Soil Fertility Improvement on Degraded Upper Terraces Formed Behind Vegetative Contour Strips: Technology Verification

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Abstract

A major disadvantage associated with contour hedgerow systems to minimize soil erosion on the slope is the development of a soil fertility gradient resulting from soil redistribution within terraces formed behind vegetative buffer strips. Differences in crop yield between the degraded upper and more fertile lower part of a single terrace are commonly greater than 100 percent. On-farm experiments were conducted to assess farmers' strategies to overcome the negative effects of soil fertility scouring in natural vegetative contour strip (NVS) systems. Fertilizer treatments showed that in a hybrid maize crop the response slope for grain yield across a single terrace approached zero when mineral fertilizer allocations were biased towards upper terrace zones. However, at the rate of NPK-fertilizer studied, the higher application of nutrient inputs on degraded terrace zones did not improve fertilizer efficiency: overall crop yield did not significantly change compared to uniform NPK application. More research is required to identify methods for the sustained rehabilitation of the degraded upper terrace through raising soil organic matter levels.

1 Introduction

In contour hedgerow systems on the slope the redistribution of eroded soil from upper to lower alley areas between two contour strips during natural terrace formation results, irrespective of hedgerow species, in the development of a fertility gradient. The upper side of a single alley-way exhibits lower organic matter and nutrient content, lower soil pH and higher Al saturation, resulting in reduced crop yields (Agus, 1993). It has been hypothesized that these effects of soil fertility scouring are a major deterrent to the large-scale adoption of hedgerow systems,

2 Material and Methods

2.1 Site description

The study was conducted at ICRAF's research site in Claveria municipality, Northern Mindanao, Philippines (8°38' N, 124°55' E). Soil conservation has become a major concern among farmers in the area since on the average 200 t ha^{-1} of soil are lost from slopes covered with insufficient amounts of biomass, due to moderate rainfall and because 59% of the cropping occurs on lands of more than 15 % slope (Fujisaka *et al.*, 1994). Soils in most parts of the agricultural area of Claveria are deep weathered Oxisols derived from volcanic parent material, classified as fine, mixed, isohyperthermic Ultic Haplorthox ranging from clays to silty clay loams with rapid drainage. They are generally acidic (pH 3.9 – 5.2) with low available P, low CEC, high Al saturation, low to moderate organic matter content (1.8 %) and low exchangeable K (Magbuana and Garrity, 1990). Average rainfall at elevations below 500 m above sea level, where experiments were conducted, is 2000 mm $year^{-1}$, with 5-6 wet months (> 200 mm rainfall $month^{-1}$) $year^{-1}$ (Garrity and Agustin, 1995).

2.2 Trial set-up and experimental treatments

Trials were conducted on-farm on five existing NVS sites (strip width = 0.5 - 1 m, alley width = 4 - 6 m, field slope 20 - 30 %) from 1995 to 1997. The experiment was laid out in a split-plot design with two replications per site. Mainplot factor: clean-scraping of the lower sides of the contour bunds, which was hypothesized to help restore inherent soil fertility on the degraded upper alley by adding biomass from the scraped strip vegetation and more fertile soil accumulated on the contour strip. Subplot factor: different levels of fertilizer allocation to the alley: zero NPK (T1), uniform NPK (T2), 1.5 times more NPK on zone 1 & 2 compared to lower alley zones (T3), and 3.0 times more NPK on zone 1 & 2 compared to lower alley zones (T4). The fertilizer rate for T2, T3 and T4 was identical, i.e. treatments differed only in the amounts of fertilizer allocated to individual zones: e.g. T4 means that 150 % of the fertilizer input is applied on zone 1 & 2 and 50 % on zones 3, 4 & 5. Fertilizer was applied at full rate (80-30-30 kg NPK ha^{-1}) for three cropping seasons (2 crops $year^{-1}$); during the final trial, half the recommended fertilizer rate was applied to assess treatment effects under low nutrient input. The area between two vegetative strips was divided into five zones from upper (zone 1: most degraded) to lower parts (zone 5: most fertile) within a single alley. Yellow hybrid maize varieties (Pioneer

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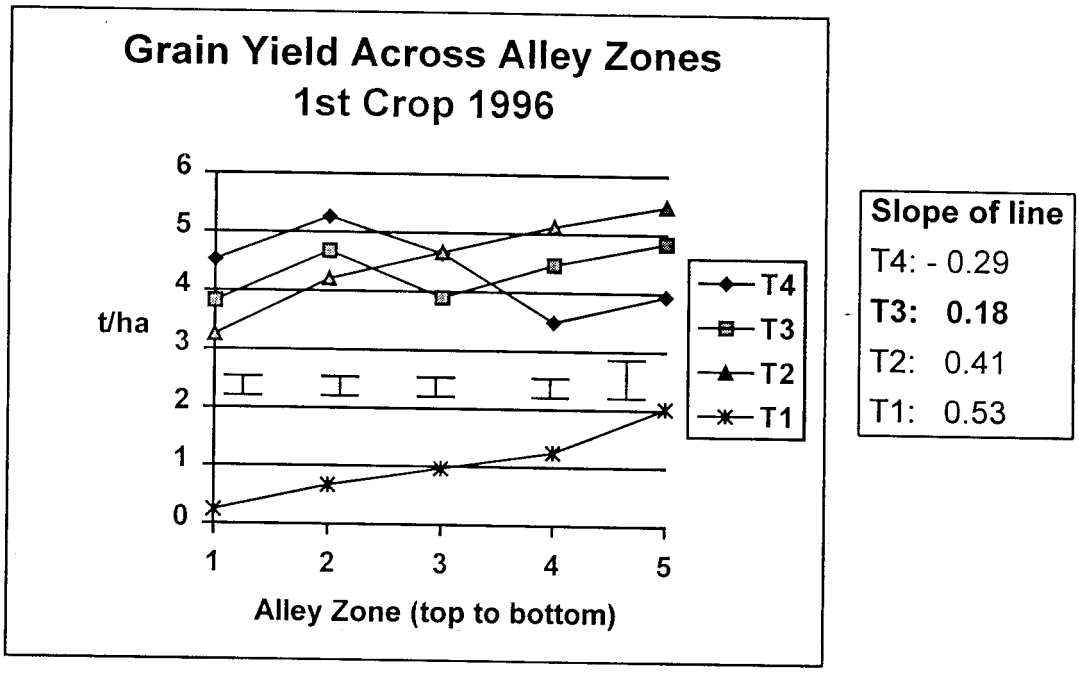

Figure 1: Effect of fertilizer treatments on hybrid maize grain yield across alley zones at 1st crop 1996: full fertilizer rate (Note: LSD values computed separately by alley zone for $P < 0.05$)

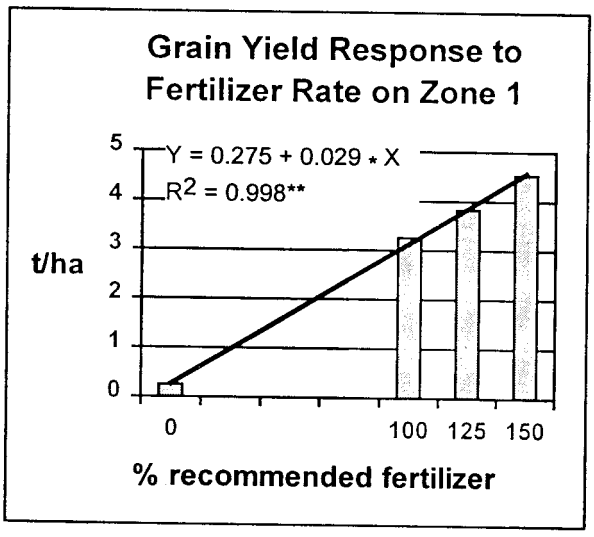

Fig. 2: Effect of fertilizer treatments on hybrid maize grain yield on zone 1 (1st crop 1996: full fertilizer rate)

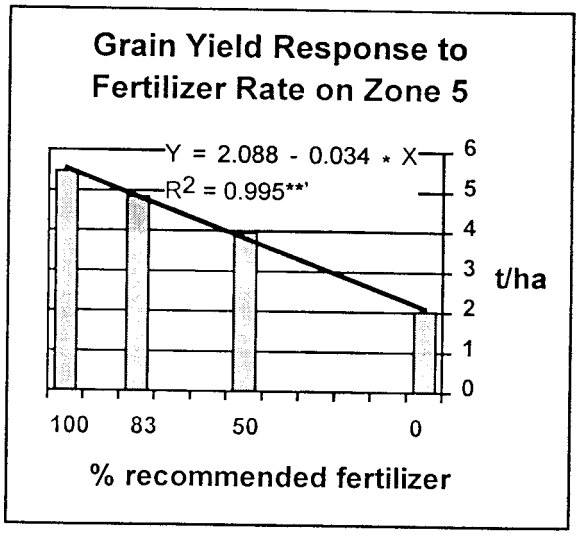

Fig. 3: Effect of fertilizer treatments on hybrid maize grain yield on zone 5 (1st crop 1996: full fertilizer rate)

Soil organic matter and nutrient additions from bund scraping had no significant effect on crop yield on the degraded upper alley. Their influence on soil physical and chemical conditions are likely to be of a longer-term nature.

4 Conclusion

Formal research did not confirm that farmers' practice of skewing the application of mineral fertilizer inputs towards degraded upper alley zones is an advantage to uniform fertilizer application. The study was, however, limited to a small number of treatment levels and maize varieties. Further investigation of methods to fully rehabilitate soil fertility on degraded alley zones are required: e.g. the long-term effects of bund scraping and the skewed distribution of crop residues need to be further evaluated. Computer models could be used to help extrapolate experimental results.

References

Agus, F. (1993): Soil Processes and Crop Production Under Contour Hedgerow Systems on Sloping Oxisols. PhD dissertation, North Carolina State University, Raleigh, USA.

Fiez, T.E., Miller, B.C. and Pan, W.L. (1994): Winter wheat yield and grain protein across varied landscape positions. In: Agron. J. 86: 1026-1032.

Fujisaka, S., Jayson, E. and Dapusala, A. (1994): Trees, grasses, and weeds: species choices in farmer-developed contour hedgerows. In: Agroforestry Systems. 25: 13-22.

Garrity, D.P. (1996): Tree-soil-crop interactions on slopes. In: Ong, C.K. and Huxley, P.: Tree-crop interactions. A physiological approach. Oxford, UK: CAB International: 299-318.

Garrity, D.P. and Agustin, P.C. (1995): Historical land use evolution in a tropical acid upland agroecosystem. Agriculture, Ecosystems and Environment 53: 83-95.

Magbuana, R.D. and Garrity, D.P. (1990): Acid upland agroecosystems: a microlevel analysis of the Claveria research site. In: Proceedings of the 1988 Acid Upland Research Design Workshop. Los Baños, Philippines: International Rice Research Institute (IRRI): 1-20.

Mercado, A.R., Sanchez, N. and Garrity, D.P. (1996): Crop productivity using forage legumes and grasses as contour hedgerow species in an acid upland soil. Paper presented at the 12 th Annual Scientific Conference of the Federation of Crop Sciences Societies of the Philippines, May 13-18, 1996, Davao, Philippines.

SAS (1988): SAS Institute Inc. SAS/SAT User's Guide, Release 6.03. Cary, NC, USA.

Thapa, B., Cassel, D.K., Garrity, D.P. and Mercado, A.R. (1996): Sustainable soil management systems on acid steepland soils in the humid tropics. Paper presented at the 12 th Annual Scientific Conference of the Federation of Crop Sciences Societies of the Philippines, May 13-18, 1996, Davao, Philippines.

Turkelboom, F., Ongprasert, S. and Taejajai, U. (1993): Alley Cropping on Steep Slopes: Soil Fertility Gradients and Sustainability. Paper presented at the International Workshop on 'Sustainable Agricultural Development: Concepts and Measures', held at AIT, Bangkok, 14-17 December 1993.

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