EVALUATION OF SOIL AND WATER CONSERVATION TECHNOLOGIES IN VEGETABLE-BASED UPLAND PRODUCTION SYSTEM OF MANUPALI WATERSHED, SOUTHERN PHILIPPINES

A.M. Dano[A] *and D.J. Midmore*[B]
[A] Ecosystems Research and Development Bureau, Laguna, Philippines.
[B] Central Queensland University, Queensland, Australia.

Abstract
Soil erosion and declining productivity resulting in low farm income have been the major constraints to the sustainability of the commercial vegetable production systems in cultivated uplands of the Philippines. Steep slopes, favorable climate, high fertilizer and pesticide application rates characterizes these production systems. Sustainability of upland vegetable production system and soil conservation technologies in Manupali watershed were analyzed. Farmers' perceptions and attitudes toward various environmental issues were initially gathered. Average soil loss in farmers' up-and-down cultivation practice was 50% greater compared to the conservation practices. Conservation technologies tested considerably reduced soil erosion but the level of adoption was less than hoped for. Among crops, tomato had more soil erosion. The difference between crops on their propensity for erosion was related to their canopy cover and tillage operations. Compatibility of trees in the vegetable production system offers encouraging results. Trees did not out-compete vegetable for below ground resources but benefited from excess nutrients in the vegetable systems. Economic benefits play prime consideration in the adoption of conservation technologies. Identifying appropriate practice for soil erosion control while at the same time improves farm income continues to be a great challenge for the sustainability of the upland vegetable production system.

Additional Keywords: soil conservation, vegetable production, erosion, fallow, hedgerows

Introduction
Soil erosion, declining land productivity and decreasing farm net income in cultivated upland production systems in the Philippines are major threats to agricultural sustainability. The sedimentation of dam reservoirs, irrigation canals and degradation of quality of freshwater and coastal habitats reflects some downstream negative impacts of soil erosion (Ciesiolka *et al.*, 1995; Heusch, 1993). Uplands serve two critical functions in the Philippines; Firstly, uplands play vital environmental roles as in these areas, the nations forest and important watersheds are located. Secondly, the natural resource base of uplands serves as an important economic function as it supports about 30 percent of Philippine population (about 24 million) who are engaged primarily in subsistence agriculture. Population growth, limited opportunities in the lowland and the common notion of "open access" continue to draw people to upland areas. These resulted into the degradation of its natural resource wealth and environmental quality. Manupali is an important watershed in Southern Philippines as it provides water to irrigate around 15000 ha of ricelands. Over a twenty-year period to 1994, the area of permanent forest shrank from about one half to a little over one-fourth of the total area. Part of the converted land went into shrubs or secondary forest, but a much larger part was converted to annual agricultural crops, especially corn and vegetables, which expanded from 20% to 40% of total land area (Coxhead and Buenavista, 2001). The increasing number of upland farmers who are attracted to the risky and input-intensive vegetable business in Manupali watershed was attributed to the favorable climate and areas well-drained soil rich in organic matter.

Upland vegetable farms operate on small landholdings and often are subjected to a total crop failure due to pest damage or drought (Poudel *et al.*, 1998). Steepland cultivations have an increased risk of soil erosion and declining productivity, and appropriate soil conservation practices, cropping sequences and plant protection measures are necessary to enhance the sustainability of the production systems. Alley cropping and several agroforestry systems have been found to minimize soil erosion and increase agricultural productivity and farm profitability (Comia *et al.*, 1994; Paningbatan *et al.*, 1995). Other widely accepted techniques to improve farm sustainability is through a diversified crop production in which failure of one crop may be partially compensated by another crop; thus the farm could remain economically viable. The current study assessed the effectiveness of soil conservation techniques and tree-vegetable systems for soil erosion and income generation on upland vegetable systems.

Materials and Methods
This study was conducted from 1998 to present (2004) in a research farm located at the footslopes of Mt. Kitanglad in Lantapan, Bukidnon Province, Southern Philippines. The climate is warm tropical, with a mean annual

temperature of 18.5ºC and a mean annual rainfall of 2400 mm. The soil is a Humic Kandiudox derived from deposits of volcanic ejecta.

Field survey and measurements

Farmers' survey was conducted at the start and middle of the study to understand farmers' perceptions, practices and attitudes on vegetable production and conservation techniques. A field experiment with 8 m wide and 19 m long erosion-runoff plots laid in a completely randomised block design was then established. The average slope of these erosion-runoff plots was 42%. Treatments (three crop sequences and four soil conservation technologies) were set-up: 1) the current practice of planting up and down the slope; 2) planting along the contour; 3) planting vegetables up and down the slope but with 5 m strips of beans across the slope at 5 m intervals (strip planting); and 4) as with number 1, but with four two-row strips at 4 m intervals of high value hedgerow crops planted on the contour. On each technology plot was super-imposed a sequence of three vegetable crops, such that each technology x vegetable species was represented during each growing season. Close to three crops were planted per year on each plot. Eroded soil, runoff and nitrate were measured after each erosion event, and soil chemical and physical characteristics were determined, as were inputs, and crop yields. Sampling of soil and crop yields within plots were undertaken systematically to reflect spatial trends within each set of measurements. Later, a new field experiment was superimposed with five randomly assigned treatments (fallow (with sunflower), trees alone, annual crops with lime/without lime and trees intercropped with vegetables). Runoff and eroded soil were collected manually every rain event. Tree diameter and height as well as annual crops harvested were monitored at the end of each cropping seasons.

Analysis

Statistical analyses of the data were performed using SAS. Appropriate ANOVA analysis were undertaken to determine treatment effects. The treatment effects were determined by Waller-Duncan Multiple Range Test.

Results and Discussion

Soil conservation technologies and cropping sequences

The study showed that on the average soil loss in farmers' up-and-down cultivation practice was 50% greater than the tested conservation measures. These values are comparable to those obtained by Daño and Siapno (1992) in a similar study conducted in Leyte, Philippines. Similar differences between treatments and crops were evident for runoff, but for nitrate in runoff water, no significant treatment/species effects were evident. As contour hedgerows became established, they were found more effective in controlling erosion (Table 1 and 2). Within the contour hedgerows 71% of total soil lost over the entire experiment was lost in the first three seasons and 24% in the last three seasons compared to values of 46% and 47% respectively in the farmer's practice.

Table 1. Effects of erosion control measures on soil loss, runoff and nitrate loss (Cropping 1-7)

Conservation Measures	Soil Loss (t ha^{-1})	Runoff (1000 l ha^{-1})	Nitrate (kg ha^{-1})
Up-and down	23.3 a	254 a	4.6 a
Contouring	13.5 b	147 b	3.3 a
Strip cropping	15.6 b	205 ab	3.5 a
Hedgerows	16.2 b	171 b	2.5 a

Values with same letter is not significantly different at P <0.05

Table 2. Effects of erosion control measures on soil loss (CS 11-12).

Conservation Measures	Soil Loss (CS11) (t ha^{-1})	Soil loss (CS 12) (t ha^{-1})
Up-and down	11.50 b	1.05 b
Contouring	3.29 a	0.33 b
Strip cropping	4.51 a	0.26 b
Hedgerows	3.02 a	0.27 b

Values with same letter is not significantly different

Among crops, tomato had more soil erosion than any other species tested. This difference between species in their propensity for erosion was related to their canopy cover and tillage operations. Most soil lost through erosion occurred during only a few erosive rainfall events. Of all rainfall events, only 6.5% resulted in measurable soil erosion and three events were responsible for almost 50% of total soil erosion. Such losses were evident at planting time when the almost bare soil was exposed to rainfall.

Table 3. Effects of crops on soil loss, runoff and nitrate loss (Cropping 1-7).

Crops	Soil Loss ($t\ ha^{-1}$)	Runoff ($1000\ l\ ha^{-1}$)	Nitrate ($kg\ ha^{-1}$)
Tomato	21.3 a	245 a	4.8 a
Corn	15.1 b	161 b	2.8 a
Cabbage	15.0 b	177 b	2.8 a

Values with same letter is not significantly different at $P < 0.05$

Marked spatial trends in soil fertility and crop yields within plots were also noted. Scouring of upper reaches, and depositions lower down, were responsible for much of this. On average over the experiment, yields on the lower half of plots were 36% greater for corn, 40% for tomato and 78% for cabbage compared to those of upper half. The lower upper yields were associated with less organic matter, P, total N, Ca and Mg and greater soil acidity and exchangeable Al. These data suggest that the overall impacts of erosion could be large even if soil per se is not removed by erosion from the fields and landscape. The movement of nutrients and organic matter down the slope on contour plantings was less than in other treatments, with little differential deposition down the slope in the former.

Fallowing

Survey conducted showed that one-fifth of farmers had land in fallow for one or more years' duration. Fallow lands often have wild sunflower (*Tithonia diversifolia*) and are re-cultivated following an average period of 3.7 years. Lands are fallowed not only due to poor fertility but also due to lack of labor and capital. Sunflowers are presumed to restore fertility particularly in the mobilization of Ca, P and K from the soil (Van Noordwijk *et al.*, 1997).

Soil samples collected to compare fallow and cultivated lands during the course of the study showed that newly fallowed lands were more acidic (pH 4.4 vs. 4.9), poor in organic matter (1.4 vs. 3.8%), and in exchangeable K and Ca (2.8 vs. 5.9 and 0.12 vs. 0.58 meq $100g^{-1}$, respectively) and high in aluminum (1.21 vs. 0.58 meq $100g^{-1}$). Profitable short-term conversion of fallow lands into crop production, therefore, would require ample fertilizers and soil amendments.

Effects of fallowing (fallowed area vegetated with sunflower) in terms of soil nutrients and erosion showed fallowed land to have higher nutrient level and minimal soil erosion as compared to areas planted with vegetable and trees with vegetables but comparable with fallow area planted with trees (*Eucalyptus grandis)*. From the beginning of the experiment, both sunflower and trees alone were effective in minimizing soil erosion whereas erosion was evident in cultivated plots, whether with or without trees. Plots with sunflower or trees developed a weed surface cover, which minimized erosion. The sunflower/fallow plots were also found to significantly raised soil pH, %N, Soil C and Mg.

Liming

Liming experiment was conducted to illustrate to the upland farmers the critical role of liming in improving site-productivity. Liming almost doubled crop yield during the four cropping seasons being studied. Crop yields (Table 4) in plots without lime were notably poorer than those with lime and by the 11th season yields were very low overall. This strengthens the argument for the application of dolomitic lime and potash to remedy the low acidity and low P availability.

Crop soil conservation decisions

The choice of crops and soil conservation technologies were found to be dependent on the level of farm employment. Less labor on the farm discouraged labor-using technologies. This is exemplified in Table 5. The percentage of plots with contour/hedgerows declined from 16% to 5% after four years of monitoring. On the other hand, the proportion of plots with trees and fallow or labor saving conservation measures increased significantly from 25% to 68%.

In terms of crop-specific soil conservation measures, Table 6 provides some information. The number of cabbage plots with soil conservation measures decrease from 86% to 50%. In the cabbage plots, contour plowing and hedgerows initially were more popular practice than trees and follow but later after four years, increasing number of farmers practiced trees and fallow. On the other hand, trees and fallow were the more popular soil conserving practices in the corn areas.

Table 4. Crop yields (t ha^{-1}) according to treatment

Treatment		**CS 8**	**CS 9**	**CS 10**	**CS 11**
Original	Newly Imposed	Corn	Cabbage	Dry beans	Cabbage
Up-down	No lime	3.4	7.5	0.34	0
Up-down	With lime	9.4	18.1	0.76	0.98
Contour	No lime	6.5	12.7	0.38	0
Contour	With lime	9.8	26.5	0.74	0.87
Strip	No lime	3.4	3.0	0.20	0
Strip	With lime	8.0	6.3	0.77	3.62

A shift from monocrop corn to vegetables would involve increased labor demand and capital, as would be shift from perennials to annuals. Less labor available for farm work should then shift crop choices to perennial. However, less labor on the farm would also discourage labor-using technologies, including soil conservation measures.

The survey also revealed that more corn farmers practiced soil conservation than vegetable farmers; and that labor-saving techniques were usually preferred among the former. In both types of soil conservation measure, there is an increasing trend of households with non-farm incomes. The rate of increase was higher among households practicing trees and fallow. The proportion of households with non-farm incomes practicing this measure increased from 52% to 79%.

Table 5. Number of plots with soil conservation measures.

Year	**Total plots (n)**	**Plots with contour/ hedgerows n**	**%**	**Plots with trees/fallow n**	**%**
Year 1	224	37	16.5	56	25.5
Year 3 - dry	129	35	27.1	54	41.9
Year 3 - wet	135	33	24.4	60	44.4
Year 4 – dry	126	6	4.7	86	68.3

Table 6. Soil conservation measures of sample parcels, by crop type.

Year	**Cabbage**		**Corn**	
	% of parcels practicing contours/hedgerows	**% of parcels practicing trees/fallow**	**% of parcels practicing contours/hedgerows**	**% of parcels practicing trees/fallow**
Year 1	85.7	14.3	37.9	62.1
Year 3 - dry	50.0	50.0	68.7	31.3
Year 3 - wet	66.6	33.3	48.6	51.4
Year 4	50.0	50.0	18.2	81.8

Tree vegetable compatibility

The effectivity of vegetation strips (hedgerows) in minimizing soil erosion has been successfully demonstrated in the area but the adoption rate is below expectation. This is mainly due to increased labor demand in managing hedgerows and insufficient economic benefits the farmers derived at. Incorporation of trees particularly fast growing species (*Gmelina arboria*, Eucalyptus spp.) in the production system is attracting growing interest among vegetable farmers due to increase economic benefits. On larger farms with land in long fallow, trees provide the ideal opportunity to gain financial returns, especially since fallowing alone is unlikely to markedly enhance soil fertility. Intercropping small trees and high-input annuals maximizes farm inputs and management costs.

A shift of a vegetable enterprise towards trees also alleviates current and anticipated labor shortages, for the management of trees after the first year growth is not labor intensive. From an environmental perspective the ability of trees to ensure constant canopy cover over the soil minimizes downstream water quality problem and on-site nutrient losses. Comparing the performance of various tree species alone and intercropped with vegetables showed attractive tree-vegetable association. The study, which was conducted over a number of seasons, showed that tree growth over the two-year period was considerably greater when intercropped (e.g. 58 m3 ha^{-1} vs. 27 m^3 ha^{-1} for non-intercropped trees). The extra growth was believed to represent nutrient uptake in excess of that for vegetables. The study also showed that intercropped trees intercepted N that had leached, or would soon leached, past the vegetable root zone. Quantification of benefits of trees on vegetables, of trees on erosion, of different tree options, planting pattern and the overall financial attractiveness of tree-vegetable intercropping are continually being evaluated.

Conclusions

Field measurements with the cultivation of corn and vegetable crops under a range of management regimes confirm high erosion rates and rapid depletion of soil nutrients and organic matter. Conservation technologies reduced soil erosion by approximately one-half, and though effective during major erosion events, the level of farmers' adoption was less than hoped for. Growth in non-farm jobs caused labor to be withdrawn from intensive agriculture without sacrificing household incomes. This in turn affects the farmers continued adoption of soil conserving technologies. In tree-vegetable intercropping, trees did not out-compete vegetable for belowground resources in the first year but benefited from excess nutrients in the vegetable systems. Once vegetable planting is not feasible anymore due to fertility and shading constraint, the period of fallowing offers farmer future income from planted trees.

Identifying appropriate practice for soil erosion control while at the same time improve farm income for steepland vegetable farms continues to be a great challenge for the sustainability of the production system. Tree-vegetable intercropping offers option to landowners to increase farm income and minimize soil erosion. In fact, growing trees and vegetables together appears to be more lucrative than compared to growing trees only as the tree volume in the tree-vegetable system was greater than that of the tree treatment alone.

Acknowledgements

This research was supported by Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP/ Southeast Asia). The authors also would like to thank field staff Ferdinand Banda and Agamer Mendez for their excellent work.

References

Ciesiolka, C.A., Coughlan, K.J., Rose, C.W. and Smith G.D. (1995). Erosion and hydrology of steeplands under commercial pineapple production. *Soil Technology* 8, 243-258.
Comia, R.A., Paningbatan, E.P. and Hakanson, I. (1994). Erosion and crop yield response to soil conditions under alley cropping systems in the Philippines. *Soil and Tillage Research* 31, 249-261.
Coxhead, I. and Buenavista, G. (Eds). 2001. Seeking sustainability: Challenges of agricultural development and environmental management in a Philippine watershed: PCARRD, 2001. 267 pp.
Dano, A.M. and Siapno, F. E. (1992). The effectiveness of soil conservation structures in steep cultivated mountain regions of the Philippines. IAHS Publication No. 209. pp. 399-405.
Heusch, B. (1993). Soil erosion in catchments and erosion plots on Java, Indonesia and Luzon, Philippines. *Soil Technology* 6, 191-202.
Midmore, D.J., Nissen, T.M. and Poudel, D.D. (2000). Making a living out of agriculture – Some reflections on vegetable production systems in Manupali watershed. In 'Economic growth and natural resource management: are they compatible?' Malaybalay, Bukidnon, SANREM CRSP pp. 1-11
Nissen, T.M. and Midmore, D.J. (1999). Aboveground and belowground competition between intercropped cabbage and young *Eucalyptus torreliana*. *Agroforestry Systems* 46, 83-93.
Paningbatan, E.P. (1994). Management of erosion for sustainable agriculture in sloping lands. *The Philippine Agriculturist* 77, 117-138.
Paningbatan, E.P., Ciesiolka, C.A., Coughlan, K.J. and Rose C.W. (1995). Alley cropping for managing soil erosion of hilly lands in the Philippines. *Soil Technology*. 8, 193-204.
Poudel, D., Midmore, D.J. and Hargrove, W.L. (1998). An analysis of commercial vegetable farms in relation to sustainability in the uplands of Southeast Asia. *Agricultural Systems* 58, 107-128.
Rola, A.C. and Coxhead, I. (2001). Soil conservation decisions and Non-farm economic conditions: A study of the rural labor market in the Philippine uplands of Bukidnon. In 'Seeking Sustainability' I. Coxhead and G. Buenavista, eds.. Los Banos, Laguna, Philippines, pp. 94-111.
Van Noordwijk, M., Hairiah, K., Part Oharjono, S., Labios, R.V. and Garrity, D.P. (1997). Food-crop based production systems as sustainable alternatives for Imperata grasslands. *Agroforestry Systems* 36, 55-82.