Analyses of Soil and Water Conservation Technologies in Vegetable Based Upland Production System of Manupali Watershed

Antonio M. Daño

Ecosystems Research and Development Bureau, College, Laguna, Philippines 4031
E-mail: tonydanolb@yahoo.com/erdb@laguna.net
David J. Midmore
Central Queensland University, Rockhampton,Queensland, Australia 4702
E-mail: d.midmore@cqu.edu.au

Abstract: The magnitude of soil and nutrient losses from corn and vegetable production system represents a major upland environmental problem. Steep slopes, favorable climate, high fertilizer and pesticide application rates characterizes these uplands. Sustainability of upland vegetable production system and soil conservation technologies in Manupali watershed were analyzed. Conservation technologies considerably reduced soil erosion but the level of adoption was less than hoped for. Compatibility of trees in the vegetable production system offers encouraging result. 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. Higher level of non-farm income, favorable policies and incentives may veer away intensive cultivation without soil conservation techniques in the upland.
Keywords: vegetable production, erosion, hedgerows, contour, fallow

1 Introduction

Uplands comprised more than half of the country's total land. The importance of uplands can be demonstrated by its two critical functions. 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% of Philippine population (about 20 million) who are engaged primarily in subsistence agriculture. Population growth, limited opportunities in the lowland and the promise of "open access" continue to draw Filipinos to uplands. These resulted into the degradation of its natural resource wealth and environmental quality.

Upland degradation also continues to accelerate largely due to the replacement of perennial land uses with short season and annual high value crops particularly vegetables. The magnitude of soil losses from upland vegetable production system represents a major environmental problem of the country. Manupali watershed, located in southern part of the Philippines typifies such problem. Manupali is an important watershed in the Philippines as it provides water to irrigate around 15,000 ha of ricelands. About 45 % of the watershed have slopes greater than 40%. 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). Rainfall is evenly distributed throughout the year with an average annual rainfall of 2,347 mm. Taxonomically, the soil is classified as Humic Kandiudox. 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.

In spite of an obvious widespread perception of the soil productivity-depleting effects of annual crops, few farmers in the area display deep knowledge of soil degradation relationships. Land fallowing and crop rotation is rare and are usually undertaken only when yields of commercial crops decline to the point of economic losses. Although, soil erosion and land degradation problems appear to be widespread, very few farmers put significant investment in soil-conserving structures or technologies.

2 Sustainability analyses of the upland production system

To understand the upland farming practices in the Manupali watershed, a survey was conducted on fifteen percent of total vegetable farms. The result revealed the precarious nature of the upland production system. One-half of the farms surveyed were cultivated up-and-down the slope, for ease of operation and enhance drainage. One-third of the farms were on slopes greater than 18%. This makes much of the cultivated land susceptible to soil erosion and runoff. On the average, pesticides were applied on 26 occasions during the tomato season, with only slightly lower figures for other vegetable crops. Such prevalent spraying could lead to build-up in pesticide resistance. During the survey, almost one-half of farmers had just change products to achieve more effective pest and diseases control. In spite, however, of too much pesticide applications, crop damage due to insect pests and diseases accounts to about 50% of production losses. Farmers practice three cropping per year and high fertilizer application rates were noted. Such practice was suspected to cause the lowering of soil pH, decrease in the Ca saturation of exchange sites, and the reduction of stable aggregates.

One-fifth of farmers had land in fallow of 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).

Farmers' acceptance on planting of trees on fallow lands (more specifically just prior to fallowing) depended upon the ability to generate income, and not necessarily on the perceived improvements of the soil. Planting of trees on lands in excess of that manageable with the current labor and capital may over the medium term raise farmers' income. For smaller farms with no opportunity for tree planting, conservation technologies that minimize soil degradation are the only options to enhance sustainability.

Responses from farmers on their perceptions about soil conservation showed that deforestation and current farming practices were responsible for soil erosion. Contour farming and cover cropping were believed to be the most suitable practices to minimize soil erosion. Contour hedgerows utilizing leguminous species were considered not suitable largely due to their labor requirements, encroachment into already limited space for vegetable crops and the perceived lack of need for biologically-fixed nitrogen. Nitrogenous fertilizers are widely available and phosphorous is perceived as the limiting nutrient in the area (Midmore *et al*., 2000).

The man-land ratio suggests the increasing scarcity of agricultural land for cultivation. In 1995, there was less than half a hectare of cropland per person. Assuming that the area of arable land remains the same and will not be converted to other uses, the arable cropland per person will drop to only 0.15 ha, or 1,500 m^2, per person by 2030. The very low available cropland per person can be attributed to the fact that almost half of the land is considered forestland.

3 Analysis of soil conservation technologies and cultural practices

3.1 Fallowing

To understand the fallow system, soil samples were collected in fallow and cultivated lands during the survey. Comparison of fallow and cultivated lands showed that fallow 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, respectively) and high in aluminum (1.21 vs. 0.58 meq/100g). Profitable short-term conversion of fallow lands into crop production, therefore, would require ample fertilizers and soil amendments. Most commonly, corn preceded land fallowing, itself following tomato or potato once bacterial wilt (*Pseudomonas solanacearum*) rendered land unsuitable for those species.

Since fallow lands truly are of low fertility, and they are of steep slopes, then land fallowing may be considered as an important step towards environmental sustainability, especially if land is permanently taken out of production. If the ratio of aggrading to degrading land is greater than unity in the watershed, progress is being made towards a sustainable management.

3.2 Soil conservation technologies and cropping sequences

Evaluation of soil and water conservation technologies aimed at verifying their effectiveness in minimizing off-site soil sediment but without sacrificing farm income were undertaken in purpose rented research site. Results of earlier survey and farmers' consultation served as basis in field testing the conservation technologies and cropping sequences which were established on replicated erosion plots (19 m × 8 m), with an average slope of 42%. In essence, the technologies include: (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 5m intervals (strip planting); and (4) as with number 1, but with four two-row strips at 4m 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× 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.

The study showed that on the average soil loss in farmers' up-and-down cultivation practice was 50% greater than in the conservation practices. 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)	Runoff (1000 l/ha)	Nitrate (kg/ha)
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)	Soil loss (CS 12) (t/ha)
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. Total amounts of nutrients removed per hectare in eroded soil over seven seasons were 320kg-637 kg N, 1.4kg—2.9 kg P, 23kg—39 kg K, 71kg—139 kg Ca, 14kg—31 kg Mg and 8,000kg—13,500 kg organic matter. In situ soil after seven cropping season was particularly deficient in organic matter, Ca, Mg, K and had a lower pH, declining from 5.8 (±0.05) to pH 3.8 (± 0.04).

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

Crops	Soil Loss (t/ha)	Runoff (1000 l/ha)	Nitrate (kg/ha)
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

Average enrichment ratio for organic matter, P, Ca, and N were 1.2, 4.7, 1.7, and 1.3 respectively. The high value of extractable P prompts particular concern both for its possible adverse effects on downstream aquatic habitats and due to the inherent low P availability in all but the fertilizer-rich Ap horizon.

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.

3.3 Effects of 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.

Table 4 Crop yields (t/ha) 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

4 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 decline from 16% in 1996 to 5% in 1999. On the other hand, the proportion of plots with trees and fallow or labor saving conservation measures increased significantly from 25% in 1996 to 68% in 1999.

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% in 1996 to 50% in 1999. In the cabbage plots, contour plowing and hedgerows initially were more popular practice than trees and follow but in 1999, 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.

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 study 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% in 1996 to 79% in 1999.

Table 5 Number of plots with soil conservation measures

Year	Total plots (n)	% of plots with contour/hedgerows n %		% plots with trees/fallow n %	
1996	224	37	16.5	56	25.5
1998 - dry	129	35	27.1	54	41.9
1998 - wet	135	33	24.4	60	44.4
1999 - 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
1996	85.7	14.3	37.9	62.1
1998 - dry	50.0	50.0	68.7	31.3
1998 - wet	66.6	33.3	48.6	51.4
1999	50.0	50.0	18.2	81.8

5 Tree-vegetable compatibility

The effectivity of vegetation strips 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*, *Paraserianthes falcataria*, 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.

Earlier study by Nissen and Midmore (1999), 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 m^3/ha vs. 27 m^3/ha 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 spacing and the overall financial attractiveness of tree-vegetable intercropping are continually being evaluated.

6 Conclusion

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. Application of dolomite and chicken dung was found necessary to improved farm productivity of upland vegetable crops. Growth in non-farm jobs cause 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 below-ground resources in the first year but benefited from excess nutrients in the vegetable systems. Compatibility of trees in vegetable production system offers encouraging result.

To arrest upland degradation, upland agriculture should veer away from intensive cultivation without soil conservation techniques. Two critical things are needed for sustainable cultivation and in loosening up the use of fallow land: technologies that will meet environmental concern and economic benefits and secondly a supportive policies. Policies are needed to influence farmer behavior. One is a package of incentives in terms of tenure security and other economic and non-market incentives that could attract investment by the private sector.

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