed in the study did not differ significantly when the sample set size varied from 5 to 114 (100% of the population). Our results indicate that farmers' fields in the Appayapally watershed are uniform in the chemical fertility parameters studied, and even a small sample set size can represent the whole population. However, such a sampling strategy may be applicable only to watersheds that are very

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gently sloping and where fertilizer use is very low, resulting in an overall low fertility in the whole watershed.

Keywords: Dryland agriculture, low chemical fertility, semi-arid region, soil sampling in watersheds, spatial variability in soil tests, stratified random sampling

INTRODUCTION

Soil sampling is an integral and essential component of soil fertility evaluation, nutrient recommendation, and fertility management. The effectiveness of soil sampling is a prerequisite for the soil testing to achieve its goal of efficient and judicious use of nutrients for improved crop yield and quality in practical agriculture. Without precise soil sampling, soil tests are unlikely to be effective in providing accurate levels of pools of potentially available nutrients and hence for determining the nutrient requirements of production systems (Black 1993; Schnug, Panten, and Haneklaus 1998; Tsegaye and Hill 1998; Pierce and Novak 1999; Sahrawat 2006).

The underlying basis for soil sampling is that a soil sample taken represents the "population," which may be a plot, field, or a watershed. It further implies that nutrient status of the representative soil sample(s) determined in a laboratory would reflect nutrient status of a plot, field, or watershed and is of interest for correcting nutrient disorders in the field or watershed (Cline 1944; Westerman 1990; Tsegaye and Hill 1998). The most important factor that influences the effectiveness of soil sampling is inherent soil heterogeneity, further modified by crop and fertility management practices (Westerman 1990; Tsegaye and Hill 1998). However, in a relatively homogenous group of fields or plots, a small number of samples may be sufficient to represent the population as compared to a more heterogeneous group of fields that would require more samples to represent the soil population (Westerman 1990; Petersen and Calvin 1996).

Little attention seems to have been devoted to developing or evaluating a methodology for sampling at the watershed-level in rainfed agricultural production systems. For sustainable increase in dryland productivity in the semi-arid tropical regions of India, the integration of soil and water conservation practices with crop and nutrient management is of critical importance (Wani et al. 2003).

This article is an attempt to evaluate and standardize soil sampling methodology in a watershed in the semi-arid tropical region of India. In our work at ICRISAT (International Crops Research Institute for the Semi-arid Tropics), soil-testing results are used as a science-based entry for the evaluation of improved nutrient management interventions in farmers' fields in watersheds (Rego et al. 2007).

MATERIALS AND METHODS

Watershed Site

The watershed selected for the standardization of the methodology for soil sampling was the Appayapally (77.9° E, 16.7° N) watershed in the Mahboobnagar district of Andhra Pradesh in the Indian semi-arid tropics (SAT). The ICRISAT and its partners are conducting on-farm evaluation of the improved watershed management technologies for enhancing the productivity of dryland systems in this watershed.

The watershed has an area of about 500 ha, and 217 farmers own lands in the watershed. The lands in this watershed are gently sloping (<1% slope). Soils in the watershed are red or red mixed types and are mostly classified as Alfisols. Most of the farmers (200) have a landholding size of 2 ha or less. Only two farmers have landholdings of more than 4 ha, and 12 farmers are landless in the watershed studied. Important crops grown in the watershed include sorghum, castor, maize, groundnut, rice, sunflower, and vegetables. The watershed receives an average annual rainfall of 710 mm, and the length of crop growing season is about 150 days with a large seasonal variability depending on the amount and distribution of the rainfall.

Soil Sampling, Preparation, and Analyses

Soil sampling strategy was based on taking samples to represent the entire watershed. The soil sampling units were decided on the basis of crop, area covered by the crop, and number of farmers owning the land. We used stratified random sampling methodology for collecting soil samples from the watershed. A total of 114 soil samples were collected from the surface (0- to 15-cm) layer to represent the entire watershed. Each sample was a composite of 7–8 cores, randomly collected from the area represented by a crop and group of farmers.

The soil samples were air dried and ground to pass a 2-mm sieve before analysis for chemical fertility characteristics. Soil samples were analyzed in the ICRISAT Central Analytical Services Laboratory following the methods described here.

Soil pH was measured by a glass electrode using a soil-to-water ratio of 1:2; electrical conductivity (EC) was determined by an EC meter using a soil to water ratio of 1:2. Organic carbon (C) was determined using the modified Walkley–Black method (Nelson and Sommers 1996) and total nitrogen (N) as described by Dalal, Sahrawat, and Myers (1984). Available phosphorus (P) was measured using the sodium bicarbonate test (Olsen and Sommers 1982); available sulfur (S) was measured using

0.15% calcium chloride as extractant (Tabatabai 1996). Extractable potassium (K) and sodium (Na) were determined as described by Helmke and Sparks (1996) and calcium (Ca) and magnesium (Mg) as described by Suarez (1996). Extractable zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) were extracted by diethylenetriaminepentaacetic acid (DTPA) reagent (Lindsay and Norvell 1978), and available boron (B) was extracted by hot water (Kern 1996).

Statistical Analysis of the Data

Using the resampling technique in the GenStat statistical analysis package (boot strapping; Payne 2002), 2000 sets of data were created from the results of analysis of 114 soil samples, consisting each of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, and 110 samples. For each 2000 sets, we calculated descriptive statistics, and the data were subjected to box-plot analysis. The values in the box accounted for 95% of the values for soil fertility characteristics.

RESULTS AND DISCUSSION

Each of the sample sizes from the population ranging from 5 to 100% from the total population were statistically tested individually for agreement in the mean, median, maximum, and minimum values of various soil chemical fertility characteristics with those obtained using the whole population. The exercise was done to develop a soil sampling strategy, considering various soil chemical fertility characteristics, that is representative and at the same time cost-effective.

The results of statistical analysis of the data showed that the mean or median values of pH, EC, organic C, total N, Olsen P, and extractable K, Ca, Mg, Na, S, Zn, Fe, Mn, B, and Cu did not differ significantly in the sample set size varying from 5 to 100% of the population (Figures 1 and 2).

The results suggest that even 5% sample of the population can represent the whole population for the soil characteristics studied for fertility evaluation. Normally, a large variability in various soil fertility parameters has been reported by several researchers at the plot or field scale (Cambardella et al. 1994; Geypens et al. 1999; Mallarino and Wittry 2004; Miao, Mulla, and Robert 2006), but the results of this study suggest that the farmers' fields in the Appayapally watershed are uniform in the chemical fertility parameters.

The homogenous nature of the soil-test parameters in our study in the watershed is most probably due to lack of use of fertilizers and other

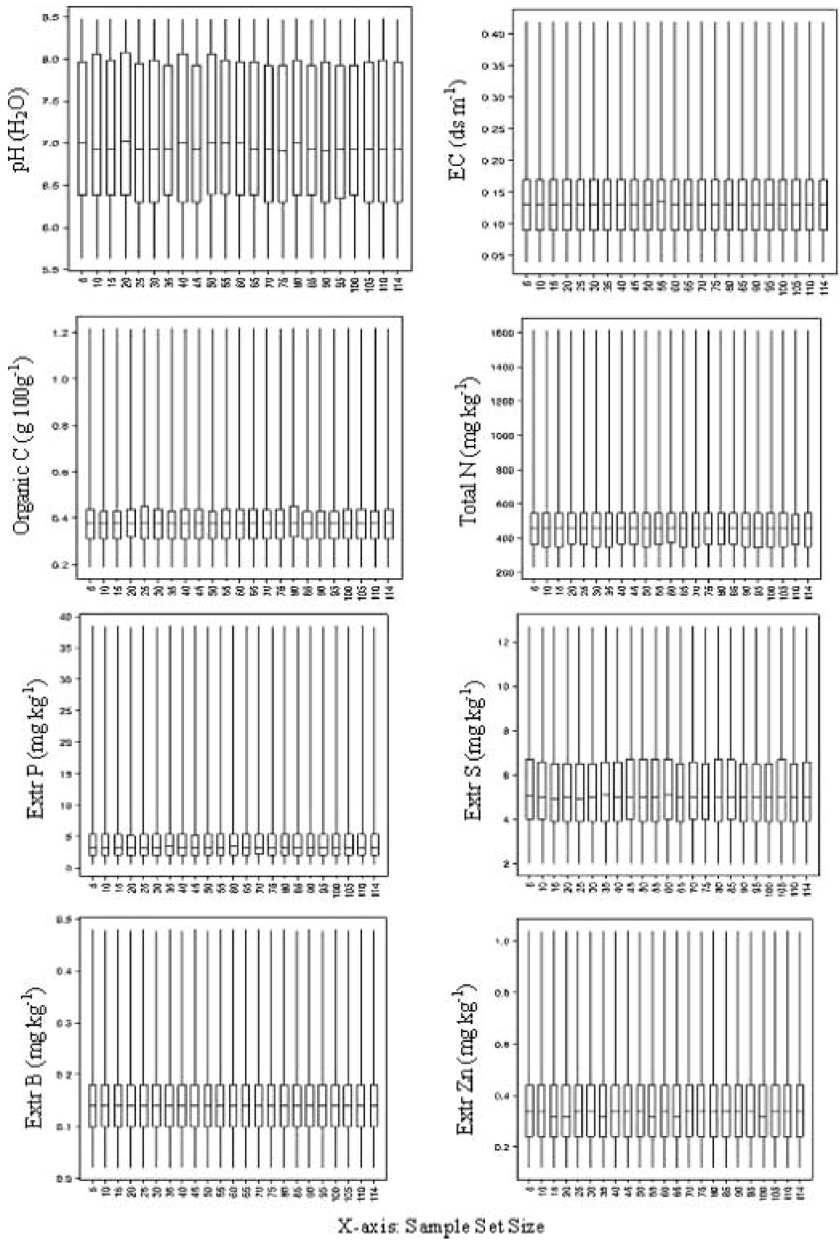

Figure 1. Mean-based box plots of various soil fertility parameters in relation to sample set size in Appayapally watershed, India. (*Continued*)

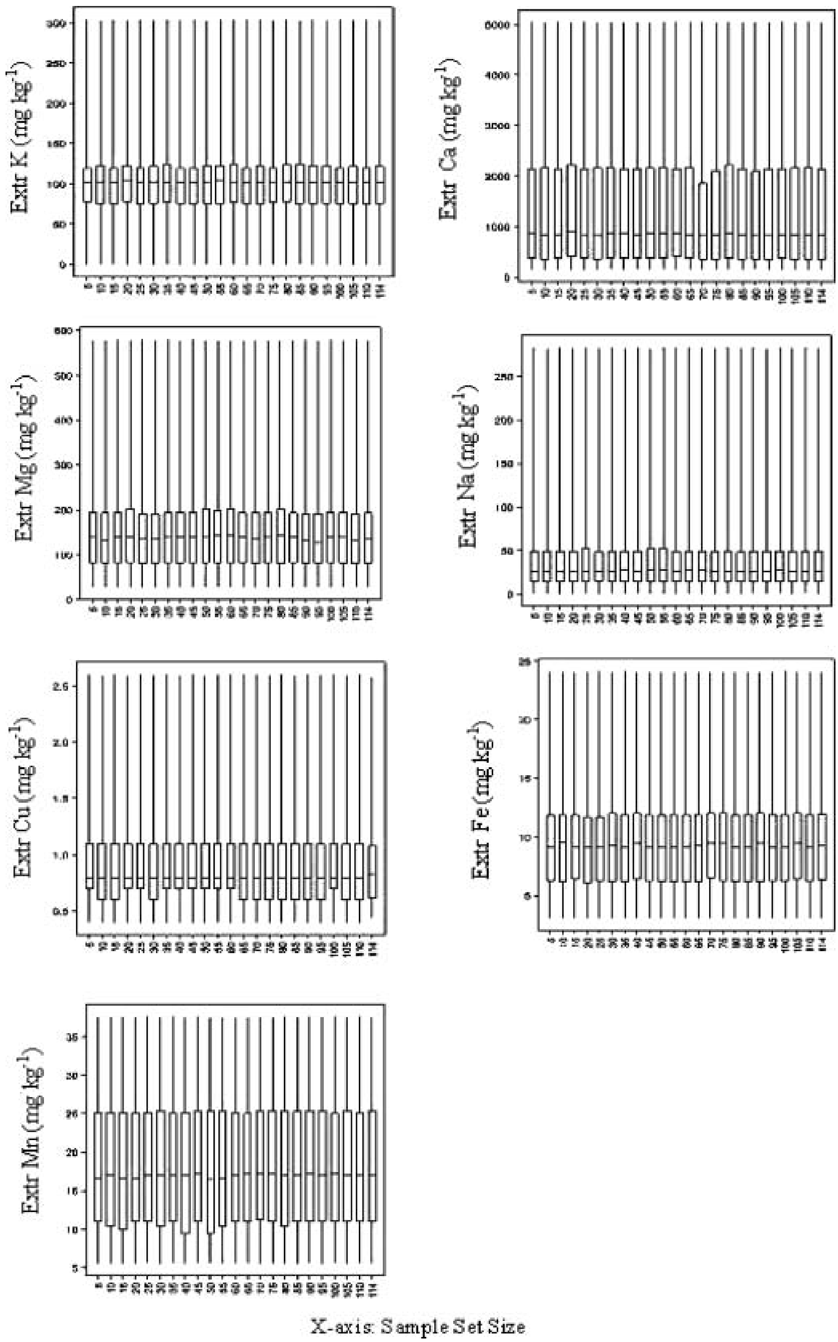

Figure 1. Continued.

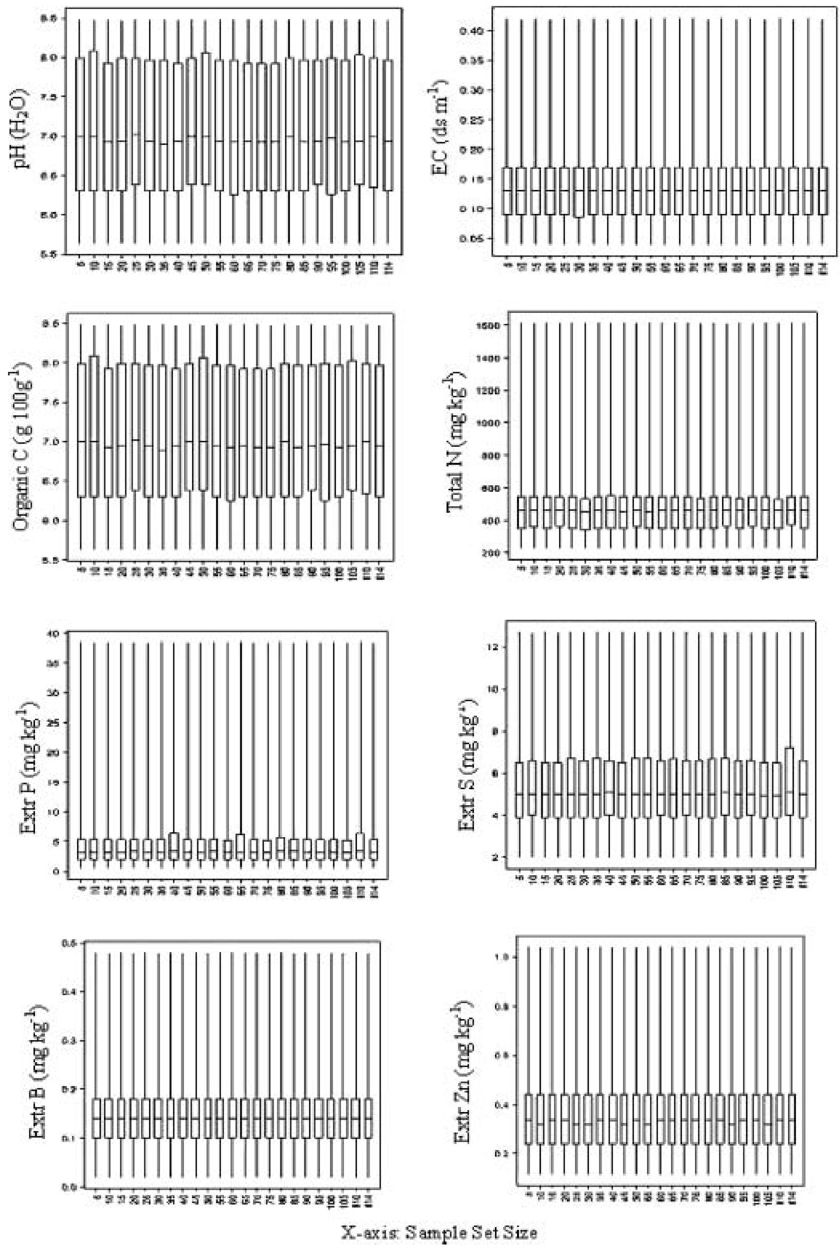

Figure 2. Median-based box plots of various soil fertility parameters in relation to sample set size in Appayapally watershed, India. (*Continued*)

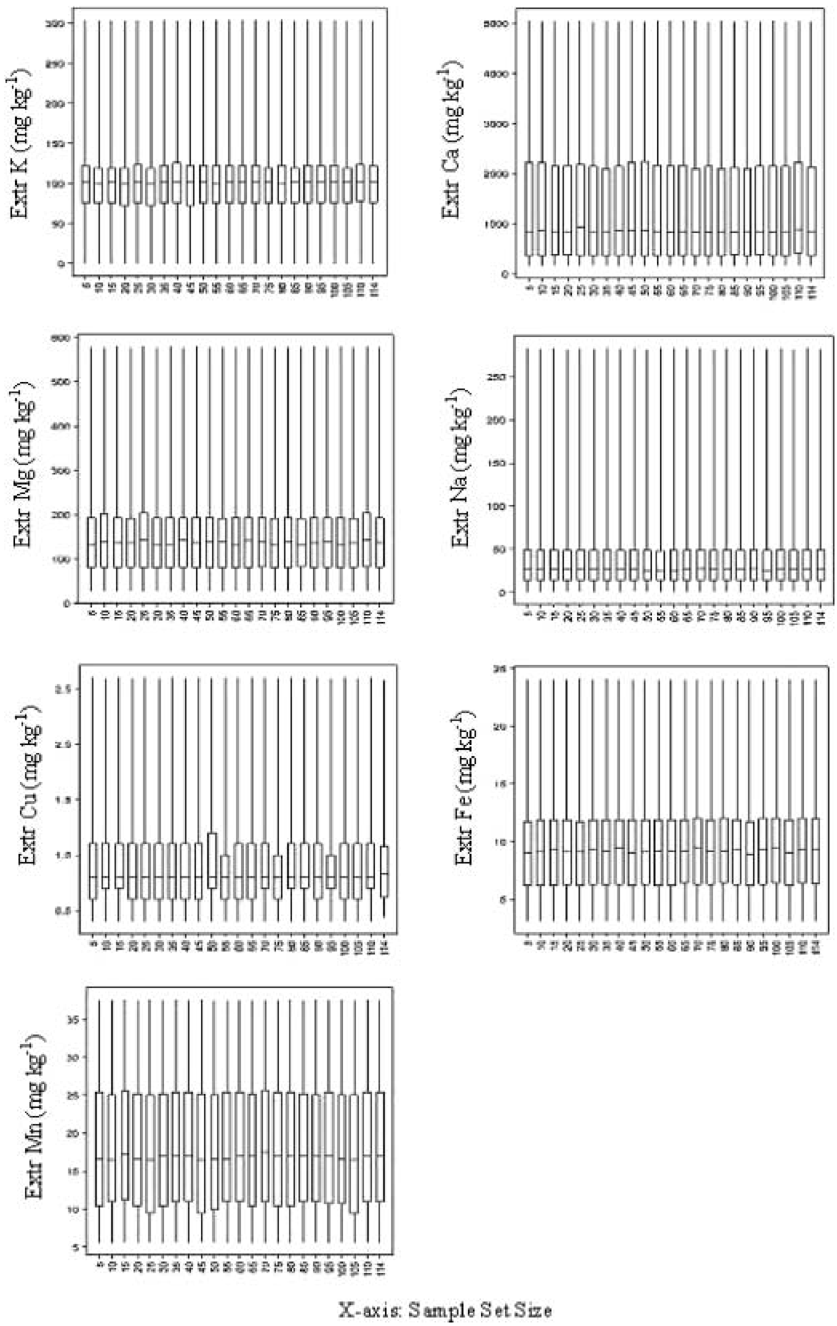

Figure 2. Continued.

purchased inputs by smallholder farmers. In most cases, farmers in the watershed use small amounts of manures applied once in 2 or 3 years, which perhaps was uniform across farmers' fields in the watershed; this practice of nutrient additions did not cause variability in soil-test parameters across fields in the watershed. For example, Khosla et al. (2006), in a 3-year study of continuous maize field (52 ha) in Colorado, USA, found that the soil-test parameters for N, P, K, Zn, pH, and organic matter varied over space and time in a field. However, management zones (similar nutrient inputs and management) were found to be effective in finding homogenous subregions within the field across time. It was concluded that management zones account for spatial and temporal variability for the various soil tests evaluated during the study (Khosla et al. 2006).

Indeed, the farmers' fields in the watershed were uniformly low in organic C, total N, and Olsen P; moderate in extractable K and Mg; relatively high in extractable Ca; low in extractable Na, available S, Zn, and B. The soil pH in the watershed was in the near-neutral range, and EC was very low (no salt-related problems).

CONCLUSIONS

The results of our study indicate that stratified random sampling methodology can be adopted for sampling a watershed about 500 ha in area. The results also emphasize that the dry lands in the Appayapally watershed are uniformly low in the chemical fertility parameters studied and even a small population of the samples can represent the whole population. It should however, be mentioned that such a sampling strategy may be applicable to watersheds with very gently sloping lands; the use of fertilizers by farmers in the watershed is minimal.

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